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Interactive PDF Forms to Conduct Online Examinations in University Education: Practical Experience and Lessons Learned

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Abstract—Due to the Corona Pandemic, paper-based examinations had to be transferred to an online format on short notice. At the Lucerne University of Applied Sciences and Arts we conducted three online examinations with a total of 816 students using an interactive PDF form. We faced two major challenges redesigning our examinations: 1) avoiding unnecessary stress to students' working memory by choosing a simple examination design and 2) minimizing the possibility of cheating. In our paper we explain how we addressed these challenges working with an interactive PDF form in combination with the learning management system Ilias. Our results show that using an interactive PDF form lowers the extraneous cognitive load on our students, increases our efficiency in correcting, reduces error rates in grading and further allows for faster feedback to our students.

Keywords—online assessment, interactive PDF forms, cognitive load theory, cheating

1 Background

The Corona pandemic has fundamentally changed university life. At short notice, all teaching activities had to be switched to online in the spring of 2020, while still maintaining the same quality of teaching. In Switzerland the Federal Council cancelled all face-to-face classes on the 13th of March 2020. In response to this, our university, the Lucerne University of Applied Sciences and Arts, started distance teaching on the 23rd of March 2020. Although our university managed the transition to online teaching smoothly, the biggest challenge we faced in the Department of Mathematics and Statistics was properly designing and conducting the remote assessment.

In general, the forms of assessment can be classified along three spectrums: invigilation, location and format [6]. These range from traditional on-site paper-based exams with in-person proctoring to online exams in which students participate under remote proctoring by using their own devices from another location. Based on this typology, our traditional exams in mathematics and statistics could be classified as paper-based, conducted on campus and proctored in person. All of this became impossible due to the

Corona crisis and the requirement for social distancing. Moreover, depending on the program, our modules have a large number of students which limits the available options for conducting assessment. While oral examinations and written assignments are suitable options for classes with few students, these options are very time-consuming with larger classes. In these larger classes, adopting traditional paper-based exams to the online setting would be a more favorable alternative.

However, redesigning the written paper-based exams to an online format is not without obstacles. First, since online exams are new to students, who have previously been taught and tested on-site, they can lead to more uncertainties and increase students' anxiety, that is often associated with anticipated technical failures [16], [25]. Additionally, online exams often require the use of learning platforms or other software, which increases the complexity of the exam design compared to paper-and-pencil assessment. This adds unnecessary stress to the students' working memory [6] and may even encourage academic dishonesty [18]. Second, in an online environment, students have numerous opportunities to cheat [5], [11], [17]. To ensure the reliability and validity of the exam results, the possibility of cheating must be taken into account when choosing the examination design [18].

In our paper we show how we addressed these theoretical challenges when adopting traditional paper-based examinations to the online setting. In particular, we explain how we are using the learning management system Ilias - in combination with an interactive PDF form - for our online assessments. We provide a detailed description on how we have designed and conducted three exams at the Lucerne University of Applied Sciences and Arts for a total of 816 students. Our paper contributes to the existing literature by providing a practical solution for online assessment, which is based on a solid theoretical background and has been tested at our university.

The following section describes the major challenges involved when designing online exams and explains how we delt with those challenges. In the following section we present the interactive PDF form in detail and share our experience. The last section concludes.

2 Literature review: Major challenges of online exams

In this section we present the theoretical challenges which arise when designing an online examination. These challenges lead to a set of recommendations which help us to find a proper solution when adopting traditional paper-based exams to the online setting.

2.1 Optimizing cognitive load

In general, the Cognitive Load Theory states that the working memory, which is responsible for problem solving and concentration, can only hold a limited amount of information at a time [24]. A distinction is made between intrinsic and extraneous cognitive load. While the intrinsic cognitive load is determined by the amount of information and complexity of the learning material itself, the extraneous cognitive load is defined by the presentation of the material and the required learning activities [1], [19].

Thus, for exams, the intrinsic cognitive load is set by the difficulty of the subjects and the learning objectives. Since this does not depend on the exam type, the intrinsic load should be the same for paper-based and online examinations. The intrinsic load is predetermined by the learning content [20]. In contrast, the extraneous cognitive load is generated by the complexity of the exam design. It unnecessarily stresses students' working memory and should be reduced as much as possible. Comparing paper-based and online examinations in this context, the latter require the use of learning platforms or software, and add further technological challenges, which all increase the extraneous cognitive load.

Because online examinations are new to our students, who are normally taught and tested on-site, they are therefore associated with many uncertainties and anxieties. The results from surveys show that students' anxieties are often related to the fear of possible technical glitches [16], [25]. In an online environment, technical issues can be related to the system itself, e.g. malfunction of a learning platform, but can also occur on the student side, e.g. due to a poor internet connection. Recent surveys discussing online assessments during the Corona crisis have revealed that most students considered infrastructure problems to be a major challenge with online examinations [3], [10]. Results also indicate that university students, accustomed to paper-based exams, find online exams particularly stressful when they are unfamiliar with the online setting [16], [26]. Authors in [6] further note that students often face problems during online examinations due to their lack of preparation and knowledge of the technical requirements.

All of the above-mentioned issues unnecessarily increase students' cognitive load. Therefore, when creating online exams, special care must be taken to minimize any additional extraneous load related to the exam design [6], [14]. In addition to this, the provision of a mock exam and very clear instructions about the requirements and technological prerequisites are necessary [6], [8], [10]. In fact, students consider clear instructions about the rules and procedures of online examinations to be extremely important for a successful online assessment [3], [15]. Finally, as technical issues cannot be completely avoided in an online environment, a clear contingency plan should be in place in case of possible technical problems [10].

2.2 Reducing cheating

Cheating poses a threat to the quality of an assessment by decreasing its reliability and validity [18]. In an online environment, students have numerous opportunities to obtain unauthorized assistance [5], [11], [17]. Therefore, the nature of cheating threats must be understood and carefully considered when choosing or designing online examinations [18].

Authors in [18] suggest that academic dishonesty can be broadly explained by two main forces: cognitive offloading and motivation to cheat coupled with the possibility to cheat. Cognitive offloading means seeking external help in order to reduce cognitive demand [21]. According to [18], students engage in cognitive offloading if the cognitive demand of the exam is too high and offloading is considered effective, i.e. unauthorized assistance is readily available. In turn, the motivation to cheat is usually more pronounced in exams that hold a heavy weight in determining the final grade. The motivation to cheat also increases if students feel unfairly treated, e.g. the time pressure during the exam is too strong. Finally, the possibility to cheat arises in exams that are not unique, i.e. when old exams are reused or when the same test is conducted asynchronously. Opportunities to cheat also increase with the absence of proctoring.

Existing literature presents multiple recommendations to minimize cheating through appropriate examination design or by influencing the environment in which the examination is conducted. These recommendations can be connected to the framework [18] described above. First, given that unnecessary cognitive load might encourage cheating [18], it is important to take the cognitive load theory into account when designing an online exam [6]. Second, to reduce the effectiveness of offloading, exam questions should require the application of the learning content [4]: critical thinking rather than simple computations. Answers should not be readily available in textbooks, on the internet or through peers [10]. Third, numerous papers state the importance of time constraints to reduce cheating opportunities [17], [18], [22]. However, time pressure must be reasonable, as motivation to cheat can increase if time constraints are unrealistic [18]. The final set of recommendations aims at reducing the possibility to cheat. According to [5] it is important to run the exam simultaneously for all candidates. Authors in [17] suggest allowing students to view only one question at a time and preventing them from going back to finished tasks. Randomization of questions is an additional tool that can increase the uniqueness of the examination [10], [12], [18]. Another related and very effective option to deter cheating is to create different exam versions [12].

Finally, one common way to reduce the possibility of cheating is by implementing proctoring technology [18]. To monitor students during an online exam, the actual student can be transmitted via a video and audio connection, or the student's desktop can be monitored [6]. In doing so, it is possible to record the connection and store it for later analysis. Additionally, the use of a special browser, such as the Lockdown Browser or the Safe Exam Browser, can increase the level of security in online examinations by limiting students' access to their own computers [9]. For example, the Safe Exam Browser only allows students to use certain applications during an exam and can also temporarily disable access to the internet [23].

Nevertheless, proctored online exams are associated with difficulties. First, proctoring may be problematic for data protection reasons as video surveillance represents an encroachment on personal rights. Students may therefore refuse and not consent to video surveillance [10]. Second, proctored online exams are subject to failures of software or internet connection and require a well-established infrastructure on the student side [10]. Finally, online surveillance involves additional licensing costs for the required software [5], [17]. Some studies that compare supervised and unsupervised online tests find no significant differences in exam results, indicating no increased cheating in an unsupervised setting [17]. Therefore, when properly designed, unsupervised exams can be a viable tool for online assessment [17].

3 Our examination design

3.1 Methodology

Based on the findings of existing literature, we were looking for a suitable solution for our online examinations. Our main goals were to optimize the cognitive load of our exams and to prevent students from cheating.

In our paper, we report on our experience with the interactive PDF form. Our research design is a two-stage triangulation. First, we qualitatively describe our procedure for creating the interactive PDF form. We explain how we designed and built our exams considering the relevant theory. Second, we apply a quantitative approach using the interactive PDF form in three of our examinations with a total of 816 students. We evaluate how the students handle the PDF form, provide the relevant statistics, and describe possible limitations and improvements.

3.2 General approach

To reduce the extraneous cognitive load, we ruled out the introduction of new software for the execution of our assessments. Instead, we decided to run the exams using our learning platform Ilias as our students were familiar with Ilias from their regular classes. At the beginning of the examination time, the students could download the exam from the platform and save it on their computers. This way, students had the exam available locally and could edit it offline in case of a network interruption. After finishing the examination, students had to upload their answers back to Ilias. As a backup, we also prepared an e-mail delivery for submission of the exams. Moreover, students could contact the lecturers by phone if they needed assistance.

All of our students received an instruction sheet, containing detailed information on preparing for and taking the exam. In addition, we provided optional mock exams, which were identical to the actual exams in terms of both procedure and design.

Based on the literature, we have implemented several measures to minimize the possibility of cheating in our exams. First, to limit the effectiveness of cognitive offloading, we decided to work with open book exams. The exercises focused on the application of the learning content. We made sure that the answers could not be easily found on the internet and that computational operations could not be performed via programs nor web pages. Second, to reduce the possibility of cheating, we created three different exam versions. We made all three versions as similar as possible by leaving the order and the content of the exercises unchanged. The students were not aware of which version they received or how many versions existed. To prevent students from finding out about the three different versions, we applied strict but adequate time constraints to the exam, i.e. the allocated time was sufficient to complete the exam but not to seek assistance from peers.

Moreover, in addition to working with different exam versions, we implemented another hurdle to prevent cheating. For the examination, we worked with two documents: an assignment document, which contained the exam questions, and an answer sheet, which presented the corresponding answer options, which had to be submitted to Ilias at the end of the exam. For each exam version, we created a different assignment document. However, the answer sheets for all three versions were made identical. Therefore, students could not simply copy the answers from peers or use an answer sheet from a third party.

For reasons of data protection, the students were not monitored, neither by video transmission nor by monitoring their desktops. Special security browsers, such as Safe Exam Browser, were also not used. Instead, the students had to sign a declaration, in which they confirmed that they were taking their exams alone and independently.

3.3 Interactive PDF form as a tool for online examinations

Importantly, in our approach, reducing extraneous cognitive load is not limited to minimizing technical issues but also implies adapting a traditional paper-based exam to an online format, without unnecessarily complicating and changing the design. In this section we show how we created an examination with a simple design using an interactive PDF form.

As mentioned in the previous section, we worked with an assignment document and an answer sheet for our examinations. The assignment document is a normal PDF and contains the exercises, but not the answer options (see Figure 1). Its design is identical to a paper-based setting and is therefore familiar to our students. Each exercise on the assignment document is presented on only one page. This provides the students with all the information they need to solve the exercise without having to scroll through the document [14]. The students can deal with the assignment document first by solving the respective exercises, as in a standard paper-based setting.

Exercise 1: Health Insurance	**Points: 3**

The Swiss health insurance system is based on a cost sharing between the insurant and the insurance. In case of a franchise of CHF 300, for example, this means that:

- The insurant pays the annual treatment cost not exceeding CHF 300 (=franchise);
- The insurant pays 10% (= patient's contribution) of the annual treatment cost exceeding CHF 300, provided the sum of franchise and patient's contribution does not exceed CHF 1,000.

Let x be the amount of the annual treatment cost attributed to an insurant, and let B the cost to be paid by that insurant. Then $B(x)$ defines a function for $x \geq 0$ that can be stated with three assignment equations.

a) Specify the assignment equation for $B(x)$ in the first interval, that is for annual treatment cost not exceeding CHF 300. *(1P)*

b) Specify the assignment equation for $B(x)$ in the second interval, that is for annual treatment cost exceeding CHF 300, but for which the sum of franchise and patient's contribution does not exceed 1,000. *(1P)*

c) Determine the treatment cost from which on the insurant has to pay the maximal amount of CHF 1,000. *(1P)*

Fig. 1. Excerpt from the assignment document of the mock examination introduction to mathematics for business and economics

The assignment document has a corresponding answer sheet. It displays the answer options but does not repeat the exam questions (see Figure 2). The students have to transfer their solutions to their answer sheets and submit them to Ilias. The answer sheets are a novelty that we specifically designed for the online setting.

Answer Sheet **AT 2020**

Candidate Information		
Last name		points
First name		
Learning group	Please select	

Exercise 1: Health Insurance				**3 Points**
a) (1P)				
☐ $B(x)=x$	☐ $B(x)=30x$	☐ $B(x)=300x$	☐ $B(x)=30$	points:
☐ $B(x)=x+30$	☐ $B(x)=x+300$	☐ $B(x)=-x$	☐ $B(x)=-30x$	
☐ $B(x)=-300x$	☐ $B(x)=-30$	☐ $B(x)=x-30$	☐ $B(x)=x-300$	
b) (1P)				
☐ $B(x)=0.1x-300$	☐ $B(x)=0.1x-120$	☐ $B(x)=0.1x$	☐ $B(x)=0.1x+90$	points:
☐ $B(x)=0.1x+270$	☐ $B(x)=x+300$	☐ $B(x)=0.1x+300$	☐ $B(x)=0.1x+120$	
☐ $B(x)=0.1x-90$	☐ $B(x)=0.1x-270$	☐ $B(x)=x-300$	☐ $B(x)=0.1x-30$	
c) (1P)				
☐1,000	☐1,600	☐3,100	☐5,100	points:
☐7,300	☐7,900	☐8,700	☐9,500	
☐10,000	☐10,500	☐12,500	☐13,200	

Fig. 2. Excerpt from the answer sheet of the mock examination introduction to mathematics for business and economics

We wanted to create an answer sheet with a fixed, unchangeable and simple design that could easily be completed by students directly on their computers. A Word file was out of the question because unlike a PDF, it can be changed, and would therefore be susceptible to manipulation by the students. We also ruled out a normal PDF because of the various options to fill it in (print and scan, filling in on the tablet, inserting text fields, etc.). The different formats would make the evaluation of the exam more difficult. In addition, students without a tablet would be at a disadvantage. We therefore chose an interactive PDF form for our online examination, which clearly and precisely specifies where and how entries are to be made.

The interactive PDF form can be filled in using Adobe Acrobat Reader, which is available free of charge. Adobe Acrobat Reader is widely used and already familiar to most of our students. All students were informed by their lecturers in class, and also on the instruction sheet, that they had to install Adobe Acrobat Reader before the exam and save the interactive PDF form on their computer before opening it with Adobe Acrobat Reader. Otherwise, when using an internet browser to edit the interactive PDF forms, solutions could get lost.

Since our university works with a specific Word template for exams, we decided to base our interactive PDF form on a Word file. Unfortunately, it is not possible to transfer interactive form fields from a Word file directly to a PDF form, because the form fields get lost in the conversion. Therefore, we developed the complete answer sheet in Word and saved it as a PDF. Adobe Acrobat can be used to convert any PDF into an interactive form. Therefore, once the PDF is converted, the interactive fields for the answers can be inserted. The simple menu navigation in Adobe Acrobat offers a large selection of buttons and text fields that can be included in the document, depending on each type of the question. For example, it can be specified whether only one or multiple answers are to be selected for an exercise. For open text fields, Adobe Acrobat allows to specify the maximum number of characters permitted. In addition, visual design options are also available, which provide the opportunity to test the students' knowledge in a similar way to a paper-based examination, as different question types (e.g. single choice, multiple choice, and open questions) can be included in the PDF form.

In order to evaluate the data from the completed interactive PDF forms in a spreadsheet program such as Excel, the data must first be imported. This is achieved by using the "Merge data files into table function" in Adobe Acrobat. If Excel is used, the imported text has to be transferred into columns. Once the imported text has been transferred, a separate column is created for each form field (see Figure 3). If a question is left unanswered, an Off is shown in the corresponding field. PDF submissions, where the interactive PDF form function has been removed, will not be transferred into the spreadsheet program (see student_1.pdf in Figure 3). Once the master solution is inserted, the respective answers can be automatically corrected and evaluated using simple Excel functions.

	A	B	C	D	E	F	G	H
1	**document**	**name**	**class**	**Ex. 1A**	**Ex. 1B**	**Ex. 1C**	**Ex. 2A**	**Ex. 2B**
2	**master solution**			1	2	2	2	1
3	**student_1.pdf**							
4	**student_2.pdf**	student_2	H2006	10	7	Off	Off	Off
5	**student_3.pdf**	student_3	H2032	1	8	2	8	1
6	**student_4.pdf**	student_4	H2034	1	7	2	8	1
7	**student_5.pdf**	student_5	H2034	1	2	2	2	4

Fig. 3. Importing the form data into the Excel spreadsheet program

3.4 Our experience with an interactive PDF form

In the autumn semester 2020, we conducted three math and statistics exams in the Bachelor of Science in Business Administration and the Master of Science in International Financial Management using the interactive PDF form with 816 students (see Table 1). Ninety-three percent of the students saved their answer sheets correctly and uploaded an interactive PDF form. These answer sheets were then imported and evaluated automatically in the spreadsheet program. Five percent of the students did not save their answer sheets correctly, and uploaded a normal PDF, which no longer contained the interactive form function. Nevertheless, these students' answers were recognizable and could be assessed manually. Despite receiving clear instructions, one percent of the students submitted answer sheets that could not be evaluated. These files were damaged, and we were unable to extract the answers. Six out of these eleven students had fortunately documented their answers using screenshots, and we were able to acknowledge and grade their results. For the remaining five students, their answers could not be reconstructed, and the answer sheets were scored with zero points. One student accidentally uploaded the assignment document instead of the answer sheet and failed accordingly (no submission).

Table 1. Form of the returned answer sheets (percentages rounded)

	Introduction to Mathematics for Business and Economics	**Risk Models and Optimization**	**Business Analytics**	**Total**
Study program	Bachelor	Bachelor	Master	
Semester	1	3	1	
Number of students	438	355	23	816
Interactive PDF form submission	389 (89%)	354 (100%)	19 (83%)	762 (93%)
Normal PDF submission	38 (9%)	0	4 (17%)	42 (5%)
Damaged file submission	10 (2%)	1 (0%)	0	11 (1%)
No submission	1 (0%)	0	0	1 (0%)

When comparing first-semester-students to third-semester-students, it is notable that all but one student in the third semester correctly saved and submitted the interactive PDF form. The students who submitted a normal PDF or a corrupt file instead of the interactive PDF form were, except for one student, in their first semester. However, the general conditions in the first and third semester were identical: All students had received the same instruction sheet and were given the opportunity to take a mock exam in preparation. We attribute the different submission behavior to the fact that the third-semester students had already taken prior exams at our university and were therefore aware of how important it is to follow the instructions carefully. Furthermore, the third-semester students had already experienced writing online exams in the spring semester of 2020, although not using an interactive PDF form. This may have had a positive effect on lowering both extraneous cognitive load and perceived stress level.

All answer sheets submitted as an interactive PDF form were aggregated and exported into Excel and assessed automatically. All answers to multiple choice and single choice questions were transferred to the spreadsheet program without any issues. Of course, the answers in open text fields had to be corrected by hand. Nevertheless, it was helpful that all students' answers to each corresponding question were listed below each other in one column. This way, the answers could be compared directly and thus assessed more easily and objectively.

4 Summary and discussion

Although the efficiency of online examinations brings major benefits, especially for classes with a large number of students [8], redesigning paper-based exams into an online format is not a straightforward task. To meet the challenges, we were looking for a suitable solution for our online examinations. First, our goal was to take advantage of an examination platform that students were familiar with, without being solely dependent on it. At the beginning of the assessment time, the students were able to download the exam from the platform and work on it offline in the event of a network interruption. The downloading and uploading process using the Ilias exam platform was quick and without any problems. We did not receive any complaints from students in regard to poor connections or any other issues with the internet. This way we reduced the vulnerability to technical problems. At the same time, the entire examination process with student access was recorded by the learning platform and could be evaluated in the event of discrepancies.

Second, we incorporated the recommendations from existing literature to minimize cheating with our exam design by creating several exam versions and also implementing strict time constraints. As the grades from our unsupervised online exams were not substantially different from their supervised paper-based counterparts, we consider the implemented measures to be effective in preventing cheating.

Finally, to reduce the extraneous cognitive load, we created an examination with a simple design using an interactive PDF form. Our overall experience with the form was positive. First of all, similarly to conducting exams directly through learning platforms, our PDF form allowed for multiple test options, including single choice, multiple choice, open questions etc. [15]. We also found it advantageous that the design of the interactive PDF form was fixed and could not be changed by the students. This made accidental deletion of exercises, or any kind of alteration, impossible. Allowing only one answer option to be checked in the interactive PDF form prevented ambiguous results and simplified the assessment.

Furthermore, the interactive form could easily be completed by students directly on their computers using Adobe Acrobat Reader, which is a free tool known to most of our students. 93% of submitted answer sheets were correctly returned to us as an interactive PDF form and could be graded automatically. Automizing evaluation and grading provided numerous benefits compared to manual correction [1]. The effort required for the correction of these exams was much lower when compared to paper-based exams [9], which was particularly important in classes with a large number of students [8]. In the case of open questions, the typewritten answers improved readability and thus also reduced the correction time when compared to handwritten answers [8]. The automatic correction was error-free and thus reliable. Finally, due to increased efficiency and error-free correction, we were able to submit the exam results earlier when compared to previous years. Therefore, using the interactive form lowered extraneous cognitive load on our students [6], increased efficiency in correction [9], reduced error rates in grading, and further allowed for faster feedback to our students [13].

Naturally, a new format of examination using the interactive PDF form was not completely without issues. Not all students saved their answer sheets as instructed. As a result, the interactive PDF form function was lost, and these documents could not be transferred to the spreadsheet program for automatic scoring. Nevertheless, a manual correction and an assessment of the results was still possible. The answer sheets of ten first-semester students and one third-semester student, who failed to follow the instructions, were damaged and were no longer readable. To prevent this from happening in the future, we will slightly modify our approach by making the mock exam mandatory for all students, as suggested by [6]. We believe that this will help to reduce the number of non-evaluable submissions in the future. Finally, for small classes, the time and effort required to create an interactive PDF form can exceed the total time required for an exam in normal PDF format. Therefore, in the future we will only continue to use an interactive PDF form for online examination with large classes.

For us, the simple technical implementation, the possibility to continue working in the event of a network interruption, and the fast and error-free correction were decisive in choosing the interactive PDF form for our online examination. Our approach received good feedback from our fellow lecturers. However, our proposed solution lacks feedback from students. In future studies, we are planning to conduct an extensive survey among our students to evaluate our approach from their perspective. Based on the survey results we would be able to compare our approach to other forms of online examination known to our students and improve our current solution.

5 References

[1] I. Akin, N. MurrellJones, "Closing the Gap in Academic Writing Using the Cognitive Load Theory," *Literacy Information and Computer Education Journal (LICEJ)*, vol. 9, issue 1, 2018. https://doi.org/10.20533/licej.2040.2589.2018.0373

[2] A. A. Alghamdi, M. A. Alanezi and Z. F. Khan, "Design and Implementation of a Computer Aided Intelligent Examination System," *International Journal of Emerging Technologies in Learning*, vol. 15, no.1, p. 30-44, 2019. https://doi.org/10.3991/ijet.v15i01.11102

[3] S. R. Alotaibi, "A Novel Framework of Success Using E-Assessment During Corona Pandemic," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 12, 2020. https://doi.org/10.3991/ijet.v16i12.22063

[4] B. Bloom, M. Englehart, E. Furst, W. Hill and D. Krathwohl, *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain*, New York, Toronto: Longmans, Green, 1956.

[5] G. R. Cluskey, C. R. Ehlen and M. H. Raiborn, "Thwarting online exam cheating without proctor supervision," *Journal of Academic & Business Ethics*, vol. 4, pp. 1–7, 2011.

[6] J. Cramp, J.F. Medlin, P. Lake, and C. Sharp, "Lessons learned from implementing remotely invigilated online exams," *Journal of University Teaching & Learning Practice*, vol. 16, no. 1, 2019. https://doi.org/10.53761/1.16.1.10

[7] J. Crawford, K. Butler-Henderson, J. Rudolph, B. Malkawi, R. Buton, P.A. Magni and S. Lam, "COVID-19: 20 countries' higher education intra-period digital pedagogy responses," *Journal of Applied Learning & Teaching*, vol. 3, no. 1, 2020. https://doi.org/10.37074/jalt.2020.3.1.7

[8] G. Frankl and S. Bitter, "Online exams: practical implications and future directions," Proceedings of the European Conference on e-Learning, pp. 158-164, 2012.

[9] G. Frankl, P. Schartner and G. Zebedin, "Secure online exams using students' devices," Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON), 2012. https://doi.org/10.1109/EDUCON.2012.6201111
[10] F.M. Guangul, A.H. Suhail, M.I. Khalit and B.A. Khidhir, "Challenges of remote assessment in higher education in the context of COVID-19: a case study of Middle East College," *Educational Assessment, Evaluation and Accountability*, vol. 32, pp. 519-535, 2020. https://doi.org/10.1007/s11092-020-09340-w
[11] O.R. Harmon and J. Lambrinos, "Are online exams an invitation to cheat?" *The Journal of Economic Education*, vol. 39, no. 2, pp. 116-125, 2008. https://doi.org/10.3200/JECE.39.2.116-125
[12] O.R. Harmon, J. Lambrinos and J. Buffolino, "Assessment design and cheating risk in online instruction," *Online Journal of Distance Learning Administration*, vol. 13, no. 3, 2010.
[13] R. James, "Tertiary student attitudes to invigilated, online summative examinations," *International Journal of Educational Technology in Higher Education*, vol. 13, no. 1, pp. 1- 13, 2016. https://doi.org/10.1186/s41239-016-0015-0
[14] H. Jarodzka, N. Janssen, P.A. Kirschner and G. Erkens, "Avoiding split attention in computer-based testing: is neglecting additional information facilitative?" *British Journal of Educational Technology*, vol. 46, no. 4, pp. 803-817, 2015. https://doi.org/10.1111/bjet.12174
[15] N. Kara, "Enablers and barriers of online learning during the COVID-19 pandemic: A case study of an online university course," *Journal of University Teaching & Learning Practice,* vol. 18, no. 4, 2021. https://doi.org/10.53761/1.18.4.11
[16] S. Khan and R.A. Khan, "Online assessments: Exploring perspectives of university students," *Education and Information Technologies*, vol. 24, pp. 661-677, 2019. https://doi.org/10.1007/s10639-018-9797-0
[17] R.K. Ladyshewsky, "Post-graduate student performance in "supervised in-class" vs. "unsupervised online" multiple choice tests: implications for cheating and test security," *Assessment & Evaluation in Higher Education*, vol. 40, no. 7, pp. 883-897, 2015. https://doi.org/10.1080/02602938.2014.956683
[18] A. Munoz and J. Mackay, "An online testing design choice typology towards cheating threat minimisation," *Journal of University Teaching & Learning Practice*, vol. 16, no. 3, 2019. https://doi.org/10.53761/1.16.3.5
[19] F. Paas, A. Renkl and J. Sweller, "Cognitive load theory: instructional implications of the interaction between information structures and cognitive architecture," *Instructional Science,* vol. 32, pp. 1-8, 2004. https://doi.org/10.1023/B:TRUC.0000021806.17516.d0
[20] A.A. Prisacari and J. Danielson, "Computer-based versus paper-based testing: investigating testing mode with cognitive load and scratch paper use," *Computers in Human Behavior,* vol. 77, pp. 1-10, 2017. https://doi.org/10.1016/j.chb.2017.07.044
[21] E.F. Risko and S.J. Gilbert "Cognitive offloading," *Trends in cognitive sciences*, vol. 20, no. 9, pp. 676-688, 2016. https://doi.org/10.1016/j.tics.2016.07.002
[22] A.P. Rovai, "Online and traditional assessments: what is the difference?" *The Internet and Higher Education*, vol. 3, no. 3, pp. 141-151, 2000. https://doi.org/10.1016/S1096-7516(01)00028-8
[23] D. Schneider, B. Volk, M. Lehre, D. Bauer and T. Piendl, "Der Safe Exam Browser. Innovative Software zur Umsetzung von Online-Prüfungen an der ETH Zürich," in G. Csanyi, F. Feichl, and A. Steiner, *Digitale Medien - Werkzeuge für exzellente Forschung und Lehre*, Waxmann, Münster, pp. 431-441, 2012.
[24] J. Sweller, "Cognitive load during problem solving: effects on learning," *Cognitive Science,* vol. 12, pp. 257-285. 1988. https://doi.org/10.1207/s15516709cog1202_4

[25] S. Washburn, J. Herman and R. Stewart, "Evaluation of performance and perceptions of electronic vs. paper multiple-choice exams," *Advances in Physiology Education,* vol. 41, pp. 548-555, 2017. https://doi.org/10.1152/advan.00138.2016

[26] S. Wibowo, S. Grandhi, R Chugh and E. Sawir, "A pilot study of an electronic exam system at an Australian university," Journal of Educational Technology Systems, vol. 45, no. 1, pp. 5-33, 2016. https://doi.org/10.1177/0047239516646746

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Developing Student Creative Problem-Solving Skills (CPSS) Using Online Digital Storytelling: A Training Course Development Method

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Abstract—This study set out to research and evaluate the needs in developing creative problem-solving skills (CPSS) of undergraduate students through developing and evaluating a digital storytelling process using Padlet. The sampling process used simple random sampling to select 332 teachers from 83 schools in Bangkok. The data was collected using a needs assessment questionnaire, training course questionnaire, and satisfaction questionnaire. Descriptive statistics used for the analysis included frequency, percentage, mean ($\bar{x}$), and standard deviation (SD). The data collected were mean scores of expert validity testing and student inter-rater reliability testing. The assessment evaluated student satisfaction toward the CPSS training course using 30 students in the Computer Education Program at Dhonburi Rajabhat University's Faculty of Education in Thailand. The findings revealed that of the four aspects identified for developing undergraduate CPSS, *elaboration* was at the top of the priority of needs ($PNI_{Modified}$ = 0.20). This was followed by *originality* and *flexibility* ($PNI_{Modified}$ = 0.19). Finally, was *fluency* ($PNI_{Modified}$ = 0.18). Also, analysis of the *prospective condition* was ranked 'high' across all four aspects with an average of $\bar{x}$ = 4.38 SD = 0.06. Further analysis of the *real condition* showed that all four aspects had an average of $\bar{x}$ = 3.67, SD = 0.06. The study contributes to the literature in that it demonstrated that correctly developed and implemented undergraduate student CPSS can increase significantly. This fact is critical in knowing as a nation's future depends on its workforce and leaders having CPSS.

Keywords—creativity, critical thinking, higher-order thinking skills, needs assessment, Thailand

1 Introduction

Teaching in the 21st century aims for students to embrace critical thinking skills (CTS), creativity, self-confidence, knowledge acquisition, understanding of one's self knowledge-construction. Students should also learn to be entrepreneurs and producers who strive for excellence, patience, diligence, teamwork, social responsibility, social consciousness, virtue, peace, and Thainess [1]. Learning design must not be class simulations but instead provide scenarios as close to real-life based on the learning context or environment. Therefore, learning situations should be based on an environment that the learner is familiar with and knows about.

New experiences should be accumulated to challenge old beliefs or values, causing individuals to abandon their old beliefs and search for new answers. In Kuhn's description concerning how paradigms are created and what they contribute to scientific or disciplined inquiry [2], the author says that all research's foundation is based on scientific achievements from the past and that these achievements can be referred to as 'paradigms.' Therefore, education paradigms become critical as they are the lens through which students view their environments. Unfortunately, new paradigms can also provide the catalyst for education reform resistance [3].

In *active learning*, student learning is placed at the center, focusing on '*how*' students learn, not just the '*what*' of learning [4], [5]. Students should also be taught how to '*think hard*,' challenging what they learn rather than passively receiving information from the teacher.

Also, self-knowledge creation is based on student collaboration and classroom activities, whose beginnings lie in *constructivist-inspired thinking* (CIT) [6]. CIT further instills knowledge acquisition through student involvement with the course content (such as in flipped and blended learning) instead of repetition and memorization [7].

Another component goal in learning has been training students to acquire *21^st^ – century skills* [8]. These include teaching how to *think critically* [9]-[13], how to be *creative*, [14]-[17], *problem solving* [10], [11], [18] and how to acquire *higher-order thinking skills* (HOTS) [19], [20].

Furthermore, research concerning university course success has identified '*habits of mind*' being essential. These include analyzing information, reasoning, interpretation, accuracy, precision, and problem-solving [18]. Also, workers in a 21st-century workforce must have the ability to think critically when they compare evidence, evaluate competing claims, and make reasonable deductions [21]. Other research points to the need for 21st-century workers to have the ability for innovation and CTS and active citizenship [22], [23].

Problem-solving skills (PSS) have also been identified in numerous studies as a prerequisite for employment for 21st-century workers [24]. In Vietnam, a World Bank report specifically identified worker cognitive skill problems in both PSS and CTS [25]. This is consistent with a study from the US-based National Association of Colleges and Employers (NACE), in which employers indicated that CTS and PSS were ranked second in importance by 96.3% of the respondents [10]. These findings are also consistent with another OECD/UNESCO report on Thailand's education policy in which it concluded that information communications technology (ICT) could play an essential role in supporting and creating innovative teaching practices and learning environments for supporting students' 21st-century competencies such as PSS and CTS [11].

In support of CTS, another report has found that a series of drills exercises can teach these skills and problem solving [26]. It has also been suggested that the outcome of cognitive development is thinking [27]. Therefore, education's purpose is not to impart knowledge but to facilitate a student's PSS and thinking processes [28].

Various teaching methods have been discussed and explored for teaching students 21st-century skills. One frequently evaluated method is *inquiry-based learn*ing (IBL), which allows students to explore, inquire, and examine knowledge that can enhance their PSS. The teacher becomes the facilitator or actor who motivates students' inquiry, solution, and individually derived conclusions [29], [30].

Closely related is *student-centered learning* (SCL), which has also become a crucial foundation in teaching 21st-century skills [31], where educators serve more as facilitators than teachers [32]. Education policies also need to focus on teacher competency development [33], as pre-service teachers are on the frontlines in training the innovators and leaders of tomorrow's workforce, which require 21st Century workforce skills [34].

Therefore, there is an emphasis on 21st-century workers who are highly skilled in learning and adapting and have the knowledge that can be linked to other subjects in work innovation. CPSS is also directly related to improving the quality of life [15], creative thinking, and applying knowledge theory to create processes and production methods that create innovation beneficial to individuals and society. In addition, in terms of learning skills and innovation, CPSS are also essential in encouraging students to develop CTA, PSS, communications, innovation, cooperation, and creativity [35]. These skills are aimed at learners who want to modify the way they learn and build their own body of knowledge. Finally, from the PISA (Program for International Student Assessment) assessment tests, CPSS is stated to be in high demand in organizations experiencing fast growth and needing technical and highly-skilled managerial professionals [36].

In addition, creative thinking processes are techniques used in advanced human thinking and innovation to produce new things or gain strategic advantages. Additionally, these skills are necessary at work and can be adapted to everyday daily living. Therefore, educators must be aware of developing student creative thinking and CPSS and how to support each student's different-yet-unique creative thinking [15], [37].

Furthermore, it has been found that US employment growth has originated in new firms and organizations which have introduced new innovative practices, services, and products [24]. Unfortunately, engineering students seldom develop designs that respond to real human problems [24]. However, according to the OECD, innovation is crucial for growth [38].

As we have seen, ICT plays a fundamental and essential role in CPSS development. As the technology has evolved and the Internet access bandwidth has increased, prices have decreased. This has allowed nearly universal access in some developing nations such as Thailand to very affordable digital education tools and learning platforms for both students and teachers. Moreover, digital mobile learning and its use in a problem-based learning (PBL) environment as a cognitive tool to promote HOTS [19], [20].

In this new environment, digital storytelling has become recognized as a valuable tool in teaching analytical thinking and HOTS [39]-[44]. Digital storytelling is a multi-media process using integrated creator voice-overs through digital technologies. Also, although a 21st-century innovation, it is not that far removed from the ancient technique and oral traditions used for millennium [45].

Moreover, new digital software-as-a-service cloud-based tools such as Padlet allow real-time hosting and student collaboration by uploading, organizing, and sharing unique content to virtual bulletin boards called '*padlets*' [46]. When digital storytelling is combined with a digital tool such as Padlet, teachers can insert questions into each step of a story's progression. This allows the digital story to reinforce a student's thinking, analysis, and synthesis skills as the story transforms.

From what has been discussed, it can be seen that these skills, ICT, and digital tools are crucial in 21^{st}-century education. It is especially essential in developing CPSS, as CPSS is critical for teachers' need in developing and equipping students to enter society and its workforce.

However, it has been pointed out in multiple Thai educator studies that many problems stand in the way of transforming students into 21^{st}-century workforce members. One of the problems is the competency readiness of primary education teachers [47], another is the continued use of 'chalk and talk' and teacher-centered teaching. Another is the inability of many teachers to keep up with the pace of change [47], and finally, the lack of teacher motivation in many.

Therefore, solutions must be sought. The complex pot of problems is the COVID-19 pandemic and the havoc created for the Thai education system and its students and teachers. Under Thailand's '*New Normal*,' online teaching has now become the required and accepted practice, but not without numerous bumps in the road. Therefore, this study investigates how a traditional and accepted method for learning and teaching (storytelling) can be adopted in a new digital educational environment while developing critically needed CPSS.

2 Objectives of the research

1. The study's objectives include determining and prioritizing needs in developing undergraduate student CPSS.
2. To develop a CPSS training course using a digital storytelling process.
3. To evaluate student satisfaction concerning their participation and use, the author developed a CPSS training course using a digital storytelling process.

3 Research methods

This research collected quantitative data, and the details are described below.

3.1 Ethics clearance

Prior to the study's commencement, the study project plan was detailed to our university's ethics overview committee. After, the two groups of experts, the sample questionnaire group and the CPSS evaluation group of undergraduate students, were informed that their input and personal information was confidential [17].

3.2 Population and sample group

The study's population included 104 schools and teachers in the Bangkok metropolitan area. Simple random sampling was used in February 2020 to select 83 schools from which four questionnaires were sent to each school. Sample size determination used the commonly accepted questionnaire to observed variable ratio of 20:1 [48], [49].

Questionnaire collection was 100% successful due to the authors' Faculty of Education having student teachers assigned to practice in the target schools. Therefore, the student teachers were asked to bring the questionnaire to the teachers in the schools and asked for their assistance in the distribution and collection. Therefore, the information was 100% complete.

3.3 Research tools

The CPSS questionnaire developed for the sample group of 332 teachers consisted of two parts. Part 1 contained four general information items concerning each teacher, while Part 2 contained 16 items on the needs in developing CPSS. Each item used a five-level Likert agreement scale whose anchor points were 5 (highest) and 1 (very low) (Table 1).

After its design, the questionnaire's accuracy, consistency, and content validity were undertaken. These items were accomplished using multiple processes [50]. The first was to use a panel of five education experts to assess each questionnaire items' validity and reliability by assigning values that were analyzed using the index of Item-Objective Congruence (IOC) [51]. The lowest IOC value retained for the questionnaire was 1.00, as studies have suggested that items with values ≤ 0.67 should be modified or eliminated based on experts' suggestions [52]. Questionnaire reliability evaluation used 30 student teachers from the authors' local campus. Assessment of the 30 student teachers' pre-survey questionnaires' reliability used Cronbach's alpha (α) for each item [53]. The calculations showed that Cronbach's reliability value α average was 0.94.

Table 1. Likert scale evaluation criteria

Rank	Expected condition/Real condition	Mean Range	Need Level
5	Highest	4.50 – 5.00	the most
4	High	3.50 – 4.49	a lot
3	Moderate	2.50 – 3.49	moderate
2	Low	1.50 – 2.49	little
1	Very Low	1.00 – 1.49	minimal

3.4 CPSS training course development

The CPSS training course using the digital storytelling development process was divided into three components. The training courses consisted of students, which were undertaken in August 2020. These were:

a) Draft the CPSS training program using digital storytelling for the 30 proposed undergraduate Computer Education Program students.
b) The appropriateness and congruency evaluation of the draft training program was checked by a different group of three experts using a training evaluation form. The

form was divided into two parts, with the first part *appropriateness evaluation* using $\bar{x}$ and SD. The results for this process were strong as the $\bar{x}$ = 4.60, SD = 0.53. The second part was the *congruency evaluation* of the program, which had an IOC = 1.00. The calculations showed that Cronbach's reliability value α average was 0.96.

c) The *inter-rater reliability* evaluation method was used to assess the creative problem-solving test by three examiners [53] (Table 2). A commonly accepted value of 75% is used for most disciplines.

Table 2. The CPSS validity check test results

Test	Examiner-1		Examiner-2		Examiner-3		Min	Max	R
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*			
1st set	6.533	1.106	6.600	1.102	6.667	1.061	0.737	0.927	0.856
2nd set	13.233	1.995	14.367	2.999	13.433	2.223	0.752	0.931	0.865
3rd set	9.733	1.818	9.867	1.815	10.200	2.413	0.747	0.930	0.862
4th set	23.100	2.090	23.967	2.236	23.567	1.695	0.764	0.934	0.871

3.5 CPSS training course student satisfaction survey

The CPSS training course undergraduate student satisfaction survey was constructed in two parts. The first part was concerned with general information about each student, while the second part was the actual survey concerning each student's satisfaction toward the CPSS training course. Responses were ranked using a 5-level Likert scale. Five experts participated in the survey's content validity check in which the I.O.C. was determined to be 1.00, and the reliability was 0.96. Descriptive statistics, including the mean, S.D., frequency, and percentage, were used to analyze the data.

4 Research results

4.1 Teacher survey characteristics

The results from the questionnaire's inquiry into each teacher's characteristics revealed that most of the teachers surveyed were women (75.90%) and under 30 years of age (62.40%). Surprisingly, 92.80% only had an undergraduate degree, while the remaining 7.20% had finished a graduate degree. Finally, 75.60% had one to five years of teaching experience.

4.2 CPSS needs analysis

The CPSS needs analysis was undertaken by analyzing the *actual condition* and *prospective condition* of the 332 teachers serving in the Secondary Educational Service Area 1 (grades 7-12) and schools under the Bangkok Primary Education Service Area Office (Grades 1-6). The $\bar{x}$ and the SD were used for data analysis. Need analysis prioritization was undertaken using $PNI_{Modified}$ (Table 3). $PNI_{Modified}$ is a tool often used as an assessment tool in Thai studies and is known as the modified priority needs index ($PNI_{Modified}$) [22], [54]-[56]. Originating from research studies conducted by [57] and [58], the modified version is a more robust version whose standard scores in the assessment of needs find the differential value between the desired outcome (I) and the actual results (D) [57]. The calculation formula used for the study was:

$$PNIModified = (I - D) / D \tag{1}$$

PNI = priority needs index

I = the $\bar{x}$ for the desired outcome

D = the $\bar{x}$ for the actual results

Moreover, a $PNI_{(modified)}$ analysis was conducted to determine the level or rank of each need according to each teacher's input.

Table 3. The teacher needs analysis results for CPSS teaching development

No.	Item	Real condition			Prospective condition			PNI_m
		$\bar{x}$	***S.D.***	***Rating Scales***	$\bar{x}$	***S.D.***	***Rating Scales***	
1.	Originality	3.63	0.03	High	4.32	0.05	High	0.19
2.	Fluency	3.70	0.08	High	4.34	0.07	High	0.18
3.	Flexibility	3.66	0.06	High	4.37	0.02	High	0.19
4.	Elaboration	3.69	0.08	High	4.43	0.06	High	0.20
Average		3.67	0.06	High	4.38	0.06	High	0.19

$PNI_m = PNI_{(modified)}$

Table 3 shows that the results for the *prospective condition* for CPSS development was high ($\bar{x}$ = 4.38, SD = 0.06) and for the *real condition* it was moderate ($\bar{x}$ = 3.67, SD = 0.06). Also, the $PNI_{Modified}$ evaluation for each of the four aspects were slightly different from 0.18 (fluency) to 0.20 (elaboration).

Using these results, the authors commenced the development of a CPSS training course focused on the *elaboration* aspect. Part 2 details the results of this process.

4.3 The CPSS training course development using digital storytelling model

The training course for CPSS reinforcement using digital storytelling consisted of four modules. These included 1) 'Let us get to know your computer,' 2) Computer viruses', 3) 'How to use your computer,' and 4) 'CPSS reinforcement .'The four modules take 30 hours which is best divided into six hours daily over five days.

The training course is a behavior that represents undergraduate students' knowledge and ability, which consists of five steps. These include: 1) problem identification, 2) problem understanding, 3) action preparation, 4) solution identification, and 5) action planning. The training steps were:

Step 1: Students complete a pre-test on CPSS, consisting of four parts. These include *originality, fluency, flexibility*, and *elaboration*.

Step 2: Students get trained according to the teaching plans in each lesson. Research has shown that using a participatory action research (P.A.R.) methodology allows participation from beginning to end [59], [60]. Under P.A.R. frameworks, the authors identified the importance of plan development and its continual improvement (*planning*) and the planning implementation for the teaching environment (*practice*). [61], [62].

Step 3: Students complete worksheets for each module. Then, each student presents answers to the class using a digital storytelling process via Padlet. The class scored their classmates' Padlet presentations to determine the highest CPSS score. In Indonesia, Padlet was an excellent digital tool in adding digital skills to each student's German essay writing exercises [46]. Padlet was also positively responded to by the experimental group from the Indonesian study and this Thai study.

Step 4: Students complete a CPSS post-test.

Step 5: The researchers compared scores from students' tests before and after applying the SPSS training course using digital storytelling (Table 4).

Table 4. Mean score comparison of undergraduate students' CPSS (*n*=30)

Score	*n*	$\bar{x}$	SD	t-value	degrees of freedom	Sig.
Student Pre-test	30	45.87	7.91	50.16	29	0.00**
Student Post-test	30	85.60	16.39			

*Significance level at .01

Table 4 compares the mean $\bar{x}$ scores of the 30 undergraduate students' pre-test and post-test CPSS. In the pre-test, the sample group had a CPSS $\bar{x}$ = 45.87, SD. = 7.91. After the 30-hour CPSS training course using digital storytelling, a significant post-test score increased to a $\bar{x}$ = 85.60, 16.39 SD. The results of the CPSS training course model using digital storytelling are shown in Figure 1.

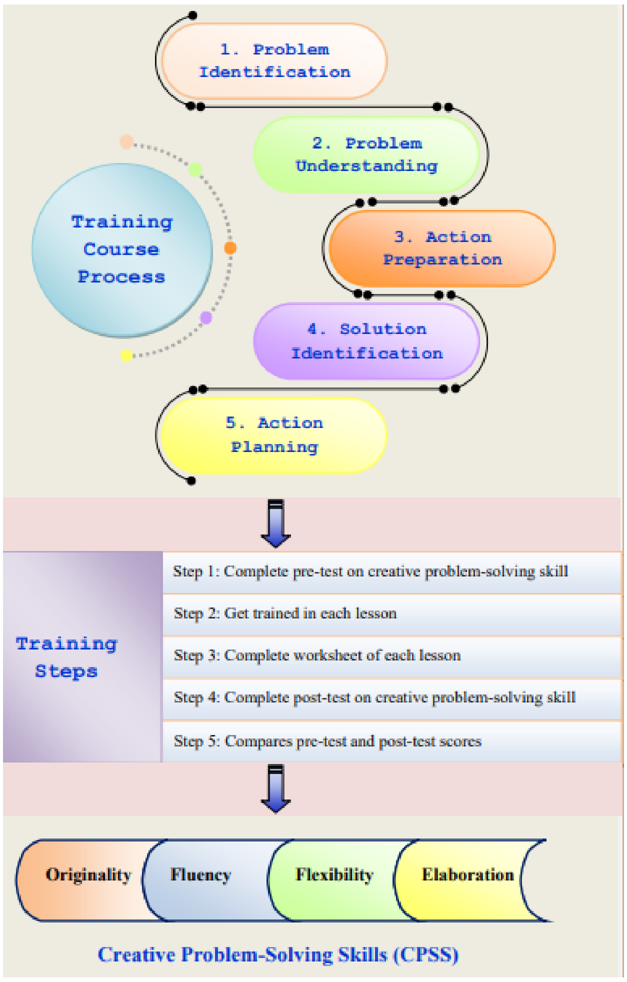

Fig. 1. The CPSS training course using a digital storytelling process model (Source: The authors)

4.4 The CPSS training course development using digital storytelling

The individuals who participated in the experimental CPSS training course were predominantly male (56.70%) and 18-20 years old (Table 5). All students who participated were student-teacher trainees in the Computer Education Program at the Dhonburi Rajabhat University's Faculty of Education.

The analysis of the 30 undergraduate students' satisfaction toward the CPSS training course using the digital storytelling process is shown in Table 6.

Table 5. CPSS training course student sample

Gender	*N*	%
Men	17	56.70
Women	13	43.30
Total	30	100.00

Furthermore, from Table 6's undergraduate experimental group, the authors collected and analyzed their opinions concerning their satisfaction with the CPSS training course using digital storytelling.

Table 6. The CPSS training course undergraduate student satisfaction results

Item	Aspect	$\bar{x}$	S.D.	Rating Scales
Contents		4.59	0.53	Highest
The content has appropriate difficulties.	x1	4.60	0.50	Highest
The content is interesting.	x2	4.57	0.50	Highest
The content is diverse.	x3	4.77	0.43	Highest
The content is related to daily living.	x4	4.43	0.63	High
Learning activities		4.59	0.64	Highest
The learning activities improved my creative problem-solving skill.	x5	4.63	0.49	Highest
The learning activities supported cooperation with classmates and teachers.	x6	4.57	0.63	Highest
The learning activities helped me in doing my research.	x7	4.47	0.82	High
The learning activities helped me search for diverse problem-solving methods.	x8	4.73	0.45	Highest
The learning activities helped me search for new problem-solving methods.	x9	4.57	0.73	Highest
Media and Materials used in the training		4.53	0.62	Highest
The media/materials were engaging.	x10	4.50	0.51	High
The media/materials were easy to understand.	x11	4.43	0.73	High
The media/materials were practical.	x12	4.53	0.73	Highest
The media/materials corresponded with contents and activities	x13	4.67	0.48	Highest
Measurement and Assessment		4.49	0.70	High
I liked helping in assessing my classmates' work.	x14	4.37	0.81	High
I like assessing my work.	x15	4.43	0.73	High
I adapted my assessment results to improve my work.	x16	4.37	0.81	High
The course had diverse measurement and assessment methods.	x17	4.57	0.63	Highest
The measurement and assessment methods corresponded with the CPSS course activities.	x18	4.70	0.47	Highest
Benefits gained from the training		4.62	0.54	Highest
I enjoy doing worksheets.	x19	4.63	0.61	Highest
I like practicing the CPSS exercises.	x20	4.77	0.43	Highest
The course allows me to use my CPSS course knowledge in daily life.	x21	4.53	0.51	Highest
I like encouraging my classmates to solve problems creatively.	x22	4.43	0.63	High
I like helping my classmates know and understand the contents more.	x23	4.73	0.45	Highest
Average		4.57	0.61	Highest

5 Discussion

The study of the needs in CPSS development of undergraduate students shows that the overall *prospective condition* of the development was at a high level ($\bar{x}$=4.38, S.D. = 0.06), which was significantly higher than the *real condition* ($\bar{x}$=3.67, S.D. = 0.06). The findings also revealed that of the four aspects identified for developing undergraduate CPSS, *elaboration* was at the top of the priority of needs ($PNI_{Modified}$ = 0.20, $\bar{x}$=4.43, S.D. = 0.06). This was followed by *flexibility* ($PNI_{Modified}$ = 0.19, $\bar{x}$=4.37, S.D. = 0.02) and *originality* ($PNI_{Modified}$ = 0.19, $\bar{x}$=4.32, S.D. = 0.05). Finally, was *fluency* ($PNI_{Modified}$ = 0.18, $\bar{x}$=4.34, S.D. = 0.07).

Support for elaboration's use in teaching creative thinking comes from a similar study from Indonesia in which elaboration was identified in teaching math [63]. This was also consistent with another study in which creative thinking's indicators were *fluency*, *flexibility*, *originality*, and *elaboration* [64].

Elaboration has been stated as the ability to solve problems by envisioning details overlooked by others. It is the ability to solve a problem with step-by-step and elaborate thinking. It can solve problems with explicit explanations and perfectly complete the main idea. This skill is suitable for undergraduate students of computer programs who need to develop multiple programs and systems. Moreover, elaboration is indispensable as it helps in creating products or processes.

This conforms to Kneller [14], who stated that elaboration is vital in successfully creating new works. Creativity is composed of unique and new things and the consciousness of creative success. However, other elements of CPSS, such as flexibility, originality, and fluency, are also crucial. They must cooperatively support each other to apply them in creative problem-solving. Therefore, with the ultimate focus on elaboration, these four aspects should also be promoted to encourage students to have CPSS [65], [66].

5.1 The CPSS training course development using digital storytelling model

Support for the model's development and usefulness comes from multiple studies. Our model identified five steps in the CPSS training course process. These included *problem identification, problem understanding, action preparation*, *solution identification*, and *action planning*. In another Thai study, the author determined that *problem identification* helped teach student *creativity* for social studies [15]. Other authors have added that an essential goal for the education system in Thailand is developing student and undergraduate problem-solving skills [67].

In Indonesia, knowledge in teaching problem-solving skills was also stated as essential as the success of student lives depends on their ability to solve various life problems [53]. Furthermore, Jonassen [68] has added that problem-solving models can also be effective when using a four-step process. His suggestion includes the *problem's presentation,* the *problem's articulation, alternative solution finding*, and *justification and argumentation.* Therefore, CPSS model goals should entail each stage's ability to teach divergent thinking and convergent thinking [69]. Other researchers have also pointed out that digital storytelling increases digital literacy and pre-service teacher professional skills [70].

5.2 The online CPSS training course and Padlet

In the CPSS training course design evolution, multiple learning management and collaboration tools were investigated. After comparing multiple applications, a decision was made to use a digital tool from the small, decade-old California firm Padlet. Padlet allowed each of the 30 Computer Education Program undergraduate students to collaborate with their writing exercises, images, and video content through their digital storytelling exercises [46]. Furthermore, other educators have found Padlet to be a helpful information literacy tool as it functions across various devices, does not need the creation of individual accounts, and needs no special technical knowledge [71].

Also importantly, Padlet was a valuable tool for each student's assessment and feedback of their classmate's 'stories .'However, due to the nature of Thai culture, critiquing another or one's work is sensitive, as can be seen from the two lowest scores of the 23 items assessed for the training course student satisfaction (*x14* and *x16*). Therefore, student assessment of any CPSS training course exercises might be a stumbling block in any future training courses.

5.3 CPSS training course pre-test and post-test

The CPSS training course using digital storytelling effectiveness was evaluated using a pre-test and post-test. Results revealed that the students' CPSS after the training course was higher .01 significance level. This shows that the training course was beneficial to the undergraduate students. It embeds undergraduate students with CPSS and thinking skills. This allows undergraduate students to envision multiple solutions to problems they encounter in life.

This study's results conform to another Thai study in which using a training package is highly effective in teaching CPSS [67]. However, CPSS model developers and implementers should pay special attention to the '*problem identification*' stage in their CPSS process, which was determined to have the highest need for development.

It is also vital that students in a CPSS training course are consistent in their attendance from the start to its completion. Instructors also need to ensure that CPSS activities are assigned which arouse each student's curiosity and creativity [72]. However, CPSS is a skill that can be developed with practice and constant training [73] - [78].

5.4 CPSS training course student satisfaction

From Table 5, we can determine that each student's satisfaction with the CPSS training course using digital storytelling was at the highest level ($\bar{x}$=4.57, S.D. = 0.61). Moreover, from the analysis of each of the 23 aspects, it was determined that the training course evaluation students placed the highest importance on the *diversity of the content* (x3) ($\bar{x}$=4.77, S.D. = 0.43) and their *CPSS practice skills* (x20) ($\bar{x}$=4.77, S.D. = 0.43). These aspects were closely followed in importance by *learning activities helping* *attendees to search for diverse problem-solving methods* (x8) ($\bar{x}$=4.73, S.D. = 0.45), and *I like helping my classmates know and understand the contents more* (x23) ($\bar{x}$=4.73, S.D. = 0.45). Interestingly, *I liked helping assess my classmates' work* (x14) ($\bar{x}$=4.37, S.D. = 0.81) was at the bottom of the list.

6 Conclusion

This study demonstrated the need to develop the CPSS of undergraduate students. Of the four skills evaluated, the most essential need was *elaboration*. Therefore, university teachers should reinforce student elaboration capabilities by developing and using training projects specifically designed to integrate *elaboration* into their day-to-day subjects.

Also, after experimenting with the training course, it was found that the course was able to develop undergraduate students' creative problem-solving skills at a high level. Therefore, persons concerned can apply this study's research results as the guideline in arranging training courses to improve and equip students with CPSS. The guidelines acquired from the training course can also be adapted in daily life.

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8 References

[1] P. Sinlarat, *Critical thinking: How to teach and create*, Bangkok: Graduate School Dhurakij Pundit University, 2014.

[2] T. S. Kuhn and I. Hacking, *The structure of scientific revolutions: 50th anniversary edition,* University of Chicago Press, 2012. https://doi.org/10.7208/chicago/9780226458144.001.0001

[3] S. Irez and C. H. Tosunoglu, "Educational reforms as paradigm shifts: Utilizing Kuhnian lenses for a better understanding of the meaning of, and resistance to, educational change," *International Journal of Environmental and Science Education,* vol. 3, no. 6, pp. 251 – 266, 2011. [Online serial]. Available: https://files.eric.ed.gov/fulltext/EJ959419.pdf [Accessed Jan. 30, 2022].

[4] W. Duangpummes and W. Kaewurai, "Learning management in Thailand 4.0 with active learning, "*Humanities and Social Sciences Journal of Pibulsongkram Rajabhat University,* vol. 11, no. 2, 1 – 14, 2017. [Online serial]. Available: https://tinyurl.com/2jhzrbmt [Accessed Jan. 30, 2022].

[5] A. Surakarn, T. Junprasert, N. Chaiakkarakan, N. Peungposop, and R. Boonlop, "Active learning and its outcomes: A case study from the Education Reform Project in Thailand," *The Journal of Behavioral Science*, vol. 15, no. 1, 34 – 51, 2020. [Online serial]. Available: https://tinyurl.com/mrjvtyta [Accessed Jan. 30, 2022].

[6] A. A. Almodaires, G. M. Alayyar, T. O Almsaud, and F. M. Almutairi, "The effectiveness of flipped learning: A quasi-experimental study of the perceptions of Kuwaiti pre-service

teachers," *International Education Studies,* vol. 12, no. 1, 10 – 23, 2018. https://doi.org/10.5539/ies.v12n1p10
[7] L. R. Kroll and V. K. Laboskey, "Practicing what we preach: Constructivism in a teacher education program," *Action in Teacher Education,* vol. 18, no. 2, 63 – 72, 1996. [Online serial].: https://doi.org/10.1080/01626620.1996.10462834
[8] Partnership for 21st Century Skills, "Framework for 21st century learning," 2011. https://tinyurl.com/9rbohol [Accessed Jan. 30, 2022].
[9] L. Barrington, J. Casner-Lotto, and M. Wright, "Are they really ready to work? Employers' perspectives on the basic knowledge and applied skills of new entrants to the 21st Century U.S. workforce". The Partnership for 21st Century Skills, 2006.
[10] NACE. (2015). "Career readiness competencies: Employer survey results," National Association of Colleges and Employers.
[11] OECD/UNESCO, *Education in Thailand: An OECD-UNESCO Perspective*. Reviews of National Policies for Education, Paris: OECD Publishing, 2016.
[12] W. S. W. Sulaiman, W. R. A. Rahman, and M. A. Dzulkifli, "Relationship between critical thinking dispositions, perceptions towards teachers, learning approaches and critical thinking skills among university students," *The Journal of Behavioral Science,* vol. 3, no. 1, pp. 122 – 133, 2008.
[13] P. Tunkham, S. Donpudsa, and P. Dornbundit, "Development of STEM activities in chemistry on "protein" to enhance 21st Century learning skills for senior high school students," *Silpakorn University Journal of Social Sciences, Humanities, and Arts*, vol. 16, no. 3, pp. 217 – 234, 2016.
[14] G. F. Kneller, *The art and science of creativity*, New York: Holt, Rinchart and Winston, 1965.
[15] P. Phuangphae, "Creativity-based learning in Social Studies," *Veridian E-Journal, Silpakorn University*, vol. 10, no. 5, pp. 365 – 374, 2017. https://tinyurl.com/3dbaey65
[16] P. Vijayaratnam, "Cooperative learning as a means to developing students'critical and creative thinking skills," *Proceedings of the 2nd International Conference of Teaching and Learning*, 2009.
[17] N. Wannapiroon and P. Pimdee, "Thai undergraduate science, technology, engineering, arts, and math (STEAM) creative thinking and innovation skill development: A conceptual model using a digital virtual classroom learning environment," *Education and Information Technologies,* 2022. https://doi.org/10.1007/s10639-021-10849-w
[18] D. T. Conley, "Toward a more comprehensive conception of college readiness," Educational Policy Improvement, Feb. 8, 2008.
[19] D. Salim and A. Hamdani, "Mobile Learning: A Good Practice," *Procedia - Social and Behavioral Sciences*," vol. 103, 665 – 674, 2013. https://doi.org/10.1016/j.sbspro.2013.10.386
[20] O-S. Tan, Ed., *Problem-based Learning and Creativity*. Singapore: Centage, 2009.
[21] S. B. Chiruguru, "The Essential Skills of 21st Century Classroom (4Cs)," 2020. https://doi.org/10.13140/RG.2.2.36190.59201
[22] P. Thammasaeng, P. Pupat, and S. Phetchaboon, "Needs assessment of information and communication technology literacy (I.C.T. Literacy) of students in secondary educational service area," *International Journal of Emerging Technologies in Learning,* vol. 11, no. 12, pp. 9 – 13, 2016. https://doi.org/10.3991/ijet.v11i12.5798
[23] UNESCO, *Report: needs assessment framework of teacher training and development to ensure Education for All (E.F.A.).* Uganda. Ministry of Education and Sports. 2014. https://tinyurl.com/yxnnldf5 [Accessed Feb. 1, 2022]
[24] B. Laduca, A. Ausdenmoore, J. Katz-Buonincontro, K. P. Hallinan, and K. Marshall, "An arts-based instructional model for student creativity in engineering design," *International*

Journal of Engineering Pedagogy (iJEP), vol. 7, no. 1, pp. 34 – 57, 2017. https://doi.org/10.3991/ijep.v7i1.6335
[25] World Bank, *Vietnam development report 2014 – Skilling up Vietnam: Preparing the workforce for a modern market economy,* 2014.
[26] J. E. McPeck, *Critical thinking and education*, New York, NY: St. Martin's Press, 1981.
[27] J .S. Bruner, *The process of education*, Cambridge, MA: Harvard Press, 1976.
[28] J .S. Bruner, "The act of discovery," *Harvard Educational Review*, vol. 31, pp. 21 – 32, 1961.
[29] S. C. Kong and Y. Song, "A principle-based pedagogical design framework for developing constructivist learning in a seamless learning environment: A teacher development model for learning and teaching in digital classrooms," *British Journal of Educational Technology,* vol, 44, no. 6, pp. E209 - E212, 2013. https://doi.org/10.1111/bjet.12073
[30] M. Pedaste, M. Mäeots, L. A. Siiman, T. de Jong, S. A. N. van Riesen, and E. T. Kamp, "Phases of inquiry-based learning: Definitions and the inquiry cycle," *Educational Research Review,* vol. 14, pp. 47 – 61, 2015. https://doi.org/10.1016/j.edurev.2015.02.003
[31] B. B. Andresen and K. van den Brink, *Multimedia in education curriculum*. 2013. https://tinyurl.com/yc5pdq5a [Accessed Feb. 1, 2022].
[32] I. Ameliana, "Teacher-centered or student-centered learning approach to promote learning?" *Jurnal Sosial Humaniora,* vol. 10, no. 2, pp. 59 – 70, 2017. https://doi.org/10.12962/j24433527.v10i2.2161
[33] P. Leekitchwatana and P. Pimdee, "Appropriate Thai high school student Internet behaviour: A Hierarchical Linear Model analysis," *International Journal of Emerging Technologies in Learning*, vol. 12, no. 10, pp. 158 – 172, 2017. https://doi.org/10.3991/ijet.v12i10.7366
[34] C. Buabeng-Andoh, "Factors influencing teachers' adoption and integration of information and communication technology into teaching: A review of the literature," *International Journal of Education and Development using Information and Communication Technology,* vol. 8, no. 1, pp. 136 – 155, 2012. https://tinyurl.com/yajcurxh
[35] T. Khammanee, *Teaching and Learning Platform: Diverse Alternatives*, 2nd ed., Bangkok, Thailand: Chulalongkorn University, 2003.
[36] OECD, *PISA 2012 Creative Problem Solving*, 2012. https://tinyurl.com/ys2vzhxk [Accessed Feb. 2, 2022]
[37] E. De Bono, *Edward De Bono's thinking course*, New York: Bridge Communications, 2004.
[38] OECD, Small businesses, job creation and growth: Facts, obstacles, and best practices, 1997. https://www.oecd.org/cfe/smes/2090740.pdf [Accessed Feb. 1, 2022].
[39] C. Chan and M. Sage, "A narrative review of digital storytelling for social work practice," *Journal of Social Work Practice*, 1 – 15, 2019. https://doi.org/10.1080/02650533.2019.1692804
[40] H. Hussain and N. Shiratuddin, "A digital storytelling process guide for designers," *Journal of Telecommunication, Electronic and Computer Engineering,* vol. 8, no. 8, pp. 13 – 17, 2016. [Online serial]. Available: https://tinyurl.com/y5zoj2jd [Accessed Feb. 1, 2022].
[41] S. Kaeophanuek, J. Na-Songkhla, and P. Nilsook, "A learning process model to enhance digital literacy using critical inquiry through digital storytelling (CIDST)," *International Journal of Emerging Technologies in Learning*, vol. 14, no. 03, 16, 2019. https://doi.org/10.3991/ijet.v14i03.8326
[42] J. B. Ohler, Digital storytelling in the classroom: new media pathways to literacy, learning, and creativity, 2nd ed., Corwin, 2013. https://doi.org/10.4135/9781452277479
[43] B. Robin, "Digital storytelling: A powerful technology tool for the 21st Century classroom," *Theory into Practice,* vol. 47, no. 3, pp. 220 – 228, 2008. https://doi.org/10.1080/00405840802153916

[44] N. Songkram, *Creating Digital video & digital storytelling for teaching and learning in the digital age*. Bangkok, Thailand: Chulalongkorn University Press, 2011.
[45] S. Papadopoulou and K. Vlachos, "Using digital storytelling to develop foundational and new literacies," *Research Papers in Language Teaching and Learning*, vol. 5, no. 1, pp. 235 – 258, 2014. [Online serial]. Available: https://tinyurl.com/bd5349aw [Accessed Feb. 1, 2022]
[46] M. Kharis, M. Ebner, P. H. Wijayati, E. Hidayat, and L. Afifah, "Microblogging with Padlet: Students' New Writing Experience on A2–B1 Common European Framework of Reference for Languages (CEFR)," *International Journal of Emerging Technologies in Learning,* vol. 15, no. 01, pp. 176–187, 2020. https://doi.org/10.3991/ijet.v15i01.11804
[47] C. Vangmeejongmee and O. Naiyapatana, Competency of Thai Teacher in 21st Century: Wind of change. *Journal of H.R. Intelligence,* vol. 12, no. 2, pp. 48 – 63, 2017. [Online serial]. Available: https://tinyurl.com/y4cpfau4 [Accessed Feb. 1, 2022].
[48] R. E. Schumacker and R. G Lomax, *A beginner's guide to structural equation modeling*, 4th ed., Routledge, 2016. https://doi.org/10.4324/9781315749105
[49] J. F. Hair, G. T. M. Hult, C. Ringle, and M. Sarstedt, *A primer on partial least squares structural equation modelling (PLS-SEM),* Sage. 2016.
[50] D. L. Kelly, *Measurement made accessible: A research approach using qualitative, quantitative, & quality improvement methods,* Sage, 1999.
[51] R. C. Turner and L. Carlson, "Indexes of item-objective congruence for multidimensional items," *International Journal of Testing,* vol. 3, no. 2, pp. 163 – 171, 2003. https://doi.org/10.1207/s15327574ijt0302_5
[52] P. Pimdee, "Antecedents of Thai student teacher sustainable consumption behavior," *Heliyon,* vol. 6, no. 8, e04676, 2020. https://doi.org/10.1016/j.heliyon.2020.e04676
[53] A. Zaeema and Z. Hassan, "Factors affecting purchase decision of canned tuna brands in Maldives," *International Journal of Accounting, Business and Management,* vol. 4, no. 1, pp. 124 – 149, 2016. https://doi.org/10.24924/ijabm/2016.04/v4.iss1/120.144
[54] E. T. Priyatni and Martutik, "The development of a critical–creative reading assessment based on problem solving," *SAGE Open*, April-June, 1 – 9, 2020. https://doi.org/10.1177/2158244020923350
[55] A. Chainut, P. Suwanjan, P. Pupat, and P., Pimdee, "Needs assessment for the global-mindedness of vocational certificate students under the Office of the Vocational Education Commission," *Mediterranean Journal of Social Sciences*, vol. 10, no. 2, pp. 25 – 33, 2019. https://doi.org/10.2478/mjss-2019-0020
[56] D. Shamsheun and R. Chomeya, Developing of the health school operating guidelines under Udon Thani Primary Education Service Area Office 1. *Journal of Educational Administration and Supervision*, vol. 8, no. 1, pp. 96 – 106, 2017. (in Thai)
[57] W. Silsawang, N. Boosabong, and H. Ajpru, "Assessment of stakeholders needs regarding desirable characteristics of graduates of Royal Thai Navy College of Nursing," *Procedia - Social and Behavioral Sciences*, vol.131, pp. 470 – 475, 2014. https://doi.org/10.1016/j.sbspro.2014.04.150
[58] S. Wongwanich, *Needs assessment*, 3rd ed., Bangkok, Thailand: Chulalongkorn University Printing, 2015.
[59] S., Wongwanich and N. Wiratchai, "A follow-up and evaluation of the government educational reform results based on the state fundamental policy and the national act," *Journal of Research Methodology*, vol. 18, no. 1, pp. 93 – 124, 2005.
[60] P. Prommun and T. Kantathanawat, "The development of an integrated design-based learning model, based on computational thinking for undergraduate students with participatory action research," *International Journal of Innovation, Creativity and Change,* vol. 13, no. 1, pp.

1505 – 1518, 2020. [Online serial]. Available: https://tinyurl.com/nubk2532 [Accessed Feb. 1, 2022].
[61] S. Kemmis, R. McTaggart, and R. Retallic, *The Action Research Planner,* Springer, 2004. https://doi.org/10.1007/978-981-4560-67-2
[62] R. McTaggart, Ed., *Participatory action research: International contexts and consequences*, Suny Press, 1997.
[63] S. Kemmis and R. McTaggart, *The action research planner*, Deakin University Press, 1988.
[64] A. A. Nugroho, N. Nizaruddin, I. Dwijayanti, and A. Tristianti, "Exploring students' creative thinking in the use of representations in solving mathematical problems based on cognitive style," *Journal of Research and Advances in Mathematics Education*, vol. 5, no. 2, pp. 202 – 217. https://doi.org/10.23917/jramathedu.v5i2.9983
[65] F. C. Chiu, C. C. Hsu, Y. N. Lin, C. H. Liu, H. C. Chen, and C. H. Lin, "Effects of creative thinking and its personality determinants on negative emotion regulation. *Psychological Reports*, vol. 122, no. 3, pp. 916 – 943, 2019. https://doi.org/10.1177/0033294118775973
[66] G. J. Puccio, "Creative Problem Solving preferences: Their Identification and Implications," *Creativity and Innovation Management*, vol. 8, no. 3, pp. 171 – 178, 1999. https://doi.org/10.1111/1467-8691.00134
[67] D. J. Treffinger, "Creative problem solving: Overview of educational implications," *Educational Psychology Review*, vol. 7, pp. 301 - 312, 1995. https://doi.org/10.1007/BF022133755
[68] M. Phaksunchai, W. Kaemkate, and S. Wongwanich, "Research and Development of a Training Package for Developing Creative Problem Solving of Undergraduate Students," *Procedia - Social and Behavioral Sciences*, vol. 116, pp. 4824 – 4828, 2014. https://doi.org/10.1016/j.sbspro.2014.01.1032
[69] D. H. Jonassen, Learning to solve problems: A handbook for designing problem-solving learning environments. Taylor & Francis. 2010. https://doi.org/10.4324/9780203847527
[70] D. R. Brophy, "A comparison of individual and group efforts to creatively solve contrasting types of problems, "*Creativity Research Journal,* vol. 18, no. 3, pp. 293 – 315, 2006. https://doi.org/10.1207/s15326934crj1803_6
[71] E. Çetin, "Digital storytelling in teacher education and its effect on the digital literacy of pre-service teachers," *Thinking Skills and Creativity,* vol. 39, 100760, 2021. https://doi.org/10.1016/j.tsc.2020.100760
[72] B. Fuchs, "The writing is on the wall: Using Padlet for whole-class engagement," *Library Faculty and Staff Publications*, 240, 2014. https://tinyurl.com/33mxv9u8
[73] D. Pusca and D. O. Northwood, "Curiosity, creativity and engineering education," *Global Journal of Engineering Education,* vol. 20, no. 3, 2018. https://tinyurl.com/ys2vzhxk
[74] H. Casakin, N. Davidovitch, and R. M. Milgram, "Creative thinking as a predictor of creative problem solving in architectural design students," *Psychology of Aesthetics, Creativity, and the Arts,* vol. 4 no. 1, pp. 31–35. https://doi.org/10.1037/a0016965
[75] S. Kim, I. Choe, and J. C. Kaufman, "The development and evaluation of the effect of creative problem-solving program on young children's creativity and character," *Thinking Skills and Creativity*, vol. 33, 100590, 2019. https://doi.org/10.1016/j.tsc.2019.100590
[76] D. J. Treffinger, *Creative problem solving: an introduction*, Waco, TX: Prufrock Press, 2005.
[77] D. J. Treffinger and S. G. Isaksen, "Creative Problem Solving: the History, Development, and Implications for gifted Education and Talent Development," *Gifted Child Quarterly*, vol. 49, no 4, pp. 342 - 353, 2005. https://doi.org/10.1177/001698620504900407
[78] D. J. Treffinger, S. G. Isaksen, and K. B. Dorval, *Creative Problem Solving (C.P.S. Version 6.1): A Contemporary Framework for Managing Change*, Center for Creative Learning, Inc. and Creative Problem Solving Group, Inc., 2005.

[79] J. J. Weir, Problem solving is everybody's problem, *Science Teacher*, vol. 4, no. 30, pp. 16-18, 1974. https://www.jstor.org/stable/24123495 [Accessed Feb. 1, 2022].

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The Effects of a Debate-Based Awareness Lecture on Cheating in Online Exams

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Abstract—Cheating in online exams has become an undeniable phenomenon throughout universities worldwide. This study examined the effect of a single factor on the scores and essay questions of online exams, helping the researcher identify cheating incidents. This factor was an awareness lecture, conducted in the form of a debate between the instructor and students, about the negative effects and ethics of cheating. The methodology of this study was based on the explanatory sequential approach, in which the researcher conducted the same online exam but with different treatments. Then, semi-structured interviews were conducted with certain students after the course had finished. The study consisted of two groups of students in the same course. Each group was given a different treatment: Group 1 consisted of 33 students who participated in an awareness debate lecture before the online exam, and Group 2 consisted of 31 students who did not participate in an awareness debate lecture. Then, 12 students were randomly recruited from Group 1 to participate in the interviews to explore more insights about the rationalization of cheating in online exams. The results showed that Group 1 had grades averaging (18.23 out of 30), and Group 2 had grades with a significantly higher average (22.1 out of 30). Conclusions and recommendations were presented to better shape the experience of online exams.

Keywords—academic integrity, online exams, cheating attempts, rationalization, debate lecture

1 Introduction

Cheating is a common phenomenon in the academic world, as some students try to obtain an unfair advantage to achieve certain results. Many models have been created to address this problem. However, cheating persists in all countries and at all levels of educational systems. In particular, cheating in online exams has been on the rise since most educational activities shifted online as a reaction to the global COVID-19 pandemic [1].

Information technologies have made cheating much easier. Students today have more opportunities to cheat than their counterparts had a generation ago [2]. In general, there are many forms of academic dishonesty, and each has been documented in an extensive body of literature. Cheating in online courses, however, has not received proper scholarly attention due to its relative newness.

Online education provides many benefits for both instructors and students. For the former, it can improve enrollment rates, and it can save the latter time and money [2]. On the other hand, information technology allows students to copy other people's work with just one click of their mouse, which has resulted in the formation and proliferation of the modern "copy and paste" culture in the academic world. A number of studies, such as that conducted by King et al. [3], have found that most students consider cheating in online exams much easier than in exams administered in a classroom setting (as cited in Watson & Sottile [2]). However, studies of online cheating behaviors have produced mixed evidence, with some of them indicating that online cheating is more common than in a classroom setting [4], while others claim that either online cheating is less common or that the two are equally common.

To resolve this inconsistency, a survey of 635 students in Appalachia was conducted by Watson and Sottile [2] to analyze two factors: the level of academic dishonesty, and its type in their online and face-to-face classes. Their survey included three parts: self-reported dishonest behaviors, perceptions of cheating, and knowledge of other students behaving dishonestly. The answers regarding self-reported dishonest behaviors showed that 32.1% and 32.7% of students admitted that they had cheated in in-person and online classes, respectively [2]. In was also reported in the study that the two most prevalent dishonest behaviors were the use of instant messaging and getting answers from other students during a quiz or test. Furthermore, students reported that they were twice as likely to be caught cheating, and reported for it, in in-person classrooms than online. The authors recommended that educators and online course designers shift their assessment from objective tests (multi-part tests or quizzes) to more subjective forms of evaluation, such as research papers and essays. Another important recommendation provided by Watson and Sottile [2] was to include a course in moral development and ethical behavior to raise awareness of the negative aspects of cheating.

In general, there are many approaches to reducing the rates of cheating in both online and in-person classrooms. One such approach focuses on eliminating factors that pressure young people to cheat. As mentioned previously, teachers can replace multiple-choice assessments (common enticement for cheating) with writing projects that make students more invested in their work. According to Simmons [5], teachers can also allow students to have one free pass each quarter on assignments they failed to complete outside of class.

The present study explores the effect of an awareness debate lecture about the disadvantages of cheating and to investigate the rationalization behind such act that can negatively affect the academic integrity.

1.1 Research questions

- RQ1: Did the debate lecture have any effect on the students' cheating rate in an online exam?
- RQ2: What is the rationalization of students' attempts to cheat in online exams?

1.2 Research gap

Most previous studies discuss and suggest techniques to narrow the opportunity for and/or the pressure on students to cheat in online exams. However, only a few addresses how students rationalize cheating, especially those studying at Middle Eastern universities. Therefore, this study attempts to highlight the rationalization of cheating in online exams after applying the intervention of an awareness debate lecture.

1.3 Research value

This study seeks to present results that can be valuable to instructors and decision-makers in academic contexts. Accordingly, academic integrity can be maintained by using pre-exam techniques to help reduce cheating attempts; one of these techniques is the awareness debate lecture. In addition, the study illustrates the reasons students cheat by using their rationalizations to summarize and categorize different types of students.

2 Literature review

Whether administered online or in classrooms, college and university examinations should be devoid of cheating to accurately determine students' abilities and maintain academic integrity. Cheating diminishes the credibility of university diplomas and creates an unfair advantage for learners involved in the malpractice. Traditionally, educational institutions have prevented cheating in examinations through student identity checks and supervision. As a result of the COVID-19 pandemic, most colleges relied, and still rely, on digital platforms to administer tests [1]. The risk of cheating in online tests is high since determining the identities of individuals who complete the examinations is difficult. Moreover, the lack of supervision means that learners can access prohibited materials when completing tests. Cases of academic dishonesty are rampant in the Middle East since most students are not educated about cheating and believe that educational institutions do not take stern actions against those who cheat [6].

2.1 Students' perceptions of cheating

Various factors motivate students to cheat in examinations. While some cases of academic dishonesty are unintentional due to insufficient knowledge of behaviors that constitute plagiarism, other incidents are intentional. Birks et al. [7] reported that 90% of the respondents stated that severe punishment would discourage them from cheating in examinations. Other students noted that they would not engage in the malpractice after signing statements of academic honesty. Some students perceive academic dishonesty as an acceptable behavior because they believe that it is caused by external factors, such as school conditions [8]. As a result, learners often take advantage of weak institutional regulations to cheat in examinations. For example, in some instances students were allowed to drop courses to avoid cheating penalties [9]. Consequently, academic dishonesty (such as cheating, copying, and plagiarism) exists in educational institutions around the world. Jordan [10] indicates that students at universities cheat at least once during their course of study. Information on social and psychological factors that lead to academic dishonesty can help instructors enhance the integrity of examinations [11]. Therefore, effective programs for preventing cheating in tests should be based on students' attitudes.

The desire to succeed in competitive circumstances also motivates learners to engage in examination irregularities. Individuals are expected to score high marks to achieve various objectives, ranging from obtaining admission to elite universities to winning prestigious awards, excelling in job interviews, and gaining coveted promotions. Recent stories of parents who bribed school officials to secure admission to prestigious universities for their children imply that competition for limited opportunities increases the risk of deceit [12]. In educational institutions, the desire to score high grades motivates students to engage in exam cheating. In a review of the main causes of academic dishonesty in higher education institutions, Tabsh et al. [13] established that pressure to score high grades was one of the primary reasons for cheating in tests. Other learners cited inadequate time to complete assignments, difficult courses, and insufficient guidance as justifications for examination irregularities. Colleges should mitigate conditions that enable cheating as students strive to score high grades.

Other studies show that many students are unaware of behaviors that constitute academic misconduct. Many students believe that the main forms of cheating include violating examination rules and seeking others' help when completing assignments [14]. However, academic dishonesty entails a wide range of practices. According to Tayan [6], improper paraphrasing, lack of citations for other authors' work, data falsification, and the use of third parties to complete tests constitute examination irregularities. Educational institutions should educate students on different forms of academic dishonesty to alleviate cheating in examinations.

Furthermore, access to modern information systems encourages students to cheat. A recent case involved students at Harvard University who conspired through Facebook to cheat in a take-home test [15]. Due to the improved use of the Internet and mobile devices, academic dishonesty has become a rampant challenge in schools and colleges. In some cases in China, female students are not allowed to wear bras during baccalaureate examinations to prevent them from sneaking listening devices into examination rooms [15]. The law also stipulates jail time for students who cheat in entrance tests. Despite frequent reports of cheating, only 1% of students are willing to report the cases to their teachers [16]. As information technologies advance, they create more opportunities for students to engage in examination irregularities.

Cheating in educational assessments is also linked to social vices. According to Orosz et al. [17], collaborative cheating and corruption are related because both behaviors are unlawful, entail cooperation between two or more individuals, and violate social values. Therefore, students can cheat in examinations because society tolerates related practices. For instance, a scandal occurred in India in 2015 when some parents attempted to assist their sons and daughters to cheat in tests by breaking into schools to bribe police officers guarding examination centers [17]. Other cases of students' collaboration entail seeking third parties' help in completing individual assignments. Fraser [18] shows that collusion is perceived as a less severe form of cheating than other practices such as plagiarism, and some instructors tolerate the behavior. Some research efforts, in the other hand, are directed towards developing student verification systems in online exams with high accuracy [19] to help in addressing vulnerabilities. Learners who believe that society tolerates various unethical activities are likely to engage in academic dishonesty.

2.2 Cheating cases in the Middle East

Various forms of cheating occur among learners in the Middle East. Tayan [6] examined the views of 138 male students at a Saudi university to assess the main forms of academic dishonesty and their primary causes. The findings show that students use different methods to cheat in examinations. Among the respondents, 64% indicated that they have used prohibited devices in examination rooms, 45% have copied other students' answers, and 44.2% have submitted their friends' work [6]. Other types of academic dishonesty revealed in the survey include improper paraphrasing and a lack of citations. Tabsh et al. [13] also indicate that 25% of students disobey copyright policies by illegally duplicating electronic materials or photocopying printed reports. Therefore, Middle Eastern students engage in various activities that compromise the integrity of learning programs.

Most of the learners in Saudi Arabia have insufficient knowledge of the consequences of academic dishonesty. In a study by Tayan [6], 60% of the respondents stated that they did not comprehend penalties for cheating in examinations, while 24% expected a warning if found guilty of academic dishonesty. In contrast, other Middle Eastern countries have reduced cheating in assessments through educational programs. For instance, instructors in Egypt emphasize the importance of ethical examination conduct during lectures to reduce cheating [20]. In Saudi Arabia, cheating frequency varies based on the approaches that different students employ. Tayan [6] shows that 23.6% of learners always pay third parties to complete their examinations, while 43% often collaborate with their peers in individual tests. Educating learners on the penalties for academic dishonesty can help institutions minimize cheating cases in the Middle East.

Other studies show that learners use modern technologies to cheat in tests. In a study by Ahmed [21], 65% of the respondents used various technologies to access prohibited materials when completing assignments. Some learners relied on tablets and smartphones to access online information, while others used calculators in prohibited settings. While students in the Middle East believe that cheating is unlawful, they suggest that schools and colleges need to enhance supervision during tests, punish individuals who engage in academic dishonesty, modify assessment approaches, and share more information on the need to maintain the integrity of assessments [21]. These findings are comparable with the results of studies on cheating in other regions. Ahmed [21] notes that learners in Western universities engage in various forms of academic dishonesty while condemning them for violating their ethical, religious, and cultural beliefs. Effective measures can help educational institutions reduce cheating in examinations.

Culture is also linked to academic dishonesty in the Middle East. For example, McCabe et al. [22] illustrate that collectivist societies tolerate cheating because helping students during assessments is considered a strategy for realizing group interests. Moreover, uncertainty avoidance in collectivist cultures encourages students to cheat since they seek clear information on penalties for their behaviors to engage in ethical conduct. The study by McCabe et al. [22] in Lebanon established a strong relationship between cheating and learners' perceptions of their peers' conduct. As a result, the level of academic dishonesty in that country is significantly higher than in individualistic societies such as the United States. According to McCabe et al. [22], 80% of Lebanese students report one or more cases of cheating compared to 54% in the United States. Many students in the Middle East are likely to cheat in examinations because they feel obliged to help their peers score high grades. Regardless of the rules established to curb examination irregularities, collaborative cheating is tolerated at some institutions [23]. Collectivist values significantly influence students' perceptions of collaborative cheating in examinations.

High rates of cheating are reported at medical schools in the Middle East. Abdulghani et al. [24] conducted a cross-sectional study at a governmental medical college to examine the prevalence of academic dishonesty at the institution. A significant percentage of the respondents admitted to cheating during their studies. However, students with higher GPAs were less likely to engage in examination irregularities than their counterparts with lower GPAs [24]. The findings imply that medical students who perform dismally in their courses perceive cheating as a strategy to enhance their scores. In addition, more male students were involved in examination cheating than female students. Abdulghani et al. [24] explain that female students are apprehensive of the effects of cheating, such as social stigma, while male learners are considered bold and untroubled by the consequences of engaging in academic malpractices. Another key finding of the research is that students staying in university hostels were less likely to cheat than those living with their families. Abdulghani et al. [24] show that family events and social obligations limit opportunities for learners to study. The high percentage of medical students who cheat implies that educational institutions should implement effective plans to enhance the integrity of their programs.

2.3 Academic dishonesty in the Jordanian scope

Educational research on academic dishonesty in Jordan is limited. In a study by Alahmad [25], 63.9% of the participants indicated that their colleges did not provide student education programs on examination irregularities. A small percentage of learners trained in academic integrity noted that they were aware of different examination irregularities. Instructors in Jordan are also not trained in academic dishonesty. Alahmad [25] shows that only 41.7% of tutors have attended seminars on the integrity of student assessment programs. The training content includes strategies for preventing cheating in examinations, definitions of academic dishonesty, and measures for promoting academic integrity. Comprehensive education on academic integrity can improve the credibility of educational programs in Jordan.

As a result of limited training in examination malpractices, cheating in examinations is a major concern in Jordanian schools and colleges. According to Kayed [26], the most prevalent forms of academic dishonesty in the country include impersonation, collaborative cheating through WhatsApp groups, and the use of the Internet to access information. While teachers have devised different techniques to curb cheating, including one-way questions, 30-second questions, authentication, and identification of students before attempting the exam and during the attempt [27], most students who complete unsupervised tests always cheat. Increased cases of cheating diminish the credibility of college programs, as students who would not have passed examinations without cheating are allowed to graduate. Academic dishonesty will widen the gap between expertise and educational qualifications if colleges fail to implement proper prevention plans.

Students cheat in examinations for various reasons. While some believe that the behavior is not punished severely, others perceive collaborative cheating as a cultural obligation. Modern information technologies also enable learners to engage in examination irregularities. Although academic dishonesty is widespread in the Middle East, schools, colleges, and universities should educate students and raise their awareness of the importance of academic integrity to encourage ethical examination conduct.

2.4 Cheating rationalization based on the fraud triangle

Academic integrity usually requires students to do and submit their coursework with the highest quality possible by maintaining a proper standing with the policies in their educational institution [28]. Academic dishonesty, on the other hand, occurs when the academic integrity policy is violated with the wrongdoings.

One of the common methods of analyzing wrongdoings is the Fraud Triangle. This method assumes that there are three elements that cause individuals to commit fraud: pressure, opportunity, and rationalization [29]. While the Fraud Triangle explains the nature of wrongdoings in many spheres, cheating within academia has unique features. For instance, a study found that slightly more than half (53%) of US students think that cheating is not a serious or critical behavior, while 34% of students reported that they have never had discussions with their parents about cheating [29]. Furthermore, 98% students do not see any problem in allowing their friends to copy their assignments [29]. The Fraud Triangle and its' parts can be illustrated as shown in Figure 1.

There are a variety of reasons that push or enable students to cheat. The first is rationalization; the second is pressure, which may emanate from parents or the need to avoid expulsion; and the third is opportunities, which, in this specific context, arise from the nature of the online environment, which provides a lot of freedom for students to engage in academic dishonesty. The motivation for cheating in online exams is mostly associated with the desire to earn good or excellent grades. However, the fraud triangle is not the only method that is used to explain cheating behavior - there are many others, such as Kohlberg's six-stage theory of moral reasoning, as well as studies exploring the role of gender and competitive athletics in the moral reasoning of students [2]. Thus, there are many ways to approach this problem.

Based on the presented literature, the next chapter explains the methodology of this study.

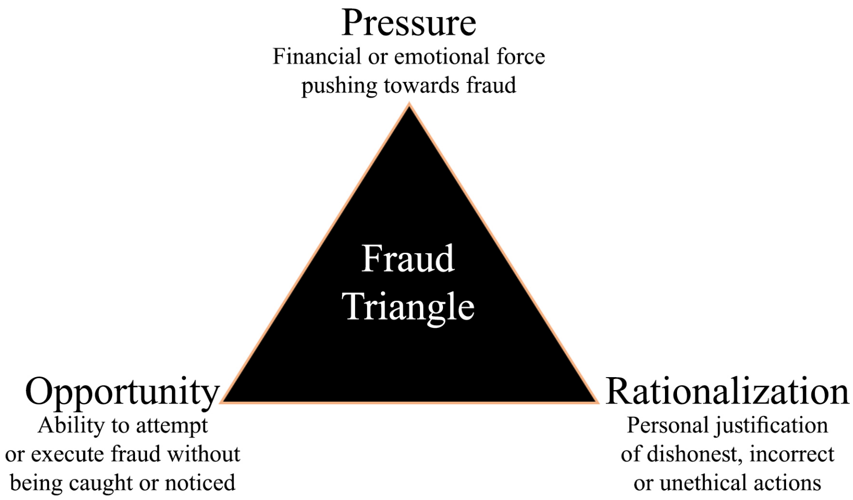


Fig. 1. The Fraud triangle model

3 Methodology

The research problem concerns the lack of studies that explore the rationalization for cheating in online exams in Jordanian universities specifically. To explore and determine the cause of rationalization, this study was conducted using a mixed-method design, namely, the explanatory sequential method. In general, a mixed-method design is an approach used to combine or utilize both quantitative and qualitative forms of data. These forms are often combined in scientific research to better understand a case, issue, or phenomena. The explanatory sequential research design used in this study involved quantitative data collection and analysis, followed by the gathering of qualitative data to substantiate the result of the initial quantitative data. In the case that the quantitative results are unclear, insufficient, or unexpectedly significant or insignificant, the results considered to be outliers may be clarified in the qualitative phase [30]. Since this study seeks to explore the rationalization from information gathered in interviews (qualitative data) for the cheating attempts that happened in online exams (quantitative data), the explanatory method design is reasonable.

Online exams have been increasingly used in fully online courses since the COVID-19 pandemic began [4]. Due to the need to limit cheating cases and maintain the quality of education and academic integrity, efforts of educators and e-learning technicians around the world shifted towards closing the gaps in online exam proctoring and thus trying to limit the opportunity for students to cheat in online exams. However, there was a shortage of efforts that aimed to question and treat the reasons that students use to rationalize cheating attempts. Therefore, the instruments used in this study were online exams and interviews. The study addresses the rationalization behind cheating by conducting an awareness lecture in the form of a debate between the instructor and students, and then measuring the effect of this lecture based on data gathered from the online exam and from the answers given by the interviews after the exam.

3.1 Population sample

The sample population included undergraduate students at a Middle Eastern university in Jordan, aged 20 years and above, and who were studying full-time at a higher education institution (whether in online, in-person, or blended formats). Taking this type of population into consideration there were no requirements regarding GPA and/or technical capabilities in order ensure a more representative sample of students.

Participants were divided into two groups. The quantitative data were collected from online exams conducted for a total of 64 students who were registered in two different sections of the same course: 33 students in Section 1 (Group 1) and 31 students in Section 2 (Group 2). The qualitative data were then collected from 12 students who were randomly chosen from Group 1 for semi-structured interviews.

3.2 Online exam

The online exam conducted for both groups was based on Moodle, which is a Learning Management System (LMS), and consisted of 29 multiple choice questions (MCQs) and one essay question. The duration of this exam was one hour and 15 minutes (a sample of the exam is show in Appendix A). The students in both groups took the exam using their own computer devices at their homes, with a basic proctoring practice via video call software running simultaneously with the exam. Therefore, each student ran two programs for the online examination: the Moodle web-based platform for completing the exam and Zoom software for live proctoring. The essay question was included in the exam to reveal any evidence of copied answers, since copying answers is considered a form of cheating and a violation to academic integrity [28]. In addition, a number of academic factors were taken into consideration while building the online exam: usefulness, ease of use, low or no cost, and level of satisfaction [31].

3.3 Awareness debate lecture

Based on the above-mentioned evidence, it seems reasonable to create an awareness lecture that would accomplish two key purposes: 1) raise awareness about the negative consequences of cheating in online exams and encourage students to remain honest in their academic work, and 2) increase students' understanding regarding academic integrity, which will also play a key role in making them more self-reliant, persistent, and resilient. One of the best ways to achieve these two purposes is to use the debate technique as a tool in the awareness lecture. Debate can be defined as "the systematic presentation of opposing arguments about a specific issue" [32, 33]. In the course of debate, participants listen and take notes regarding multiple points of view, evaluate each of them, and make judgements.

Therefore, by engaging in a debate during the awareness lecture, students will have an opportunity to examine their views regarding cheating and the way they rationalize this unethical practice. One of the advantages of debate is that it can be conducted online, which is important in the current circumstances, but there are also many other benefits. For instance, debate helps students develop their content expertise [32]. To achieve success in a debate, students have to consult a wide range of sources and find relevant evidence to support their arguments. Another benefit of debate is that it develops critical thinking because it requires students to apply reason to find logical fallacies and elements that either weaken or justify their perspective [32].

Debate also facilitates communication among the participants because they constantly interact with each other and try to prove their points of view. This communicational dynamic results in better knowledge retention compared to reading or listening alone because students associate new knowledge with their emotional experiences during the debate. In fact, allowing students to argue in favor of cheating can be an engaging way to expose their deeply held beliefs about the insignificance of cheating. At the same time, each of these beliefs will be examined and disproved by other students. However, teachers should be careful to maintain a healthy discussion and avoid confrontations between students. Taking all these benefits into consideration, it is clear that debate is an ideal technique for facilitating a deep, honest discussion regarding the effects of cheating in online exams.

With the awareness debate lecture and online exams, the scheme of this study is illustrated in Figure 2.

The effectiveness of debate-based awareness lectures is widely supported by current research. The COVID-19 pandemic has reignited research in the field of academic integrity, as educational institutions have started providing remote services and thus have become increasingly concerned about the honesty of their students. At the same time, there has been a growing shift from strict behavioral sanctioning (expulsion) to developmental sanctioning, which entails a wide range of educational activities, such as writing journals, working with a mentor, participating in special projects, and holding other students accountable to the honor code [34]. The use of awareness lectures is a developmental or soft strategy of dealing with academic misconduct. It can allow educational institutions to prevent cheating in the first place. Alternatively, awareness-based lectures can be used as a supplemental tool for the developmental sanctioning of students who have engaged in minor cheating offenses. Therefore, instead of using strict sanctions and limiting students' educational opportunities, it is more reasonable to allow students to take a probation period to work on their moral judgment and reconsider their priorities. The use of awareness lectures during such probations would be beneficial, especially in the form of debate, because it would give students an opportunity to think deeply about this problem, find workable solutions, and support each other on their paths towards improvement.

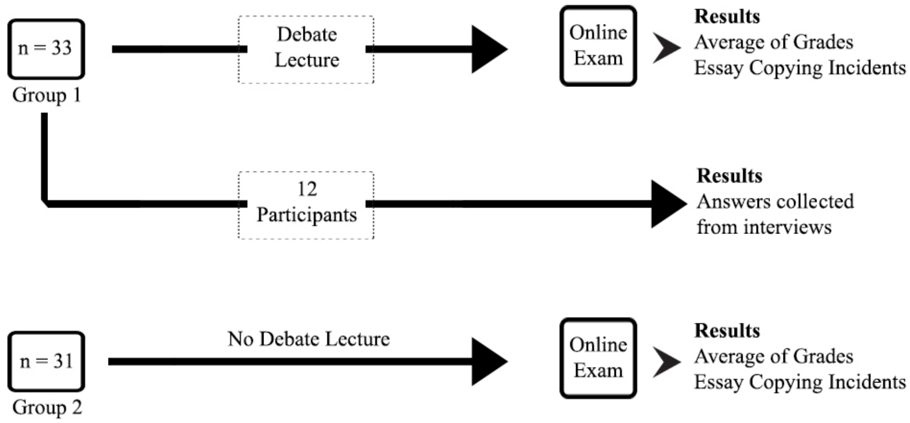


Fig. 2. The scheme of the study

Therefore, debate can enrich students' knowledge as well as help them develop crucial academic skills and personality traits associated with self-reliance, avoiding cheating, thinking critically, and believing in their capacity to achieve better results. Thus, it appears that debate allows students to go beyond mere knowledge acquisition; rather, it gives them the opportunity to consider various ways they can avoid academic dishonesty, discuss these issues with their peers, and strengthen their confidence.

3.4 Interviews

There were two communication methods that the researcher used to recruit students for the study: email invitations sent by the researcher and a public announcement sent by their department. First, the email invitations provided a synopsis of what this study aims to achieve, the value and contribution of the outcomes of this study to the academic integrity and scientific research, and the reason why this study is being conducted. The email was written in English and Arabic to ensure the validity of instruction for interested students. This form of invitation was heavily used to recruit students because they are likely to periodically check their emails on their smartphones [35]. Second, an announcement was made by the department head office on the online page of the course in which the participants were enrolled. The announcement and the email provided identical descriptions of the study and contained the contact information of the researcher and the date, time, and location of the interview. The announcement was also written in Arabic and English.

Participants' reactions and answers were recorded via an audio recorder. The recorded files were stored in an external encrypted hard disk, and this hard disk was locked with a password and securely stored in the researcher's office. The plan was initially to conduct a focus group after the online exam. However, due to COVID-19, the plan was changed, and a one-to-one, semi-structured interview was conducted with each participant individually. The researcher prepared the room for interviews by adhering to strict health regulations and social distancing guidelines due to the pandemic. A specific appointment was made with each interviewee to conduct the interview. In addition, the participants were handed an assuring statement (through the signed consent form) that their information will be kept confidential, and that it will never be used against them in any way (IRB approval is included in Appendix B).

After all the answers by participating students were recorded and noted, they were first translated from Arabic to English and then transcribed using the intelligent verbatim transcription technique (sample available in Appendix C). An analysis of their answers was conducted and summarized in a response table (sample available in Appendix D).

Finally, all collected evidence was analyzed and discussed in terms of rationalization to answer both research questions, as shown in Figure 3.

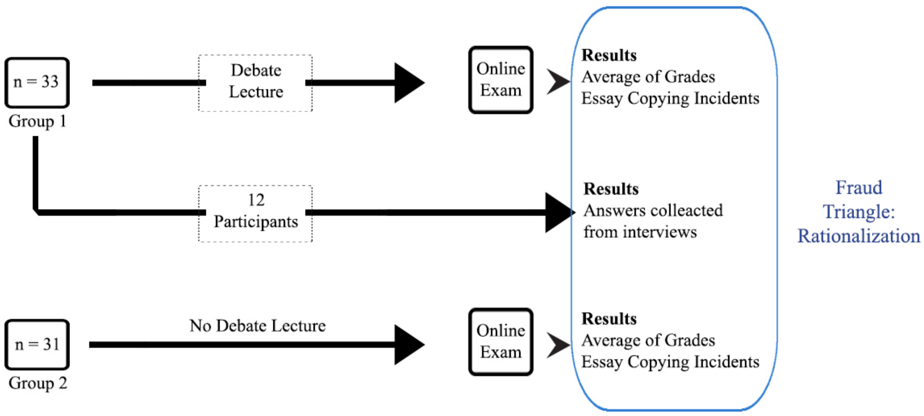


Fig. 3. The scheme of the study, including the analysis

The goal of this explanatory sequential approach was to explore the rationalization behind cheating in online exams as one aspect of the fraud triangle. The average grades of both groups and copied essay answers were the quantitative indications of the effect of the awareness debate lecture, while the answers from interviews indicated the reasons behind cheating attempts.

4 Findings

Based on the sequential explanatory method illustrated in the previous chapter, the findings of this study are divided to two sections: the quantitative findings and qualitative findings. The quantitative findings were collected from the results of the online exams taken by both groups of students (total of 64 students), whereas the quantitative findings were collected from the one-to-one semi-structured interviews conducted with 12 students who were randomly selected from Group 1.

4.1 Quantitative findings

The quantitative findings were applied to a null and an alternative hypothesis.

Null Hypothesis: There is no difference between Group 1 and Group 2.

Alternative Hypothesis: There is a significant difference between Group 1 and Group 2.

A paired sample t-test was used to compare the means of Group 1 and Group 2. The t-test was statistically significant, with the mean of Group 2 ($M = 22.10$, $SD = 6.272$) significantly higher than that of Group 1, ($M = 18.23$, $SD = 5.691$, $t(30) = -2.491$, $p < 0.05$, two-tailed). Therefore, the null hypothesis that there is no difference between Group 1 and Group 2 is rejected. It can be concluded that there is a significant difference between Group 1 and Group 2 in the population, ($p < 0.05$). Accordingly, the results are summarized in Table 1.

Table 1. Mean difference of Group 1 and Group 2

Groups	N	Mean	SD	t
Group 1	30	18.23	5.691	–2.491
Group 2	30	22.10	6.272	

$p < 0.05$

The mean and standard deviation (SD) for both groups are presented in Figure 4.

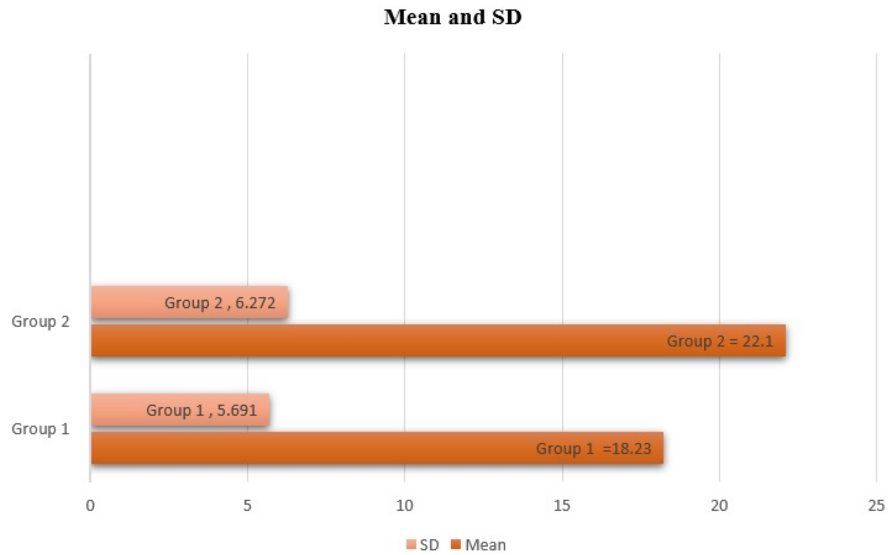
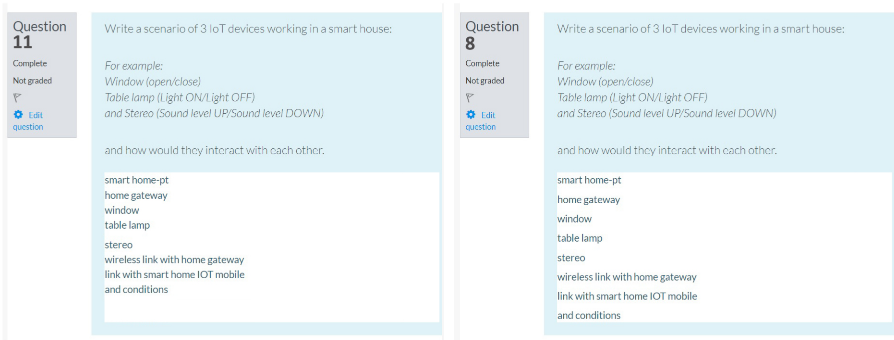


Fig. 4. The mean and standard deviation of the two groups

Based on the data summarized in Table 1 and Figure 4 above, the online exam results showed that Group 1, who participated in a debate lecture, scored an average of 18.23 out of 30, and Group 2, who did not participate in a debate lecture, averaged 22.1/30. There was a significant difference between the average grades of both groups. An essay question was also used in the online exam for both groups to determine if there were similarities between answers and thus attempts at copying the answer between students. A sample demonstrating the similarity is shown in Figure 5.



Note: Question numbers are different due to shuffling option applied on each student's attempt

Fig. 5. A sample of a copied answer in the essay question

In Group 1, there was evidence of similar answers to the essay questions found between two students. In Group 2, there was evidence of similar answers between four students. This difference shows that Group 2 had a higher number of copying incidents than Group 1.

4.2 Qualitative findings

The researcher asked 12 students a group of 14 questions each to highlight their overall experience in online exams, further explore their cheating attempts (if any occurred) and reveal the rationalization behind these attempts. The interviews have been transcribed and analyzed to derive a structured group of answers (transcription sample available in Appendix C). The findings are then reported in the response table in Appendix D.

4.3 Experience

The interviewees were asked about the dominant types of questions that appear in online exams, their level of difficulty, possible technical issues they have faced, how they think online and in-person exams compare, and their overall rating of their online exam experience on a 10-point scale. All twelve participants reported MCQs as the dominant type of question, and some participants indicated that essay (nine participants), coding (four participants), and project-based (seven participants) questions were also used. The difficulty of these questions ranged from mostly easy (six participants), to mostly difficult (two participants). However, 4 participants indicated that there was an inequality of difficulty levels among the questions. Regarding the technical issues, students reported that internet disconnections, eLearning platform malfunctions, webcam issues, and microphone cuts were the main problems faced during online exams. After the participants were asked about how they think online and in-person exams compare, five participants reported that they found no difference between the two, four favored in-person exams, and three favored online exams. Finally, the average rating participants gave the online exam experience was 5.9 out of 10.

4.4 Cheating attempts

The interviewees were asked whether they had ever attempted to cheat in an online exam in their course, the method they used if they had attempted to cheat, and whether they know someone who has cheated in the exam. The findings showed that nine out of twelve participants have attempted to cheat in the online exam in the course used for this study, while three answered that they have never attempted to cheat on the exam. The methods of cheating consisted of checking answers from the book/slides, joining cheating groups on WhatsApp, using open phone calls where the person on the line helps answer the questions, surfing the Internet for answers, and using a remote desktop software to allow someone else to control their computer and answer questions. All participants reported that they know peers who have cheated in online exams.

4.5 Rationalization

Participants were asked about the reasons behind their attempts to cheat, advantages and disadvantages of cheating, their feelings after the attempts to cheat, the possible reasons behind other students' attempts to cheat, and whether the debate lecture had any effect on their perspective about cheating in exams. The findings revealed that rationalization for cheating relies on the following reasons:

1. The student is unsure about the answer, so they need a confirmation to double-check their answer.
2. The student needs to maintain their GPA, prevent it from decreasing, or increase it.
3. The exams are very long, and the student does not have enough time to go through all questions.
4. The student is unable to afford to pay the course fees again should they fail.
5. The student embraces cheating as "fun and smart," and they find joy in breaking the rules.
6. The opportunity to cheat is there. As one of the participants stated, "Other students are doing it too, why shouldn't I?"

On the other hand, participants who reported no attempt of cheating explained their reasons: They had the flexibility to retake the course or receive a pass/fail rather than a letter grade, and they consider cheating in general to be a waste of time and effort. One participant indicated that it was not worth losing their reputation and respect as a student.

Participants also indicated that reasons why other students might cheat could include the feeling of fulfillment that comes with “breaking the rules” and the pressure to maintain or raise one’s GPA. These were also considered advantages of cheating. However, eleven participants agreed that attempts to cheat can have a negative impact on academic standing, knowledge acquisition and understanding of the topics covered in any course, time and effort required to pass the exam, trust from potential employers while searching for a job after graduation. Five participants expressed a feeling of regret after cheating, four participants expressed no regret after cheating, and two participants expressed having a sense of fulfillment and achievement after cheating. The debate lecture reinforced the opinions of seven participants against cheating and convinced one participant of the benefits of cheating.

5 Discussion and conclusion

The discussion is based on the quantitative and qualitative results that can answer both research questions presented in Chapter 1.

RQ1: Did the debate lecture have any effect on the students’ cheating rate in an online exam?

The quantitative results indicate that the average grades of Group 1 were significantly lower than those of Group 2, meaning that the debate lecture might have altered the perceptions and convictions of the students who participated. In addition, the higher degree of similarity in the essay answers in Group 2 can also support that that group was more willing to cheat by copying answers. This finding could also imply that if Group 2 had participated in a debate lecture before the exam, the attempts to cheat in the online exam would have been fewer.

The students’ experience with online exams in general explains the pressure they felt due to the disparity in the difficulty of the questions used within these exams. The technical issues also could have added to the pressure students felt during online exams, leading them to attempt to search for quick answers or copying them from their peers. This type of pressure is apparent from the students’ preference for in-person exams. The overall average rating of online exam experience (5.9/10) was not high enough to conclude that students prefer this method of examination.

The methods used to cheat, as indicated by the interviewees, can be used to shape a better, more secure online exam experience. Their answers revealed problems that can be solved by modern exam technologies to maintain academic integrity. However, it is not possible to conclude that all methods of cheating can be stopped, but rather, they can be limited.

RQ2: What is the rationalization of students’ attempt to cheat in online exams?

Based on the interviewees’ answers, they can be divided into three types:

- Type 1: Students who embrace cheating and consider it a smart way to pass courses
- Type 2: Students who are unsure of the long-term value of cheating but attempted it due to pressure rather than a solid rationalization
- Type 3: Students who embrace academic integrity and consider it part of their good professional standing in their career, both in the short and long term

Based on these conclusions, students' GPAs were checked again after the interviews were analyzed; their GPAs (out of 100) are shown in Table 2.

Table 2. The GPAs of the three types of interviewees

Type 1	Type 2	Type 3
68.4	69.3	66.4
77.1	72.4	67.8
88	77.5	79.8
	94.1	80.2
		92.4

These findings imply that further research can be conducted to investigate the correlation between GPA and students' perceptions of cheating. The correlations and differences between male and female students' perceptions on cheating also provide an opportunity for further research.

In general, students clearly understand that cheating is wrong, yet they consider their cheating behaviors exceptions to the established rule [5]. They cheat to an extent that allows them to preserve their self-image as honest individuals. Therefore, cheating students still consider themselves principled people who need to cheat for legitimate reasons [5]. For example, in many cases, students copy their peers' homework when they do not see value in doing it themselves. In other cases, they focus only on content that is associated with highly important tests while plagiarizing or copying work that is perceived as less important.

However, it is also quite common for students to cheat on assignments that they consider providing high value. Students who exhibit high academic performance and study at top academic institutions may often find themselves in an extremely competitive environment, which pressures them to cheat in order to make their work more outstanding or distinguishable from others. Furthermore, many of such students want to avoid a bad test score, as it might undermine their months of hard work [2, 5, 6]. Cheating behavior can be explained from the perspective of developmental psychology, as adolescents are found to be more active risk takers than older individuals. This natural inclination to take risk and explore their environment pushes many young people to engage in unethical conduct, such as rebelling against rules, experimenting with illicit substances, and cheating in academic settings. Simmons [5] also explains that peer groups in which the culture of academic dishonesty is normalized exert pressure on young people to cheat in order to preserve their social status within such groups. Technology is also a prominent facilitating factor of cheating.

5.1 Recommendations to lower the pressure on students

In general, there are many approaches to reducing the rates of cheating in both online and in-person classrooms. One of which could be to revise the teaching and learning techniques, and provide students with extra resources, trainings, and guidance on how to improve their learning styles with effective techniques [36]. These learning techniques, as explained by Dunlosky et al. [36], have the potential to support students' learning experience depending on their learning conditions, characteristics, and course material. Improving the learning techniques (e.g. re-reading, highlighting, imagery use, and mock exams) can have the potential to boost students' performance, hence reducing pressure to take an exam in educational context.

Another option is to allow students to drop their lowest score on a homework assignment each quarter. Teachers can also use the strategy of praising students for their progress and effort rather than for simply being smart. Such an approach helps give students the sense that they are making tangible progress and thus inspires them to rely more on their own efforts instead of succumbing to cheating. There is also the option of creating student honor councils, where students can enforce/amend their honor codes and increase one another's awareness of the negative aspects of cheating. Members of these honor councils should be encouraged to teach their honor codes to younger students in order to pass a culture of academic integrity from one generation to the next. It is also possible to limit cheating by activating students' metacognition (thinking about their own thinking habits) and directing it at their motivations and rationalizations for cheating. Finally, cheating can be limited by including direct discussions on this topic into the curriculum. This can be organized in the form of an awareness lecture, a media literacy lesson, or a homework assignment requiring students to reflect on their experiences with cheating.

6 Acknowledgment

None.

7 References

[1] UNESCO. (2020). COVID-19: A glance of national coping strategies on high stakes examinations and assessments. Accessed: 05.02.2022. [Online]. Available: https://en.unesco.org/sites/default/files/unesco_review_of_high-stakes_exams_and_assessments_during_covid-19_en.pdf
[2] Watson, G. and Sottile, J. (2010). Cheating in the digital age: Do students cheat more in online courses? Online Journal of Distance Learning Administration, 13(1). Accessed: 05.02.2022. [Online]. Available: https://mds.marshall.edu/cgi/viewcontent.cgi?article=1000&context=eft_faculty
[3] King, C. Guyette, R. and Piotrowski, C. (2009). Online exams and cheating: An empirical analysis of business students' views. The Journal of Educators Online, 6(1): 1-11. https://doi.org/10.9743/JEO.2009.1.5
[4] Bilen, E. and Matros, A. (2020). Online cheating amid COVID-19. Journal of Economic Behavior and Organization, 182: 196-211. https://doi.org/10.1016/j.jebo.2020.12.004
[5] Simmons, A. (2018). Why students cheat — And what to do about it. Edutopia. Accessed: 05.02.2022. [Online]. Available: https://www.edutopia.org/article/why-students-cheat-and-what-do-about-it

[6] Tayan, B. M. (2017). Academic misconduct: An investigation into male students' perceptions, experiences & attitudes towards cheating and plagiarism in a Middle Eastern university context. Journal of Education and Learning, 6(1): 158-166. http://doi.org/10.5539/jel.v6n1p158
[7] Birks, M., Smithson, J., Antney, J., Zhao, L. and Burkot, C. (2018). Exploring the paradox: A cross sectional study of academic dishonesty among Australian nursing students. Nurse Education Today, 65: 96-101. https://doi.org/10.1016/j.nedt.2018.02.040
[8] Miranda, M. S. and Freire, C. (2011, July). Academic dishonesty: Understanding how undergraduate students think and act. 15th Biennial International Study Association on Teachers and Teaching (ISATT) - Back to the future: Legacies, continuities and changes in educational policy, practice and research, Universidade do Minho, July 4-8 2011, Braga, Portuga, pp. 1-15. https://core.ac.uk/download/pdf/47130778.pdf
[9] Coalter, T., Lim, C. L. and Wanorie, T. (2007). Factors that influence faculty actions: A study on faculty responses to academic dishonesty. International Journal for the Scholarship of Teaching and Learning, 1(1): 1-33. https://doi.org/10.20429/ijsotl.2007.010112
[10] Jordan, A. E. (2003). Implications of academic dishonesty for teaching in psychology. Teaching of Psychology, 30(3): 216-219. https://doi.org/10.1207/S15328023TOP3003_03
[11] Brodowsky, G. H., Tarr, E., Ho, F. N. and Sciglimpaglia, D. (2020). Tolerance for cheating from the classroom to the boardroom: A study of underlying personal and cultural drivers. Journal of Marketing Education, 42(1): 23-36. https://doi.org/10.1177/0273475319878810
[12] Chui, C., Kouchaki, M. and Gino, F. (2021). "Many others are doing it, so why shouldn't I?" How being in larger competitions leads to more cheating. Organizational Behavior and Human Decision Processes, 164: 102-115. https://doi.org/10.1016/j.obhdp.2021.01.004
[13] Tabsh, S. W., El-Kadi, H. A. and Abdelfatah, A. S. (2016, April). Engineering students' perception of academic dishonesty at an American university in the UAE. 2016 IEEE Global Engineering Education Conference (EDUCON), IEEE, April 10-13 2016, Abu Dhabi, United Arab Emirates, pp. 729-732. https://doi.org/10.1109/EDUCON.2016.7474632
[14] Adzima, K. (2020). Examining online cheating in higher education using traditional classroom cheating as a guide. The Electronic Journal of E-Learning, 18(6): 476-493. https://doi.org/10.34190/JEL.18.6.002
[15] Parks, R., Lowry, P. B., Wigand, R. T., Agarwal, N. and Williams, T. (2018). Why students engage in cyber-cheating through a collective movement: A case of deviance and collusion. Computers and Education, 125: 308-326. https://doi.org/10.1016/j.compedu.2018.04.003
[16] Waltzer, T., Samuelson, A. and Dahl, A. (2021). Students' reasoning about whether to report when others cheat: Conflict, confusion, and consequences. Journal of Academic Ethics [Published Online]. https://doi.org/10.1007/s10805-021-09414-4
[17] Orosz, G., Tóth-Király, I., Bothe, B., Paskuj, B., Berkics, M., Fülöp, M. and Roland-Lévy, C. (2018). Linking cheating in school and corruption. European Review of Applied Psychology, 68(2): 89-97. https://doi.org/10.1016/j.erap.2018.02.001
[18] Fraser, R. (2014). Collaboration, collusion and plagiarism in computer science coursework. Informatics in Education, 13(2): 179-195. http://doi.org/10.15388/infedu.2014.01
[19] Indi, C. S., Pritham, V., Acharya, V., & Prakasha, K. (2021). Detection of Malpractice in E-exams by Head Pose and Gaze Estimation. International Journal of Emerging Technologies in Learning (iJET), 16(08), pp. 47–60. https://doi.org/10.3991/ijet.v16i08.15995
[20] Metwally, D. (2013). Academic cheating in Egyptian universities: Is it all about corporate code of ethics? Journal of Educational and Social Research, 3(7): 588-601. http://doi.org/10.5901/jesr.2013.v3n7p588

[21] Ahmed, K. (2018). Student perceptions of academic dishonesty in a private Middle Eastern university. Higher Learning Research Communications, 8(1): 16-29. http://doi.org/10.18870/hlrc.v8i1.400
[22] McCabe, D. L., Feghali, T. and Abdallah, H. (2008). Academic dishonesty in the Middle East: Individual and contextual factors. Research in Higher Education, 49: 451-467. http://doi.org/10.1007/s11162-008-9092-9
[23] Aljurf, S., Kemp, L. J. and Williams, P. (2019). Exploring academic dishonesty in the Middle East: A qualitative analysis of students' perceptions. Studies in Higher Education, 45(7): 1461-1473. https://doi.org/10.1080/03075079.2018.1564262
[24] Abdulghani, H. M., Haque, S., Almusalam, Y. A., Alanezi, S. L., Alsulaiman, Y. A., Irshad, M., Shaik, S. A. and Khamis, N. (2018). Self-reported cheating among medical students: An alarming finding in a cross-sectional study from Saudi Arabia. PLoS One 13(3): 1-14. https://doi.org/10.1371/journal.pone.0194963
[25] Alahmad, A. (2011). An investigation of academic integrity in Jordanian universities (Doctoral dissertation). The University of the Incarnate Word. Accessed: 05.02.2022. [Online]. Available: https://en.arij.net/investigation/how-jordanian-students-cheat-at-high-school-exams/
[26] Kayed, M. (2020, December 11). Calls continue for 'pass/fail' grading systems in universities in wake of exam cheating allegations. The Jordan Times. Accessed: 05.02.2022. [Online]. Available: https://jordantimes.com/news/local/calls-continue-%E2%80%98passfail%E2%80%99-grading-systems-universities-wake-exam-cheating-allegations
[27] Shdaifat, A. M., Obeidallah, R. A., Ghazal, G., Abu Sarhan, A., & Abu Spetan, N. R. (2020). A proposed Iris Recognition Model for Authentication in Mobile Exams. International Journal of Emerging Technologies in Learning (iJET), 15(12), pp. 205–216. https://doi.org/10.3991/ijet.v15i12.13741
[28] Jones, L. R. (2011). Academic integrity & academic dishonesty: A handbook about cheating & plagiarism. Florida Institute of Technology, Melbourne, Florida. Accessed: 05.02.2022. [Online]. Available: http://hdl.handle.net/11141/2601
[29] Susanti, S., Lestari, D. and Takidah, E. (2019). The influence of pressure, opportunity and rationalization on academic fraud of vocational student. Universal Journal of Educational Research, 7(9): 1976-1982. https://doi.org/10.13189/ujer.2019.070918
[30] Ivankova, N. V., Creswell, J. W. and Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. Field Methods, 18(1): 3-20. https://doi.org/10.1177/1525822X05282260
[31] Alotaibi, S. R. (2021). A Novel Framework of Success Using of E-Assessment During Corona Pandemic. International Journal of Emerging Technologies in Learning (iJET), 16(12), pp. 215–232. https://doi.org/10.3991/ijet.v16i12.22063
[32] Roy, A. and Macchiette, B. (2005). Debating the issues: A tool for augmenting critical thinking skills of marketing students. Journal of Marketing Education, 27(3): 264-276. https://doi.org/10.1177/0273475305280533
[33] Schwartz, M. (2019). Best practices in debate in the classroom. Centre for Excellence in Learning and Teaching. Accessed: 05.02.2022. [Online]. Available: https://www.ryerson.ca/content/dam/learning-teaching/teaching-resources/teach-a-course/debate-in-the-classroom.pdf
[34] Gamage, K. A. A., de Silva, E. K. and Gunawardhana, N. (2020). Online delivery and assessment during COVID-19: Safeguarding academic integrity. Education Sciences, 10(11). https://doi.org/10.3390/educsci10110301

[35] Atas, A. H. and Çelik, B. (2019). Smartphone use of university students: Patterns, purposes, and situations. Malaysian Online Journal of Educational Technology, 7(2): 59-70. https://doi.org/10.17220/mojet.2019.02.004

[36] Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J. and Willingham, D. T. (2013). Improving students' learning with effective learning techniques: promising directions from cognitive and educational psychology. Psychological Science in the Public Interest, 14(1): 4-58. https://doi.org/10.1177/1529100612453266

8 Author

Adiy Tweissi holds a PhD in Instructional Design and Technology, Master's degree in Computer Science, and Bachelor's degree in Computer Engineering. He's been working for more than 10 years in the development, execution, evaluation, and management of collaborative programs for a number of universities around the world. Dr. Tweissi's research focuses on online education development in the MENA region, Artificial Intelligence integration with e-Learning, Computer Networking, and Technology Futurism. In addition, one of Dr. Tweissi's focus areas is fostering the elements that build an innovative atmosphere for higher education.

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9 Appendix A

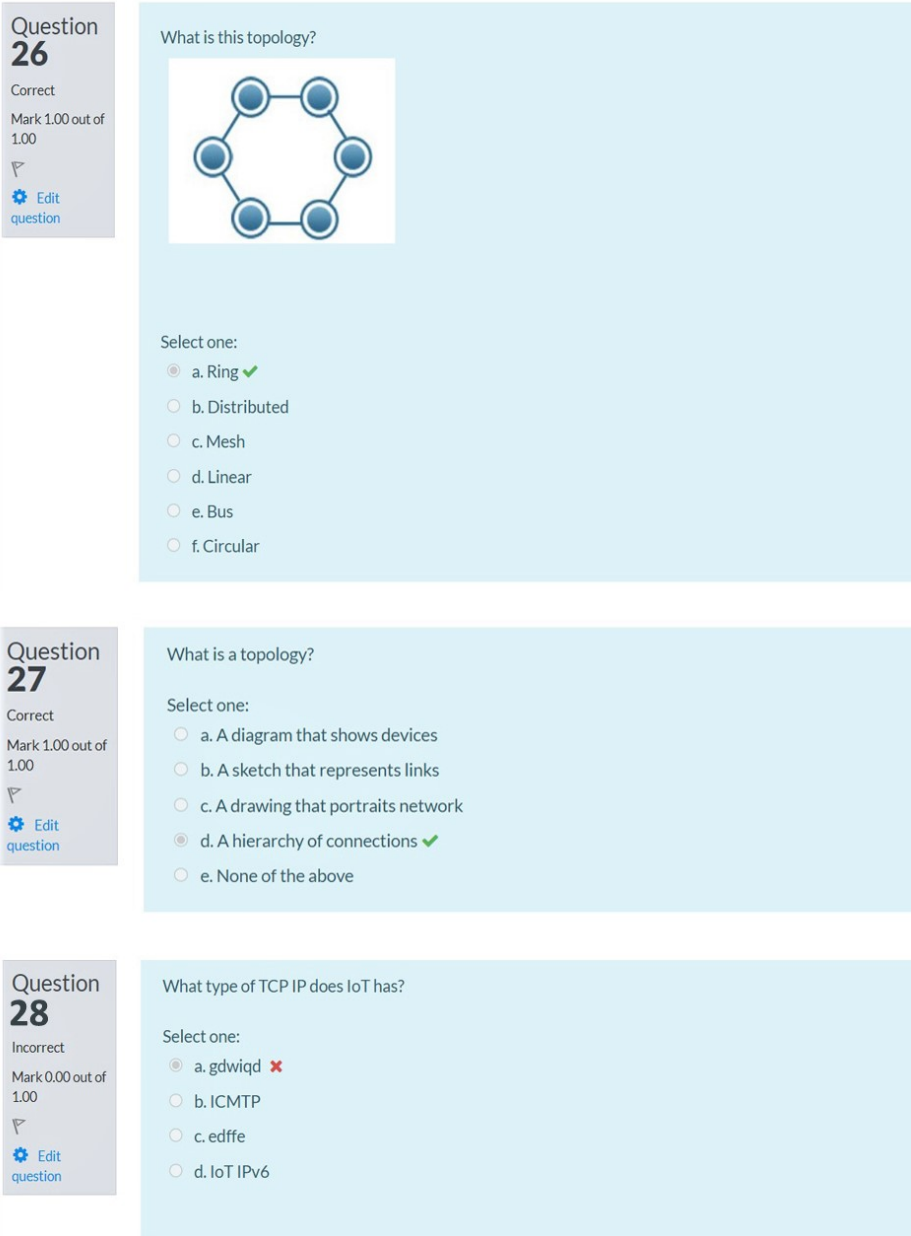
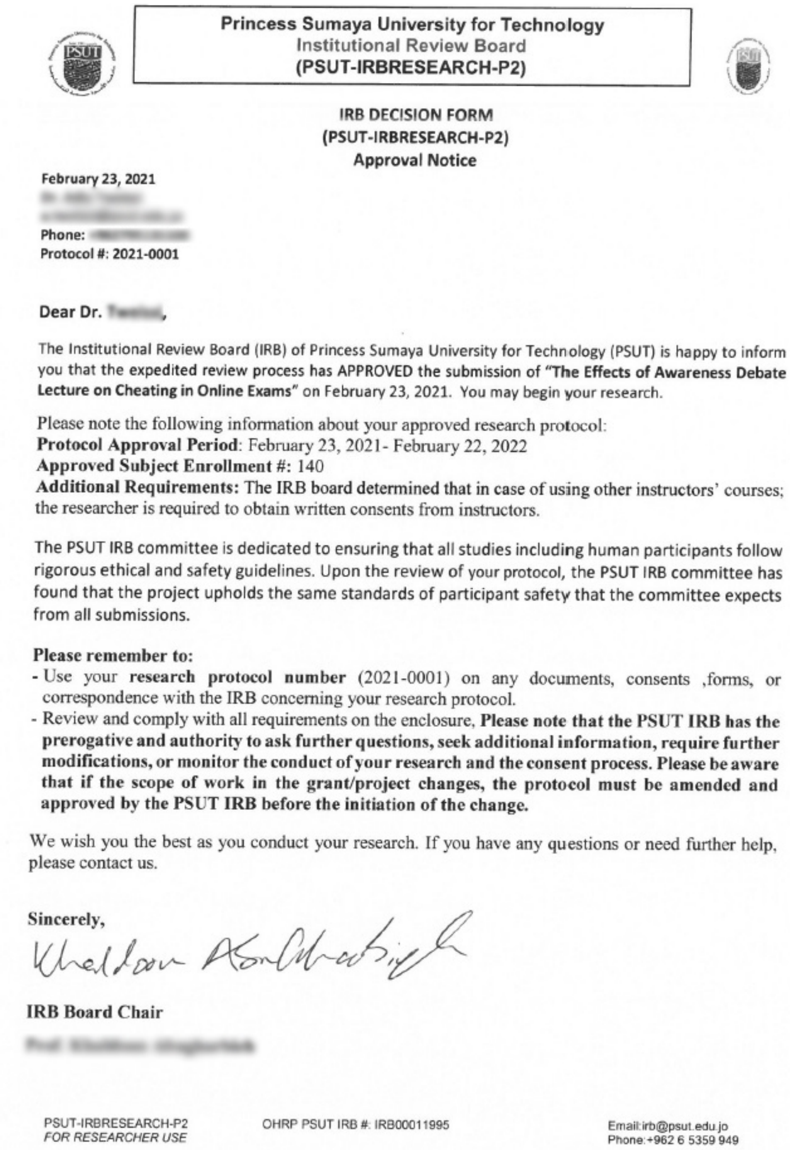


Fig. 6. A sample of the online exam used in this study

10 Appendix B



Princess Sumaya University for Technology
Institutional Review Board
(PSUT-IRBRESEARCH-P2)

IRB DECISION FORM
(PSUT-IRBRESEARCH-P2)
Approval Notice

February 23, 2021
[redacted]
Phone: [redacted]
Protocol #: 2021-0001

Dear Dr. [redacted]**,**

The Institutional Review Board (IRB) of Princess Sumaya University for Technology (PSUT) is happy to inform you that the expedited review process has APPROVED the submission of **"The Effects of Awareness Debate Lecture on Cheating in Online Exams"** on February 23, 2021. You may begin your research.

Please note the following information about your approved research protocol:
Protocol Approval Period: February 23, 2021- February 22, 2022
Approved Subject Enrollment #: 140
Additional Requirements: The IRB board determined that in case of using other instructors' courses; the researcher is required to obtain written consents from instructors.

The PSUT IRB committee is dedicated to ensuring that all studies including human participants follow rigorous ethical and safety guidelines. Upon the review of your protocol, the PSUT IRB committee has found that the project upholds the same standards of participant safety that the committee expects from all submissions.

Please remember to:
- Use your **research protocol number** (2021-0001) on any documents, consents ,forms, or correspondence with the IRB concerning your research protocol.
- Review and comply with all requirements on the enclosure, **Please note that the PSUT IRB has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process. Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the PSUT IRB before the initiation of the change.**

We wish you the best as you conduct your research. If you have any questions or need further help, please contact us.

Sincerely,

Khaldoun AbuAlhasiyeh

IRB Board Chair

[redacted]

PSUT-IRBRESEARCH-P2
FOR RESEARCHER USE

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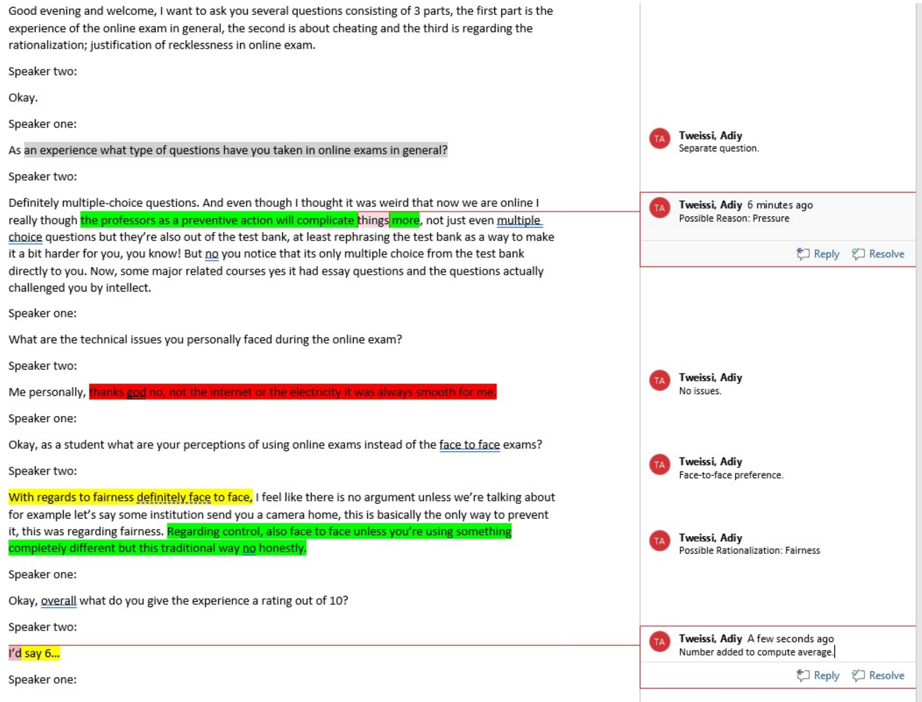
Fig. 7. The Institutional Review Board (IRB) approval

11 Appendix C



Good evening and welcome, I want to ask you several questions consisting of 3 parts, the first part is the experience of the online exam in general, the second is about cheating and the third is regarding the rationalization; justification of recklessness in online exam.

Speaker two:

Okay.

Speaker one:

As an experience what type of questions have you taken in online exams in general?

Speaker two:

Definitely multiple-choice questions. And even though I thought it was weird that now we are online I really though the professors as a preventive action will complicate things more, not just even multiple choice questions but they're also out of the test bank, at least rephrasing the test bank as a way to make it a bit harder for you, you know! But no you notice that its only multiple choice from the test bank directly to you. Now, some major related courses yes it had essay questions and the questions actually challenged you by intellect.

Speaker one:

What are the technical issues you personally faced during the online exam?

Speaker two:

Me personally, thanks god no, not the internet or the electricity it was always smooth for me.

Speaker one:

Okay, as a student what are your perceptions of using online exams instead of the face to face exams?

Speaker two:

With regards to fairness definitely face to face, I feel like there is no argument unless we're talking about for example let's say some institution send you a camera home, this is basically the only way to prevent it, this was regarding fairness. Regarding control, also face to face unless you're using something completely different but this traditional way no honestly.

Speaker one:

Okay, overall what do you give the experience a rating out of 10?

Speaker two:

I'd say 6...

Speaker one:

Tweissi, Adiy
Separate question.

Tweissi, Adiy 6 minutes ago
Possible Reason: Pressure
Reply Resolve

Tweissi, Adiy
No issues.

Tweissi, Adiy
Face-to-face preference.

Tweissi, Adiy
Possible Rationalization: Fairness

Tweissi, Adiy A few seconds ago
Number added to compute average.
Reply Resolve

Fig. 8. A sample from the transcription

12 Appendix D

Question	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Total and AVG
Q1: type of questions?	MCQ Essay Project-based	MCQ Essay Coding	MCQ ESSAY Project based	MCQ Coding	MCQ ESSAY Project based	MCQ Essay	MCQ ESSAY Project based	MCQ ESSAY Project based	MCQ ESSAY Project based	MCQ ESSAY Project based	MCQ Coding	MCQ Coding	12 =MCQ 9 = essay 4 =coding 7 = project based
Q2: Difficulty of questions?	Inequality of difficulty levels.	Mostly easy	Mostly easy	Mostly easy	Inequality of difficulty levels.	Inequality of difficulty levels.	Mostly easy	Mostly easy	Mostly difficult	Mostly easy	Inequality of difficulty levels.	Mostly difficult	6 = Mostly easy 0 = Mostly medium 2 = Mostly difficult 4 = Inequality of difficulty levels.
Q3: technical issue	Internet disconnections eLearning platform malfunctions	Internet disconnections Webcam issues Microphone cuts	Internet disconnections Webcam issues	Internet disconnections Webcam issues Microphone cuts	Internet disconnections Microphone cuts	Webcam issues Microphone cuts	No issues at all.	No issues at all.	Internet disconnections eLearning platform malfunctions Webcam issues Microphone cuts	Internet disconnections Microphone cuts	Internet disconnections eLearning platform malfunctions Webcam issues Microphone cuts	Internet disconnections eLearning platform malfunctions Webcam issues Microphone cuts	2 = No issues at all 9 = Internet disconnections 4 = eLearning platform malfunctions 7 = Webcam issues 8 = Microphone cuts
Q4: perception of online vs face-to-face?	They are both equivalent	Online exams are better	They are both equivalent	Face-to-face exams are better	They are both equivalent	Online exams are better	They are both equivalent	Online exams are better	Face-to-face exams are better	They are both equivalent	Face-to-face exams are better	Face-to-face exams are better	5 = They are both equivalent 4 = Face-to-face exams are better 3 = Online exams are better
Q5: rate of online exam experience	6/10	8/10	8/10	3/10	7/10	8/10	8/10	9/10	1/10	4/10	5/10	4/10	5.9/10
Q6: have you ever cheated?	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9 = Yes 3 = No
Q7: What was the Method?	Checking answers from the book/slides	None	None	Checking answers from the book/slides Surfing the internet for answers Remote desktop	Checking answers from the book/slides Cheating groups on Whatsapp Phone calls Surfing the internet for answers	Checking answers from the book/slides Surfing the internet for answers	Checking answers from the book/slides Cheating groups on Whatsapp Remote desktop	Checking answers from the book/slides Cheating groups on Whatsapp Phone calls Surfing the internet for answers	Cheating groups on Whatsapp Phone calls Surfing the internet for answers	None	Checking answers from the book/slides Cheating groups on Whatsapp Phone calls Surfing the internet for answers Remote desktop	Checking answers from the book/slides Surfing the internet for answers Remote desktop	3 = None 8 = Checking answers from the book/slides 5 = Cheating groups on Whatsapp 4 = Phone calls 7 = Surfing the internet for answers 4= Remote desktop
Q9: Do you know someone who cheated?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	12 = Yes 0 = No

Fig. 9. A sample from the response table

Correlations Between Teaching and Scientific Research Ability and Professional Development of College Teachers

https://doi.org/10.3991/ijet.v17i11.32031

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Abstract—In the new era, the professional development (PD) of college teachers is significantly affected by their teaching and scientific research (TSR) ability. With a high TSR ability, teachers can enhance their professional literacy, explore the student behaviors in teaching practice, and optimize and improve the teaching mode. The research of college teachers' TSR ability has just started, lacking systematic, in-depth exploration. There is no report on the TSR subjects, or the effect of TSR ability on PD, not to mention empirical analysis of the correlations between TSR ability and PD. Therefore, this paper probes into the correlations between the TSR ability and PD of college teachers. Firstly, the data correlation principles were introduced for TSR ability and PD of college teachers, and an evaluation index system (EIS) was established for college teachers' TSR ability. Then, the scores of college teachers' TSR ability in a region were associated with the scores of college teachers' PD. On this basis, the nearest neighbor algorithm and the joint compatibility branch and bound (JCBB) algorithm were combined to derive an improved index data correlation model. Through experiments, the proposed model was proved effective, and the regional analysis results were obtained.

Keywords—college teachers, teaching and scientific research (TSR) ability, professional development (PD), correlation analysis

1 Introduction

In the new era, a high-quality team of teachers is necessary to train outstanding talents for the society [1-4]. The effective enhancement of college teachers' professional development (PD) directly bears on the training of new teachers into expert teachers, and guarantees high-quality teaching [5-9]. With the dawn of the new era, college teachers' professional literacy becomes increasingly diverse and complex. The PD of college teachers is significantly affected by their teaching and scientific research (TSR) ability [10-16]. College teachers must have an educational concept compatible with the reform and development of higher education, boast good classroom teaching ability and TSR ability, and support PD with these abilities [17-20]. Traditionally, college education aims to teach professional knowledge. By contrast, the PD behavior of college teachers in the new era should be innovative. Education and scientific research are important aspects of the teachers' innovation ability. With a high TSR ability, teachers can enhance their professional literacy, explore the student behaviors in teaching practice, and optimize and improve the teaching mode.

On the relationship between teaching and scientific research, the traditional research ends up with many contradictory results, because the research data mainly come from the job performance of teachers. Based on the big data, Li et al. [21] proposed a research hypothesis different from that of traditional research. Targeting the details of teachers' TSR behaviors recorded in the educational big data system, the features of teachers' TSR behaviors were extracted by user portrait method. Then, the association rule mining algorithm was employed to derive the correlations between teaching behaviors and scientific research behaviors. Experimental results fully support their hypothesis, which effectively reveals the true relationship between teaching and scientific research. Zhang and Liu [22] highlighted that college teachers in the new era should do two things from the first day of work. The first is to stand on the podium and teach classes well. The other is to carry out scientific research, and write quality papers. The former is a basic requirement on teachers, and the latter is needed for teacher development. Both are indispensable.

In the era of big data and intelligent technology, it is very important and necessary to study the scientific research ability of college teachers. This ability is related to the development and progress of national education, and science and technology. Therefore, it is of great necessity to devise a smarter and more objective evaluation approach. After fully considering the above factors, Zhao and Sun [23] constructed a scientific ability evaluation model through analytic hierarchy process (AHP), which provides a reference for restoring the literacy of modern college teachers, and offers reasonable suggestions for teachers to pursue personal development. The progress of education is impossible without teacher development. High-quality education calls for high-quality teachers. Fu [24] adopted backpropagation (BP) neural network to appraise the teacher performance in applied colleges, and changed the appraisal method to guide the PD of teachers. With the aim to extend qualitative analysis to quantitative analysis, Zhao ang Sun [23] comprehensively considered various factors, assigned proper weights, and calculated by Mathematica. During this process, a specific evaluation model was developed for scientific research ability, which facilitates the literacy restoration of modern college teachers, and guides the reasonable development of each teacher.

The research of college teachers' TSR ability has just started, lacking systematic, in-depth exploration. Some studies only mention the teaching or scientific research ability of college teachers in the introductory part, failing to examine TSR subjects, or the effect of TSR ability on PD, not to mention empirical analysis of the correlations between TSR ability and PD. Therefore, this paper probes into the correlations between the TSR ability and PD of college teachers. Section 2 explains the data correlation principles for TSR ability and PD of college teachers, and establishes an evaluation index system (EIS) for college teachers' TSR ability. Section 3 associates the scores of college teachers' TSR ability in a region with the scores of college teachers' PD, constructs an improved index data correlation model based on the nearest neighbor algorithm and the joint compatibility branch and bound (JCBB) algorithm, and analyzes the correlations between TSR ability and PD of college teachers. Through experiments, the proposed model was proved effective, and the regional analysis results were obtained.

2 Data correlation principles

In the new era, college teachers must possess the following basic skills and abilities, in order to meet various teaching needs:

1. The professional knowledge and skills necessary for teaching
   College teachers should master the basic strategies and skills for information teaching, curriculum activity design, and evaluation/appraisal of different types of students.
2. PD awareness and habit
   College teachers should always maintain good PD awareness and habit. They need to actively participate in academic training in related majors, keep a positive view of learning and progress, and frequently reflect on themselves.
3. Communication and exchanges with students and other teachers
   College teachers should be able to communicate and exchange effectively with students of different genders, races, religions, and gender orientations, and to discuss TSR topics with other teachers of different disciplines.
4. Identification as TSR subjects
   Apart from lecturing the knowledge in their field, college teachers should identify as TSR experts in their disciplines.

Currently, the reform and development of higher education in China requires college teachers to have a certain reserve of professional knowledge, a strong ability of information teaching, as well as the abilities to reflect on classroom teaching methods, and carry out the TSR in their disciplines. Teachers are the subjects responsible for developing school-based curriculums, based on intra- and extramural education resources. The development and integration of research courses rely on the organic integration between information technology and discipline teaching by college teachers. In other words, a key requirement for college teachers is the strong awareness and ability for TSR. Colleges must take the initiative to change the professional training model of teachers, and train a batch of new college teachers with TSR literacy, who can adapt to the reform and development of higher education in the new era.

This paper aims to fully analyze and explore the correlations between TSR ability and PD of college teachers, and verify the mutual promotion/inhibition between them, laying the basis for effective enhancement of college teachers' ability. Based on the research results, colleges can realize supervision and early warning of the TSR ability variation of their teachers, and maintain the college teachers' PD in the ideal range.

Referring to the existing EISs, this paper establishes the following EIS for college teachers' TSR ability:

Layer 1 (criteria layer):

TAS={TAS_1, TAS_2 , TAS_3}={TSR knowledge reserve, TSR capacity, TSR awareness};

Layer 2 (alternative layer)

TAS_1={TAS_{11}, TAS_{12}, TAS_{13}, TAS_{14}, TAS_{15}, TAS_{16}, TAS_{17}, TAS_{18}}={professional knowledge, professional skills, education principles, knowledge in teaching practice, information teaching technology, TSR methodology, education psychology, generation mechanism of research results};

TAS_2={TAS_{21}, TAS_{22}, TAS_{23}, TAS_{24}, TAS_{25}, TAS_{26}, TAS_{27}, TAS_{28}}={innovation ability, information retrieval ability, information mining ability, literature comprehension ability, literature summarization ability, TSR methodology utilization ability, data processing ability, research report writing ability};

TAS_3={TAS_{31}, TAS_{32}, TAS_{33}, TAS_{34}, TAS_{35}}={collaborative innovation spirit, enthusiasm for TSR, attitude towards academic misconduct, self-development awareness}.

Next, this paper associates the scores of college teachers' TSR ability in a region with the scores of college teachers' PD, and analyzes the data correlations between TSR ability and PD of college teachers. Figure 1 shows the data correlation principles for TSR ability and PD of college teachers.

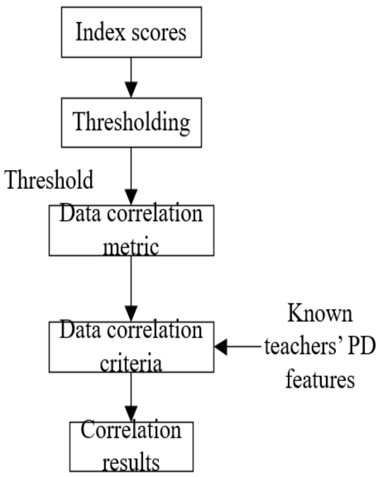

Fig. 1. Data correlation principles for TSR ability and PD of college teachers

3 Data correlation model

In each region, there are numerous scores of college teachers' TSR ability, and scores of college teachers' PD. The accuracy of data correlations depends on the evaluation index features at different time and locations. To ensure the correlation accuracy between TSR ability and PD of college teachers, this paper constructs an improved index data correlation model based on the nearest neighbor algorithm and the JCBB algorithm. Figure 2 shows the philosophy of the data correlation model.

The nearest neighbor algorithm is a simple and lightweight model. In this paper, the correlation between TSR ability and PD of college teachers is estimated by the shortest Euclidean distance between index score and subject features within the threshold. Based on this metric, the locations of the feature points of TSR ability and PD were corrected, before further estimating the location of the subject.

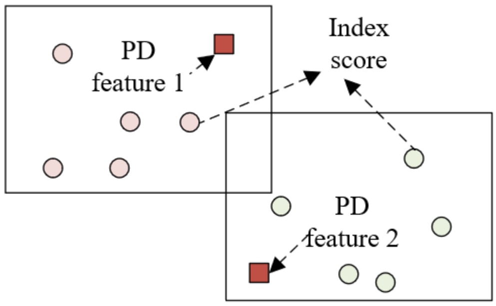

Fig. 2. Philosophy of the data correlation model

Let $c_i(l+1)$ be the score of the i-th index within the correlation threshold at time l+1 in the EIS; $c_i^*(l+1|l)$ be the predicted position of feature point correlation. Then, we have:

$$u_i(l+1) = c_i(l+1) - c_i{}^*(l+1|l) \tag{1}$$

Let $S(k+1)FC(l+1)$ be the covariance. Then, the norm can be expressed as:

$$h_i(l+1) = u_i^T(l+1)FC^{-1}(l+1)u_i(l+1) \tag{2}$$

The JCBB overcomes the incompleteness of test conditions, and improves the correlation accuracy of index data. Under the joint compatibility test condition, the compatibility between the scores is tested for the indices of the same class, in the light of the correlations between PD features of the subject. The difficulty of data correlation increases with the range of the study area. The JCBB reduces the joint compatibility of incorrect correlation between index data, making it more accurate to associate different data.

In the JCBB, the joint observation vector of known teachers' PD features for the indices of the same class can be expressed as:

$$c_{F_l} = \left[c_{F_1}, c_{F_2}, \ldots, c_{F_n}\right]^T \tag{3}$$

Let f_{Fl} be the observation model of the EIS. Then, the joint compatibility predicted observation $c_{Fl}{}^*$ for teachers' PD features can be calculated by:

$$\hat{c}_{F_l} = f_{F_l}\left(\hat{A_{l|l-1}}\right) = \begin{bmatrix} f_{j_1}\left(\hat{A_{l|l-1}}\right) \\ g_{j_n}\left(\hat{A_{l|l-1}}\right) \end{bmatrix} \tag{4}$$

The information vector u_{Fl}, and its covariance matrix FC_{Fl} can be respectively calculated by:

$$u_{F_l} = C_{F_l} - f_{F_l}(\hat{A}_{l|l-1}) \tag{5}$$

$$FC_{F_l} = F_{F_l} T_{l|l-1} F^T{}_{F_l} + S_{F_l} \tag{6}$$

where,

$$F_{F_l} = \begin{bmatrix} F_{j1} \\ N \\ F_{jn} \end{bmatrix} \tag{7}$$

$$F_{jn} = \frac{\partial f_{jn}}{\partial A_{l|l-1}} \Big| \hat{A}_{l|l-1} \tag{8}$$

Let 1-x be the expected confidence. The chi-square distribution ξ^2 is assumed as an e-dimensional matrix satisfying 1-x. Then, the joint compatibility data correlation criterion can be expressed as:

$$E_{v_l}^2 = u_{F_l}^T R_{F_l}^{-1} u_{F_l} < \xi_{e,1-\beta}^2 \tag{9}$$

The computing load of the algorithm grows exponentially with the rising index scores, and teachers' PD features. The exponential increase brings a huge impact on the accuracy of data correlations, and the analysis of data correlations.

Let N be the set of scores for the collected indices; N_{NEW} be the set of scores for the indices newly acquired at time l; N_{DA} be the set of scores for the indices with successful data correlations. Then, we have:

$$N = N_{NEW} \cup N_{DA} \tag{10}$$

Let P be the set of known teachers' PD features; P_{DA} be the set of indices in need of data correlation; P_{ELI} be the set of teachers' PD features, which do not need to be considered for associating the index data at time l. Then, we have:

$$P = P_{DA} \cup P_{ELI} \tag{11}$$

Let P_i of the teachers' PD features compatible with the index score i at time l. Then, we have:

$$P_{DA} = \bigcup_{i \in N_{DA}} P_i \tag{12}$$

For the elements in P_{DA} and N_{DA}, this paper searches for the optimal data correlations based on similarity, using the grey wolf optimization (GWO) algorithm, under the relevant constraints. The adopted likelihood function can be defined as:

$$KF = \bigcup_{\substack{n \in N_{DA} \\ m \in P_{DA}}} \Omega(c_n, g_m) \tag{13}$$

where,

$$\Omega(c_n, g_m) = \frac{1}{|2\pi R|^{\frac{1}{2}}} \exp\{[c_n - \hat{c}_m]^T R^{-1} [c_n - \hat{c}_m]\} \tag{14}$$

Formula (14) shows the probability for index score n to match teachers' PD feature m. Note that c_n is the index score of n; $\hat{c}_m$ is the estimation of m; R is the covariance of c_n-$\hat{c}_m$. Then, we have:

$$D_{nm} = -\ln[\Omega(c_n, g_m)] \tag{15}$$

Then, the minimum sum of the maximum number of D_{nm} can be found by transforming formula (14) with formula (15). In the combinatory optimization of index data correlations, it is a must to ensure that $n \in N_{DA}$, and $m \in P_{DA}$, and that, in d_{i1j1} and d_{i2j2}, i_1 is not equal to i_2, and j_1 is not equal to j_2. The improved index data correlation model can be implemented in the following steps:

Step 1. Initialize P_{DA}, N_{DA}, P_i and N_{NEW}.

Step 2. Construct the correlation matrix for evaluation indices.

Step 3. Preprocess the index data, search for elements satisfying A_{ij}=1 in the correlation matrix, match index score i with teachers' PD feature j, and remove the corresponding elements from P_{DA} and N_{DA}.

Step 4. Solve $D_{i,j}=\sum^{n}_{i=1}L_i$, which depends on both N and P. Note that N_{DA}, P_i, and P_{DA} have n, L_i, and m elements, respectively.

Step 5. Compute the covariance distance N_{ij}, j=1,2,...,m between every index score i within the correlation threshold, and the known teachers' PD features. Note that every N_{ij} must satisfy:

$$\min_j N_{ij} > \alpha \tag{16}$$

Step 6. Ensure that the index score i is different from teachers' PD feature j in the set of solutions, i.e., guarantee that the subscripts of any two values in the set are independent of each other.

4 Experiments and results analysis

Figure 3 shows the success rate for the matching between the scores of 21 TSR ability indices and the known PD features of 2,000 college teachers, using the proposed index data correlation algorithm. Figure 4 shows the error in the matching of the index data during the operation of our model in a simulation environment. It can be seen that our model can effectively associate the index scores with college teachers' PD scores in the region.

Overall, the grand average and standard deviation of the TSR ability scores of the 2,000 subjects were 3.58, and 0.41, respectively. About 53.9% (1,248) college teachers stayed above the average, while 45.1% (915) stayed below the average. Table 1 lists the statistical and test results on college teachers' TSR ability.

As shown in Table 1, the grand average of college teachers' TSR ability fell between slightly good and strongly good in the scale, indicating that the college teachers possess a good TSR ability. Specifically, the highest average score (3.92) was achieved in the dimension of TSR knowledge reserve. Thus, the college teachers in the region mostly have a certain TSR knowledge reserve. The second highest average score (3.59) was found in the dimension of TSR awareness. The lowest average score (3.34) was produced by TSR capacity, falling short of the threshold (3.5) for slightly good. Thus, the TSR capacity of the college teachers should be further enhanced. Table 1 also presents the single-sample t-test results on the three dimensions of college teachers' TSR ability. The results show that the p-values of all three dimensions, namely, TSR knowledge reserve, TSR capacity, and TSR awareness, were smaller than 0.05, and the t-values of all dimensions were all significant.

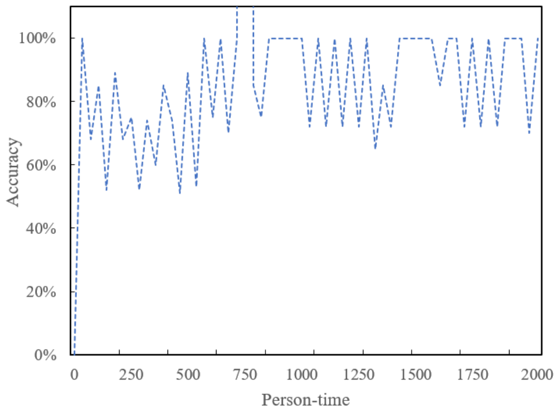

Fig. 3. Accuracy of index data correlations

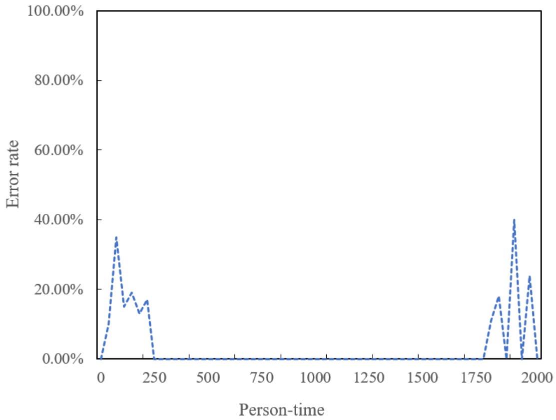

Fig. 4. Error rate of index data correlations

Table 1. Statistical and test results on college teachers' TSR ability

Dimension	Total	TSR knowledge reserve	TSR capacity	TSR awareness
Average	3.58	3.92	3.34	3.59
Standard deviation	0.41	0.35	0.52	0.57
T	11.53	12.37	-16.05	13.17
P	0.02	0.05	0.01	0.04
Below the average	915(45.1%)	948(49.2%)	864(42.7%)	1126(52.4%)
Above the average	1248(53.9%)	1436(51.8%)	1294(57.3%)	972(47.6%)

The three dimensions of college teachers' TSR ability have different functions and merits in practice. To reveal the correlations between TSR ability and PD of college teachers, it is insufficient to evaluate, judge, and compare the three dimensions of college teachers' TSR ability, solely based on the average. This paper decides to compare the number of college teachers below the average and that above the average in each dimension. Figure 5 shows the distribution of college teachers' TSR ability in each dimension. It can be seen that, there were more below-the-average college teachers than above-the-average teachers in TSR capacity and TSR knowledge reserve. The opposite was observed in TSR awareness. Judging by the total score, fewer college teachers surpassed the average than those remaining below the average. Although the college teachers in the region have a high grand score of TSR ability, the proportion of below-the-average teachers indicates the necessity of further enhancing the education and research ability. This is consistent with the conclusions of previous studies.

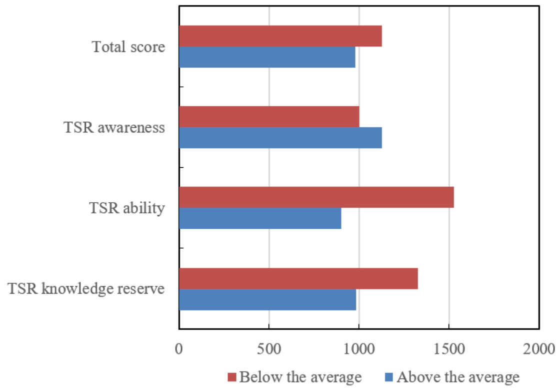

Fig. 5. Distribution of college teachers' TSR ability in each dimension

Tables 2 and 3 summarize the correlations between the three dimensions of TSR ability and the PD of college teachers. As shown in Table 2, for the regional college teachers, the average correlation between each of the eight aspects of TSR knowledge reserve (professional knowledge, professional skills, education principles, knowledge in teaching practice, information teaching technology, TSR methodology, education psychology, and generation mechanism of research results) and the PD was greater than 3. Thus, the regional college teachers have an ideal PD situation, under the effects of these indices. Of course, the correlation scores of the eight aspects differed slightly, indicating that the subjects develop by different degrees in each direction of TSR ability. This means, the PD of regional college teachers is greatly affected by the subjects' TSR knowledge reserve, and the evaluation alternatives of TSR knowledge reserve should be more balanced.

As shown in Table 3, for the regional college teachers, the average correlation between each of the eight aspects of TSR capacity (innovation ability, information retrieval ability, information mining ability, literature comprehension ability, literature summarization ability, TSR methodology utilization ability, data processing ability, and research report writing ability) and the PD was greater than 3; the average correlation between each of the four aspects of TSR awareness (collaborative innovation spirit, enthusiasm for TSR, attitude towards academic misconduct, and self-development awareness) and the PD was greater than 3, too. These results confirm that regional college teachers have an ideal PD situation, under the effects of these indices. It can also be learned that the college teachers' PD in the region is significantly affected by TSR capacity, and TSR awareness. But the alternatives of evaluation should be further balanced in future.

Table 2. Correlations between TSR knowledge reserve and PD of college teachers

	Sample size	**Average**	**Standard deviation**	**Mean standard error**
Professional knowledge	174	3.68	7.61	0.51
Professional skills	168	3.16	7.87	0.58
Education principles	172	4.27	8.69	0.62
Knowledge in teaching practice	169	4.05	7.64	0.67
Information teaching technology	174	3.92	7.05	0.63
TSR methodology	169	3.75	6.37	0.59
Education psychology	173	3.81	6.29	0.64
Generation mechanism of research results	171	3.95	6.84	0.66

Table 3. Correlations between TSR capacity, TSR awareness, and PD of college teachers

	Sample size	**Average**	**Standard deviation**	**Mean standard error**
Innovation ability	179	3.62	8.42	0.68
Information retrieval ability	165	3.17	7.95	0.52
Information mining ability	172	4.28	7.52	0.57
Literature comprehension ability	176	3.69	7.63	0.51
Literature summarization ability	168	3.47	7.98	0.59
TSR methodology utilization ability	171	3.05	7.46	0.55
Data processing ability	169	3.82	7.38	0.52
Research report writing ability	174	3.46	7.21	0.57
Collaborative innovation spirit	162	3.71	7.46	0.53
Enthusiasm for TSR	178	3.86	7.05	0.51
Attitude towards academic misconduct	177	4.38	6.81	0.55
Self-development awareness	177	4.37	8.59	0.68

5 Conclusions

This paper explores the correlations between the TSR ability and PD of college teachers. Firstly, the authors expounded on the data correlation principles for TSR ability and PD of college teachers, and built up an EIS for college teachers' TSR ability. Then, the scores of college teachers' TSR ability in a region were associated with the scores of college teachers' PD, and an improved index data correlation model was established based on the nearest neighbor algorithm and the JCBB. After that, experiments were carried out to obtain the accuracy and error rate of our model in index data correlations. It was found that our model can effectively associate the index scores with college teachers' PD scores in the region. Next, the authors summed up the statistical and test results on college teachers' TSR ability, as well as the distribution of college teachers' TSR ability in each dimension. The overall correlations between PD and each dimension of college teachers' TSR ability (TSR knowledge reserve, TSR capacity, and TSR awareness) were also summarized. It was concluded that the college teachers' PD in the region is significantly affected by the three dimensions of TSR ability. But the alternatives of evaluation should be further balanced in future.

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7 References

[1] Kong, X.F. (2017). The status quo and countermeasures of the construction of the double-qualified teacher team in maritime vocational colleges. AGRO Food Industry Hi-Tech, 28(3): 1045-1049.

[2] Zhao, F.H., Guo, X.F., He, Y. (2014). The study and practice of constructing featured specialty based on the double qualified teacher and double mentors. In Advanced Materials Research, 971: 2685-2687. https://doi.org/10.4028/www.scientific.net/AMR.971-973.2685

[3] Zhang, N. Zhang, Y. (2012). Evolution and tendency to" double-qualified" teacher competency: A literature review on Chinese higher vocational education. 2012 Fourth International Conference on Multimedia Information Networking and Security, pp. 529-532. https://doi.org/10.1109/MINES.2012.109

[4] Li, H.D., Lin, C.L. (2019). Research on the ability evaluation of" Double-qualified and double-ability" teacher in M university based on fuzzy-AHP. In 2019 15th International Conference on Computational Intelligence and Security (CIS), pp. 292-295. https://doi.org/10.1109/CIS.2019.00068

[5] Friend, M., Twarek, B., Koontz, J., Bell, A., Joseph, A. (2022). Trends in CS Teacher Professional Development: A Report from the CSTA PD Committee. In Proceedings of the 53rd ACM Technical Symposium on Computer Science Education, pp. 390-396. https://doi.org/10.1145/3478431.3499292

[6] Gunning, A.M., Marrero, M.E., Larson, K.V. (2021). Studying In-service Teacher Professional Development on Purposeful Integration of Engineering into K-12 STEM

Teaching (Research to Practice). In 2021 ASEE Virtual Annual Conference Content Access.
[7] Riel, J., Lawless, K.A. (2022). Enhancing student affect from multi-classroom simulation games via teacher professional development: Supporting game implementation with the ROPD model. In Research Anthology on Developments in Gamification and Game-Based Learning, pp. 1703-1725. https://doi.org/10.4018/978-1-6684-3710-0.ch083
[8] Chen, G. (2020). A visual learning analytics (VLA) approach to video-based teacher professional development: Impact on teachers' beliefs, self-efficacy, and classroom talk practice. Computers & Education, 144: 103670. https://doi.org/10.1016/j.compedu.2019.103670
[9] Yang, R., Porter, A.C., Massey, C.M., Merlino, J.F., Desimone, L.M. (2020). Curriculum-based teacher professional development in middle school science: A comparison of training focused on cognitive science principles versus content knowledge. Journal of Research in Science Teaching, 57(4): 536-566. https://doi.org/10.1002/tea.21605
[10] Guo, S.Y., Wu, W.C., Cai, A.T. (2020). A study on promoting teachers' professional quality to achieve sustainable development goals. In IOP Conference Series: Earth and Environmental Science, 576(1): 012013. https://doi.org/10.1088/1755-1315/576/1/012013
[11] Chiu, C.F. (2020). Facilitating K-12 Teachers in Creating Apps by Visual Programming and Project-based Learning, International Journal of Emerging Technologies in Learning, 15(3): 103-118. https://doi.org/10.3991/ijet.v15i01.11013
[12] Li, Y.X. (2015). Study on special education teachers' professional quality based on the survey data analysis. In 2015 Seventh International Conference on Measuring Technology and Mechatronics Automation, pp. 1066-1071. https://doi.org/10.1109/ICMTMA.2015.260
[13] Kong, F.W. (2020). Evaluation Model of Adaptive Teaching Ability of College Art Teachers, International Journal of Emerging Technologies in Learning, 15(9): 143-155. https://doi.org/10.3991/ijet.v15i09.14031
[14] Zhao, X., Guo, Z., Liu, S. (2021). Exploring key competencies and professional development of music teachers in primary schools in the era of artificial intelligence. Scientific Programming. https://doi.org/10.1155/2021/5097003
[15] Chen, Z., Chen, Q. (2021). Optimization of teaching evaluation system for football professional teachers based on multievaluation model. Complexity. https://doi.org/10.1155/2021/9943989
[16] Goode, J., Peterson, K., Malyn-Smith, J., Chapman, G. (2020). Online professional development for high school computer science teachers: Features that support an equity-based professional learning community. Computing in Science & Engineering, 22(5): 51-59. https://doi.org/10.1109/MCSE.2020.2989622
[17] Asnawati, S., Dewi, I.L.K. (2020). Mathematical representation ability using website for learning transformation geometry in a teacher education classroom. In Journal of Physics: Conference Serie, 1511(1): 012115. https://doi.org/10.1088/1742-6596/1511/1/012115
[18] Tang, M., Wei, D. (2021). Cultivation Strategies for Scientific Research and Innovation Ability of College Students Majoring in Sports. International Journal of Emerging Technologies in Learning, 16(6): 154-166. https://doi.org/10.3991/ijet.v16i06.21093
[19] Reynolds, W.M., Park, S. (2021). Examining the relationship between the Educative Teacher Performance Assessment and preservice teachers' pedagogical content knowledge. Journal of Research in Science Teaching, 58(5): 721-748. https://doi.org/10.1002/tea.21676
[20] Chen, S.Y., Wang, T.H., Li, X.M., Zhu, L., Wu, D.Y. (2021). Research on the improvement of teachers' teaching ability based on machine learning and digital twin technology. Journal of Intelligent & Fuzzy Systems, 40(4): 7323-7334. https://doi.org/10.3233/JIFS-189557
[21] Li, Y., Fu, H., Tang, Y., Fu, C. (2019). Empirical research on the relationship between teaching and scientific research based on educational big data in China. In CCF Conference

on Computer Supported Cooperative Work and Social Computing, pp. 390-398. https://doi.org/10.1007/978-981-15-1377-0_30
[22] Zhang, Y., Liu, W. (2021). University teachers improve teaching by doing scientific research. In The Sixth International Conference on Information Management and Technology, pp. 1-4. https://doi.org/10.1145/3465631.3465953
[23] Zhao, C., Sun, Z. (2021). Study on the Evaluation of Scientific Research Ability of University Teachers Based on the Mathematica Software. In 2021 2nd International Conference on Big Data and Informatization Education (ICBDIE), pp. 334-338. https://doi.org/10.1109/ICBDIE52740.2021.00082
[24] Fu, G. (2020). Evaluation strategy of teacher professional development in applied universities based on BP neural network. In International Conference on Application of Intelligent Systems in Multi-modal Information Analytics, pp. 479-486. https://doi.org/10.1007/978-3-030-51431-0_70

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Online Live Teaching is Effective: An Empirical Study

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Abstract—This research is single-group quasi-experimental teaching research, which controls the teaching form of the course for the participants. Based on literature analysis, it is pointed out that online live teaching is a vital teaching form, and the research on it has both theoretical value and practical significance. The research framework and measurement tools are constructed. The researchers selected the course on mathematical methodology as the teaching content. Twenty-six pre-service mathematics teachers were taught 17 times with 51 class hours in online live teaching. Pretest and post-test were carried out. The study found that online live teaching is effective. However, the interview result shows that most participants hope to combine online and offline learning. They prefer to communicate with teachers face to face in the classroom.

Keywords—online live teaching, distance education, empirical research

1 Introduction

Online teaching has become more and more popular in the last two decades [1]. Under the influence of the COVID-19 pandemic, many universities worldwide cannot start school usually. Traditional classroom teaching methods no longer work [2]. Many universities adopt online teaching methods to ensure that students can continue to study [3]. The latest trend in online teaching is to adopt and integrate web conferencing tools to enable real-time online classrooms and reproduce the spirit of traditional face-to-face meetings [4]. With the development of information and communication technology, online live teaching has gradually become an essential form of instruction.

In many countries, online live teaching has become a valuable method in emergencies. When students are isolated at home to prevent illness and cannot return to school, thousands of teachers use online live teaching to teach students. This teaching method has achieved outstanding results, but it also has a wrong side. A few years ago, researchers analyzed teachers' online live teaching behavior and pointed out that teachers who conduct online live teaching should change their traditional teaching concepts and strengthen their interaction with learners [5].

However, the research was not comprehensive. Although studies have pointed out that online live teaching is productive, many issues are still worth exploring [6]. A survey pointed out that online teaching cannot replace face-to-face teaching [7]. Understanding what students and faculty consider the most significant advantages and disadvantages of online courses is essential to developing new procedures for enhancing the learning experience [8]. Some studies have analyzed the advantages and disadvantages of online live teaching and proposed that the evaluation of courses and online live teaching platforms should evaluate the learning process in ordinary times [9]. Online live teaching is a valuable supplement to traditional classroom teaching. Educators can integrate theory into students' life experiences through online teaching forums, improving students' learning participation and motivation [10]. The era puts forward new requirements for teaching, and pre-service teachers should cultivate their sense of identity with online live teaching. The curriculum design of pre-service teachers should fully consider these recent changes. Pre-service teachers should understand online live learning and be willing to teach in this way [11]. For this reason, pre-service teacher trainers can try to use online live teaching as a demonstration of the teaching method.

The mathematical methodology is a subject of knowledge about mathematical thinking methods and the laws of discovery, invention, and mathematics innovation. The mathematical methodology is a basic course that pre-service mathematics teachers need to take. One of the critical purposes of the mathematical methodology course is to develop the problem-solving skills of pre-service mathematics teachers. This research explores how to use online live teaching to teach mathematical methodology courses to develop pre-service mathematics teachers' problem-solving ability. This research will provide evidence for the effectiveness and prospects of online live education and point out strategies for improvement.

The objective of the research is to answer:

1. Can the online live teaching of mathematical methodology course improve the problem-solving ability of pre-service mathematics teachers?
2. What is the attitude of pre-service mathematics teachers towards online live teaching of mathematical methodology courses?

2 Concept definition

2.1 Pre-service mathematics teacher

In this article, pre-service mathematics teachers refer to students who will become mathematics teachers, mainly undergraduate and junior mathematics normal students and postgraduates in curriculum and teaching theory (mathematics) and subject teaching (mathematics). There have been many research results on the training of pre-service mathematics teachers [12] - [15].

2.2 Mathematical problem solving

Mathematics problems in this research refer to the mathematics questions that are obstructive and exploratory, and the students need to think and explore to solve them.

Sound problems are the problems that the problem-solving process helps improve students' thinking ability and the problems that should be solved by severe thinking [16]. Mathematical problem solving is considered to be the most typical human intellectual activity. It requires finding ways to eliminate difficulties, bypass obstacles, and achieve goals that cannot be fulfilled immediately [17].

2.3 Mathematical methodology

Future mathematics teachers should have better problem-solving skills. Normal schools should appropriately increase mathematics problem-solving and teaching courses to improve pre-service mathematics teachers' mathematical problem-solving skills [18] and mathematical problem-solving teaching ability. The mathematical methodology is just such a course. The mathematical methodology in this research is about the theory of mathematical thinking methods.

3 Online live teaching media

Some teachers use videos to provide students with online learning opportunities, such as teaching a statistics course for teachers and administrators [19]. However, video is a static medium, and a dedicated teaching platform is to realize online live teaching. The following platform is the teaching platform used in this study, and the research design is carried out after introducing the use of the platform.

3.1 Teaching platform

Most studies about online learning environments primarily focus on technology-related issues or instructional methods, and little attention has been given to online teachers and their teaching approaches. Still, this study is different [20]. Online teaching is considered distinct from traditional education [21], but the teaching platform used in this study retains the advantages of conventional teaching as much as possible. The teaching platform used in this research is based on the teacher's own choice, which can better achieve the teaching purpose.

This study's online live teaching platform is the *Tencent Classroom Application*. Teachers should check and adjust the camera and microphone before class. The teaching process of *Tencent Classroom* is: log in to the *Tencent Classroom,* → click *Start-Class*, enter the course name of this section, and click *Confirm* to join the live broadcast room → click *Invite students to attend a class*, and the link to the class is sent to the students, and the students can click on the link to enter the class through their mobile phones, flat computer or computers → after the course is over, click the *Class* button in the lower-left corner to dismiss the class, and the students will no longer receive the audio and video.

The teaching interface of *Tencent Classroom* includes a functional area, teaching area, and discussion area.

The functional area has five main functions:

1. drawing board, which can be marked on the screen, supports four types of drawing board tools: brush, text, circle, and rectangle;
2. sign-in and answer, post a sign-in or answer activity, students receive a bullets box, you can click to sign in and answer questions;
3. picture-in-picture mode, when the screen is shared, the camera will be turned on, and the camera screen will appear in the lower right corner of the student's screen;
4. raise your hand to turn on the microphone mode, and the student can apply for connection on the client; the students can use the microphone to interact with the teacher in real-time;
5. preview, open a small window to preview the current screen.

The teaching area displays the teaching content. The teaching area and the sharing area screen can be adjusted manually. In the discussion area, students can communicate with classmates and teachers.

Although the blended teaching method has existed in universities for decades, the ways teachers teach are inconsistent, so students' combined teaching experience varies greatly [22]. The function of the teaching mentioned above platform is to simulate traditional education, which can generate a face-to-face atmosphere so that students can adapt.

3.2 Teaching mode

A survey pointed out that there are some problems in online teaching: teachers and students are not suitable for online teaching methods; they are not familiar with network platform software; there are problems in the teaching process such as technical difficulties, inability to log in, and inability to open web pages [23]. Considering these issues, the teaching model of the platform should be operable and straightforward. The teaching model of *Tencent Classroom* is easy to operate. It has four main lesson modes:

1. screen sharing and teaching, click the *Share Area* button, and use the mark to select the area to share the screen in the area;
2. PowerPoint lesson, click the *Open PPT* button, Select the PowerPoint file; you can use PowerPoint to teach;
3. video lecture, click the *Add Video* button, select and open the video file; you can use the video file to teach;
4. camera lecture, click the *Open camera* button to use the camera to live the lesson.

Studies find that aside from technological and contextual factors, faculty's personal, incredibly motivational factors also play an essential role in their goals and attitudes towards changing teaching mode [24]. Researchers of this experiment believe that online live teaching is feasible; this study comprehensively fully adopts the above four clauses to motivate learners.

4 Research methodology

There has been a lot of research on online teaching, including teaching experiments. The characteristic of this research is to use the form of online live education throughout the whole teaching process to discuss the effect of online live teaching. The study helps compare online teaching and traditional teaching to judge whether online teaching provides a new and independent teaching form. This part shows the research methodology and mainly introduces the tools to measure the learning effect of online live education, the research participants, and the research process.

4.1 Research tool

This study is a single-group quasi-experimental study. At the same time, the interview method is adopted. The mathematical problem-solving ability in the research refers to the actual ability, that is, the demonstrated problem-solving ability, which is described from the five sub-abilities of induction, analogy, reduction, construction, and transformation.

The measurement framework of pre-service mathematics teachers' problem-solving ability and corresponding measurement items are shown in Table 1 for pretest and post-test. The pretest problems consist of the odd-numbered items in the table, and the post-test problems consist of the even-numbered items. The pre-test and post-test are equivalent (the Spearman rank correlation coefficient is 0.953, and the significance coefficient (Two-tailed) $p = 0.000 < 0.01$). Both the pretest and post-test paper contain five problems, each question is assigned 20 points, and each test paper has a full score of 100 points. Both the pretest and the post-test are in the form of paper-based tests. Participants have 60 minutes to answer the questions.

The two questions for pre-service mathematics teachers' interviews are:

1. Please briefly evaluate the online live teaching adopted in this course. How do you want teachers to teach?
2. In your opinion, what are the deficiencies in the curriculum and teaching?

Table 1. Measurement framework of mathematical problem-solving ability

Target	Indicators	Measurement items
Math Problem Solving skills	Induction	It is known that there are 2020 points in triangle ABC and the three vertices of the total of 2023 points. How many non-overlapping triangle regions are divided by these points (any three points form a triangle)?
		$f(x) = x / \sqrt{(1 + x^2)}, f_n(x) = f\{f[f\cdots f(x)]\}$(the number of f is n, n is a positive integer), among them, $f_1(x) = f(x)$, Find $f_n(x)$.
	Analogy	Let $(z - x)^2 - 4(x - y)(y - z) = 0$, proof: $2y = x + z$.
		Proof: The sum of the distance from any point to each surface in the tetrahedron is a fixed value.
	Reduction	If $x_1, x_2, \cdots, x_n$ are all positive, proof: $x_1^2 / x_2 + x_2^2 / x_3 + \cdots + x_n^2 / x_1 \geq x_1 + x_2 + \cdots + x_n$.
		Let $a > b > 0$, proof: $a^2 + 1 / \sqrt{b}(b - a) \geq 4$.
	Construction	Knowing that a is a real number, and $x, y \in [-\pi / 4, \pi / 4]$, and meet the condition $x^3 + \sin x - 2a = 0$ and $8y^3 + \sin 2y + 2a = 0$, find the value of $\cos(x + 2y)$.
		Knowing that x and y are real numbers, meeting the condition $(x - 2)^5 + 2020(x - 2) = - 2021$ and $(y - 2)^5 + 2020(y - 2) = 2021$, find the value of $x^2 + 2xy + y^2 - x - y$.
	Transformation	9. Knowing that x is a real number, find the value range of $\sqrt{(x^2+x+1)} - \sqrt{(x^2-x+1)}$.
		10. Knowing that k and θ are real numbers, proof: $\mid k\cos\theta - \sin\theta \mid / \sqrt{(1+k^2)} \leq 1$.

4.2 Participants

The research participant comes from 26 pre-service mathematics teachers who are taking the mathematical methodology course in a key provincial normal university in China. They have studied Mathematical Analysis, Advanced Algebra, Modern Algebra, Real Variable Functions, Complex Variable Functions, and Topology at the undergraduate level.

4.3 Research process

There has been some research on the teaching experiment of online teaching. Compared with the existing research [25] - [26], this research is more focused on teacher-student online interaction. The research process was: a pretest on the pre-service mathematics teachers' → intervention → post-test on the pre-service mathematics teachers. The pretest and post-test were both in the form of online exams. An interview was conducted after the post-test.

The form of intervention was online live teaching. The teaching intervention lasted for 17 weeks (51 hours, 3 hours per week). Teaching content includes Polya's problem-solving methods, mathematical intuition, induction and analogy methods, Descartes' methodology, axiomatic methods, abstract mathematical methods, mathematical proof methods, mathematical aesthetics methods, RMI methods, mathematical problem-solving psychology, Calculus method, probability and statistics methods, as well as specific middle schools mathematical problem-solving methods such as transformation, structure, and combination of number and shape.

5 Results and discussion

5.1 The development of the mathematical problem-solving ability

To describe the mathematical problem-solving ability of pre-service mathematics teachers, the researchers compared the score data of the pretest and post-test of their mathematical problem-solving ability (see Table 2).

Compared with the previous test, the total score increased by 11.15. The lower quartile difference was 7.50, and the median difference was 10.00, the upper quartile difference was 27.50, the maximum and minimum Increased by 20.00 in value. It can be seen that the post-test results of the subjects are better than the pretest results in the distribution of total scores.

Table 2. Basic statistics of subjects' problem-solving ability

Statistics		Post-test	Pre-test	Difference
Average		61.15	50.00	11.15
Median		60.00	50.00	10.00
Standard deviation		21.23	18.97	2.26
Minimum value		20.00	0.00	20.00
Maximum		100	80.00	20.00
Percentile (P)	25	47.50	40.00	7.50
	50	60.00	50.00	10.00
	75	80.00	52.50	27.50

The results of the matched-sample t-test for the total scores of the post-test and pre-test are shown in Table 3.

Table 3. Examination of pre-test and post-test scores (*p < 0.05, **p < 0.01)

Total score	Correlation coefficient	p	Correlation significance	t	p	Difference significance
Post & pre-test	0.646	0.000	**	3.336	0.003	**

According to Table 3, there is a statistically significant difference between the subjects' post-test and pretest ($t = 3.336$, $p = 0.003 < 0.01$, $r = 0.27$), and the post-test score is significantly higher than the pretest.

5.2 Attitudes towards online live teaching

The researcher conducted interviews with students. The two questions asked were:

1. Please briefly evaluate the online live teaching adopted in this course. How do you want teachers to teach?
2. In your opinion, what are the deficiencies in the curriculum and teaching?

In the interview, 11 pre-service mathematics teachers commented on the online live teaching mode, and four pre-service mathematics teachers pointed out the shortcomings.

The interview records compiled by the researcher are shown in Table 4. Among the 15 interviewed pre-service mathematics teachers, three had a positive attitude, two had a negative attitude, three had a neutral attitude, three had an approved attitude, and four had a critical perspective. Institutions and educators should improve the satisfaction of teachers' online teaching and students' online learning.

Table 4. Results of interviews with pre-service maths teachers

Question	Interviewer's answer	Attitude
1	This combination of online, offline, pre-class, in-class, and after-class allows us to have sufficient time for thinking and learning about knowledge. Specifically, through the pre-class preview, you can clarify the questions in advance, and the teacher also gives answers during the class, which is very targeted. Secondly, the teacher gives us a more intuitive understanding of concepts through examples in class. Finally, in the form of homework, let us express our views or ideas and form our knowledge contract. Through the study of this course, I have a newer understanding of mathematical methods and have greatly improved my thinking, which has increased my deep learning. This method can promote timely communication between students, which is very pleasant.	Positive
	Affected by the epidemic this year, online live learning is rapidly expanding. It is a new type of class, a new way of taking the initiative to preview offline, discuss with group members when problems are found, and then class. The teacher's explanation will test the students' independent learning ability to a large extent and provide them with opportunities for independent thinking, communication, and cooperation. This learning method can be used well to benefit the students and teachers.	Positive
	We are now at the graduate level. I feel very comfortable with this online teaching and offline self-learning method, and it saves a little time.	Positive
	I prefer offline. If there are problems online, it is sometimes inconvenient to ask questions, and I speak a little faster. Sometimes I can't remember or think of it.	Negative
	Offline. Because there is less online interaction, mainly when the professor solves the problem, the teacher will be easy to talk alone if there is no immediate feedback from the students. The students' difficulties and unintelligible points cannot be communicated in time, and the teaching efficiency is not high. In addition, teachers and students do not pay much attention to online classes.	Negative
	The method is relatively new, but online teaching has advantages and disadvantages, and the efficiency of offline active learning is not the same. Both online and offline emphasize "autonomy." I think both are fine. Because students with solid learning initiative and high self-consciousness, no matter what type of course, can achieve the best results under the teacher's careful guidance.	Neutral
	I think both are ok. Because students with solid learning initiative and high self-consciousness, no matter what type of course, can achieve the best results under the teacher's careful guidance.	Neutral
	I hope that the teacher will combine these two methods.	Neutral
	The combination of online live teaching and offline active learning is more innovative. It has advantages and disadvantages.	Approved
	Combining online live teaching and offline active learning can meet our learning needs.	Approved
	Online live teaching is convenient for students to watch videos that they don't understand.	Approved
2	This course is challenging for me, and the teacher speaks very quickly.	Critical
	There is too much work to be done after class.	Critical
	The effect of online teaching is not ideal.	Critical
	This course regrets that it has always been online classes.	Critical

6 Conclusion

Pre-service mathematics teachers have significantly improved their mathematical problem-solving ability, and the online live teaching of mathematical methodology courses are practical. Pre-service mathematics teachers have positive and negative attitudes towards online live teaching mode. Among them, more people believe that the teaching model can be improved. They prefer the combination of online teaching and offline teaching, and they hope to communicate face to face with teachers in the classroom. The advantages of online live education are that it can save resources, be played back, and help students develop the habit of active learning. The disadvantage is that the teaching progress is too fast, students cannot discuss issues with teachers face to face, and they do not get timely feedback. Studies have pointed out that the interaction between students and online live teaching should be encouraged [27]. It is a pity that the teaching method adopted in this research ignores this point. The future of online live education should fully consider the multi-dimensionality of online interaction in technology and the teaching process. In addition, teaching knowledge and educational psychology knowledge in online teaching is very important for teachers, which is currently lacking [28]. The future curriculum design and implementation should pay attention to teaching and psychology knowledge.

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8 References

[1] F. Martin, T. Sun, and C. D. Westine, "Computers & Education A systematic review of research on online teaching and learning from 2009 to 2018," Comput. Educ., vol. 159, no. April, p. 104009, 2020. https://doi.org/10.1016/j.compedu.2020.104009

[2] M. Kurni and S. K, "Applying Collaborative Learning for Enhancing the Teaching-Learning Process in Online Learning through Social Media," *Int. J. Emerg. Technol. Learn.*, vol. 16, no. 16, p. 251, 2021. https://doi.org/10.3991/ijet.v16i16.23207

[3] R. M. Cutri, J. Mena, and E. F. Whiting, "Faculty readiness for online crisis teaching: transitioning to online teaching during the COVID-19 pandemic," Eur. J. Teach. Educ., vol. 43, no. 4, pp. 523–541, Aug. 2020. https://doi.org/10.1080/02619768.2020.1815702

[4] M. Sabin and B. Higgs, "Teaching and Learning in Live Online Classrooms," in Proceedings of the 8th ACM SIGITE Conference on Information Technology Education, 2007, pp. 41–48. https://doi.org/10.1145/1324302.1324314

[5] C. Zhao, H. Li, Z. Jiang and Z. Xiong, "Learners' Appeal: An Analysis of Teachers' Behavior in Online Live Teaching," 2017 International Symposium on Educational Technology (ISET), 2017, pp. 44-47. https://doi.org/10.1109/ISET.2017.18

[6] J. Liu, "Construction of real-time interactive mode-based online course live broadcast teaching platform for physical training," Int. J. Emerg. Technol. Learn., vol. 13, no. 6, pp. 73–85, 2018. https://doi.org/10.3991/ijet.v13i06.8583

[7] Q. Yu, L. Liu, Q. Tang, and W. Wu, "Online teaching- present situation and its future: a survey of online study for medical students during the COVID-19 epidemic," Irish Educ. Stud., vol. 40, no. 2, pp. 207–215, 2021. https://doi.org/10.1080/03323315.2021.1916557
[8] N. L. Davis, M. Gough, and L. L. Taylor, "Online teaching: advantages, obstacles and tools for getting it right," J. Teach. Travel Tour., vol. 19, no. 3, pp. 256–263, 2019. https://doi.org/10.1080/15313220.2019.1612313
[9] W. Zhang, "Exploration and Practice of online teaching mode of operating system course," J. Phys. Conf. Ser., vol. 1634, no. 1, 2020. https://doi.org/10.1088/1742-6596/1634/1/012079
[10] X. Kang and W. Zhang, "An experimental case study on forum-based online teaching to improve student's engagement and motivation in higher education," Interact. Learn. Environ., Sep. 2020. https://doi.org/10.1080/10494820.2020.1817758
[11] S. Grono, Y. Masters, and S. Gregory, PST Online: Preparing pre-service teachers for teaching in virtual schools. 2015.
[12] S. Lutovac, "Pre-service mathematics teachers' narrated failure: Stories of resilience," Int. J. Educ. Res., vol. 98, pp. 237–244, 2019, doi: https://doi.org/10.1016/j.ijer.2019.09.006
[13] C. Paolucci, "Changing perspectives: Examining the potential for advanced mathematical studies to influence pre-service teachers' beliefs about mathematics," Teach. Teach. Educ., vol. 49, pp. 97–107, 2015, doi: https://doi.org/10.1016/j.tate.2015.03.002
[14] D. L. Beers and E. M. Davidson, "A learning community for pre-service elementary teachers: A collaboration between mathematics and education," Primus, vol. 19, no. 6, pp. 519–540, 2009. https://doi.org/10.1080/10511970802067574
[15] A. M. Hodge, "The design and benefits of a teaching Seminar for pre-service secondary mathematics teachers," Primus, vol. 21, no. 3, pp. 263–273, 2011. https://doi.org/10.1080/10511970903008949
[16] P. Jiang and B. Xiong, "Analyze the Quality of Math Kangaroo Problems with a Content Analysis," J. Phys. Conf. Ser., vol. 1875, no. 1, p. 2021, 2021. https://doi.org/10.1088/1742-6596/1875/1/012015
[17] G. Polya, Mathematical Discovery. On Understanding, Learning and Teaching Problem Solving. Combined Edition, New York: John Wiley & Sons, 1981.
[18] Z. B. Özdoğan, E. Seyitoğlu, and B. Güven, "The change over the years of problem solving skills of pre-service elementary mathematics teachers," Procedia - Soc. Behav. Sci., vol. 15, pp. 2278–2283, 2011, doi: https://doi.org/10.1016/j.sbspro.2011.04.093
[19] D. Lee, "Teaching statistics online to prepare educators for evidence-based practice," J. Educ. Teach., vol. 46, no. 3, pp. 424–429, 2020. https://doi.org/10.1080/02607476.2020.1766303
[20] A. Badia, C. Garcia, and J. Meneses, "Approaches to teaching online : Exploring factors influencing teachers in a fully online university," vol. 48, no. 6, pp. 1193–1208, 2017. https://doi.org/10.1111/bjet.12475
[21] S. I. Lei and A. S. I. So, "Online Teaching and Learning Experiences During the COVID-19 Pandemic–A Comparison of Teacher and Student Perceptions," J. Hosp. Tour. Educ., vol. 33, no. 3, pp. 148–162, 2021. https://doi.org/10.1080/10963758.2021.1907196
[22] R. Scherer, S. K. Howard, J. Tondeur, and F. Siddiq, "Profiling teachers' readiness for online teaching and learning in higher education: Who's ready?," Comput. Human Behav., vol. 118, no. October 2020, p. 106675, 2021. https://doi.org/10.1016/j.chb.2020.106675
[23] J. Zheng, "Analysis of Online Teaching Mode and Effect of Computer Network under Large-Scale Users," Int. J. Emerg. Technol. Learn., vol. 15, no. 20, pp. 182–193, 2020. https://doi.org/10.3991/ijet.v15i20.17423

[24] M. Daumiller, R. Rinas, J. Hein, S. Janke, O. Dickhäuser, and M. Dresel, "Shifting from face-to-face to online teaching during COVID-19: The role of university faculty achievement goals for attitudes towards this sudden change, and their relevance for burnout/engagement and student evaluations of teaching quality," Comput. Human Behav., vol. 118, 2021. https://doi.org/10.1016/j.chb.2020.106677
[25] Y. Mu and W. Yang, "A Teaching Experiment on a Knowledge-Network-Based Online Translation Learning Platform BT - Emerging Technologies for Education," 2020, pp. 319–328. https://doi.org/10.1007/978-3-030-38778-5_35
[26] X. Li, "Computer-Supported Teaching Experiment of Sports Social Sciences BT - Frontier Computing," 2020, pp. 1532–1538. https://doi.org/10.1007/978-981-15-3250-4_200
[27] Y. Ming et al., "Computers & Education Comparative analysis of Student ' s live online learning readiness during the coronavirus (COVID-19) pandemic in the higher education sector," vol. 168, no. March, 2021. https://doi.org/10.1016/j.compedu.2021.104211
[28] C. Paper, "Challenges of Implementing Online Teaching in Universities during Covid-19 Global Pandemic : A Developing Country' s Perspective," vol. 7, no. 11, pp. 675–683, 2020.

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The Emergence of the Emergency in Higher Education in Argentina

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Abstract—The context of COVID-19 has deeply penetrated various aspects of university life such as academic and administrative management; teaching practices and learning have been challenged, shaken and, in some way, transformed. This article will describe an ongoing study of trends in relation to the inclusion of technologies; the representations about online teaching itself, before and during the COVID-19 emergency, and also a projection into the post-COVID and the implications for student's achievements before and during the emergency. A comparison will be made between the data obtained from these two Argentinean universities and the information published by the IAU Global Survey Report [1] in order to develop a broader map about the challenges ahead for Higher Education (HE). Besides, the article will include some inquiries about whether post-pandemic pedagogical practices will change according to teachers' own views. Based on the results of the survey, we have delved into a qualitative study that focuses on changes in teaching and assessment practices in HE that allow us to extract from the voices of practicing professors with many years of experience, possible scenarios that account for transformations in teaching practices and ways of learning for the next few years. The empirical statistical survey carried out on more than 400 professors and the in-depth qualitative study offer results that are enlightening to review, in addition, management, training and relationship decisions with the student body for the coming years.

Keywords—COVID-19, higher education, learning technologies

1 Introduction

The "network society" [2] [3] constitutes the contextual framework within which both the scope of education technology as a field and the reasons for including technologies in education must be reviewed. On the one hand, information and communication technologies are expanding and are part of central activities in society including the economy, research, and social movements. On the other hand, they are starting to support the emergence of a cognitive ecology that interpellates the literate culture, including not only the forms of specialized knowledge but also the social and cultural trends in which young people have central participation and which demand a review of teaching practices [4] [5] [6] [7] [8] [9].

In the last few years, many reports have studied trends observed in practices impacted by technology in educational settings, explicitly stating the learning possibilities offered by information and communication technologies in higher education. These reports highlight the extended opportunities for continuous, active, personalized and rhizomatic learning [10], game-based learning and the culture of doing [11], story and event-based learning [12] and dynamic and incidental learning [13]. A prospective study addressing the challenges faced by European educational policies for the 2020 horizon, based on experts' opinions, indicated that as a result of the evolution of the information and communication technologies, constructive and student-centered pedagogies will become trends, and personalized learning as well as individual coaching will be more common, with a focus on generic, cross-cutting and intersectoral skills [14]. Moreover, based on a systematization work of the most relevant prospective studies, [15] conclude that the challenges mentioned for higher education are notably recurrent and that knowing the trends makes sense only if political action is taken in order to change the orientation of initial and continuous teacher training programs. In this sense, there are several studies which have been creating analytical categories about technology-mediated education (face-to-face and online). This study specifically explores the situation arisen as a result of the pandemic in relation to online education.

The UNESCO IESALC estimates show that the temporary closure affects approximately 23.4 million higher education students and 1.4 million teachers in Latin America and the Caribbean; this represents approximately more than 98% of the region's population of higher education students and teachers [16].

According to a survey developed by the OECD about E-Learning in Higher Education in Latin America, before the COVID-19 pandemic face-to-face education was still highly prevalent being the predominant model in 65% of the universities, compared to 16% with a predominant hybrid model and 19% centered on e-learning. Particularly, in Argentina, virtual education is still at the early stages of development. However, there is a considerable number of virtual education programs in Argentina. One case worth highlighting is the Universidad Tecnologica Nacional (UTN), which provides the entire university community with access to a range of ICT resources through its UTN Virtual platform. The UTN also has a Global Virtual Campus platform, a pilot project it set up in 2007 to provide access to seminars and virtual classrooms which supplement subjects taught using face-to-face learning at the university's various sites [17].

Other very important and long-standing distance learning program is the one developed by the Universidad de Buenos Aires (UBA) with the denomination UBA XXI. The UBA XXI university admission program was created in 1986 and is taught completely online. In other words, it has been in place for over 30 years and takes on approximately 100,000 students every year. In its beginning, it was a Distance Education Program which included booklets, radio, and TV programs. From 2008, it added a virtual environment for teaching all the required university entrance courses.

2 About the universities involved in this study

The Universidad de Buenos Aires (UBA) has 13 Schools, around 30,000 teachers and over 400,000 students. It is one of the best ranked Universities in South America and it was created in 1821. It is located in the Autonomous City of Buenos Aires and its Schools and Rectorate are distributed among various neighborhoods. It is run by governing bodies made up of representatives chosen through a democratic voting system divided by areas (Faculty members, Graduates, Students and Non-faculty staff). Each of the 13 Schools has their own governing body (Governing Council, composed of teachers, graduates, students and non-faculty staff) to make decisions. In addition, each department chair is free to make didactic and curricular decisions at their discretion as long as they are in line with institutional guidelines. As a result, there is a variety of curricular and didactic approaches considering each institutional context and each teacher in particular.

The Universidad Tecnologica Nacional (UTN) is a Higher Education Institution exclusively devoted to STEM education and, in that field, it is the most important university in Argentina. It was created in 1948 and currently has 30 regional schools across the Argentine Republic, with approximately 11,000 professors and 85,000 students. In addition, it is the only federal university and that feature results in each school having its own strong identity, related to the region where they are located. Like the UBA, and all state-run public universities in Argentina, it is governed by a democratic system of government with representatives from all sectors of the university community both for running the University and each of its schools.

3 About the study

The data and information collected in this study are relevant since they provide the viewpoint of teacher colleagues from two institutions renowned not only in Argentina but also in the region and, in addition, they show the perspectives from various disciplines and different regions across the country. Although other surveys have been conducted about the impact of the pandemic on Higher Education[1,2], most of them collect data from private and/or very small universities, a fact that might lead to important biases in the results due to the very specific features of such institutions. This study comprises more than 400 individuals from 8 different provinces and, since it uses a quantitative as well as a qualitative methodology, it yields results which, in our view, provide a description which is quite close to the reality currently faced by Argentine universities and what might be expected in the near future.

This work is part of a research conducted in 10 universities from different countries in three different continents (North and South America, Europe, and Asia). The study described in this article was carried out in two phases, a quantitative one, in which a

[1] https://www.untref.edu.ar/mundountref/encuesta-coronavirus-comunidad-untref-afectada

[2] http://noticias.unsam.edu.ar/2020/06/10/resultados-preliminares-de-la-encuesta-sobre-ensenanza-y-aprendizaje-en-tiempos-de-cuarentena/

survey was distributed among approximately 450 university professors of both institutions, and a qualitative one, in which 20 teachers (10 from each university) were interviewed in depth.

The survey was divided into three parts. In each of them, the participants were asked about teaching before, during and after the Corona-Related Teaching Situation (CRTS), respectively. The survey included a total of 27 questions, inquiring into the use of technology tools in lessons, the extent to which teaching has been enriched by the use of such tools, the reasons for not using them, perceptions about the teaching experience and changes in teaching practices, the institutional support received in terms of training, students' achievements (any changes compared to face-to-face lessons), the types of tools used (synchronic meetings; virtual environments) and their relation with teaching, and the possible impact on teaching after the CRTS, among other questions.

In the in-depth interviews, the focus was placed on the interviewees' personal opinions about the possible transformations in terms of conceptions of teaching and didactic strategies used, during the CRTS and in the future. Questions were asked about the context, the teaching practice, the impact of distance education on teaching practices, institutional perspectives, and expectations about the future return to normal classroom activities.

Seventy percent of the participants from UBA are full-time teachers while most of the participants from UTN are part-time teachers (63% of then work less than 12 h a week). In both institutions, the age of the participants mainly ranged between 46 and 65, with more than 18 years of teaching experience at the university.

They characterize themselves as very good to excellent teachers (46.9% at UBA and 35.3% at UTN) or good (43% at UBA and 54% at UTN), that is, they have a highly positive self-perception as university professors.

4 About the results

4.1 Most popular strategies and tools

One prominent trend observed is that before the CRTS, the use of technology tools by teachers ranged from very little to moderate (74% on average in both institutions). As a result of the Preventive and Compulsory Social Isolation (in Spanish, ASPO), they were able to review the strategies and tools used and now consider that technologies enrich their teaching practice (Figure 1). This shows a change in the representation about the value of technology tools for university teaching. It is true that the context forced them to use tools such as synchronous videoconferencing and virtual environments. For this reason, the most commonly used tools are synchronous videoconferencing tools, YouTube videos or videos created by faculty members, and the use of virtual environments to upload materials and various activities.

These results are in complete accordance with those obtained through a survey developed by the International Association of Universities showing that "at almost all HEIs, COVID-19 affected teaching and learning, with two-thirds of them reporting that classroom teaching has been replaced by distance teaching and learning. The shift from face-to-face to distance teaching did not come without challenges, the main ones being access to technical infrastructure, competences and pedagogies for distance learning and the requirements of specific fields of study. At the same time, the forced move to distance teaching and learning offers important opportunities to propose more flexible learning possibilities, explore blended or hybrid learning and to mix synchronous learning with asynchronous learning [1].

Furthermore, according to the results of the study described in this article, most professors point out that they feel capable of including digital tools as long as they receive proper training, since they state they lack pedagogic experience in relation to them (67.4% at UBA and 83% at UTN). The institutional contexts are different, but the trend indicates a lack of training in the use of technology for university teaching.

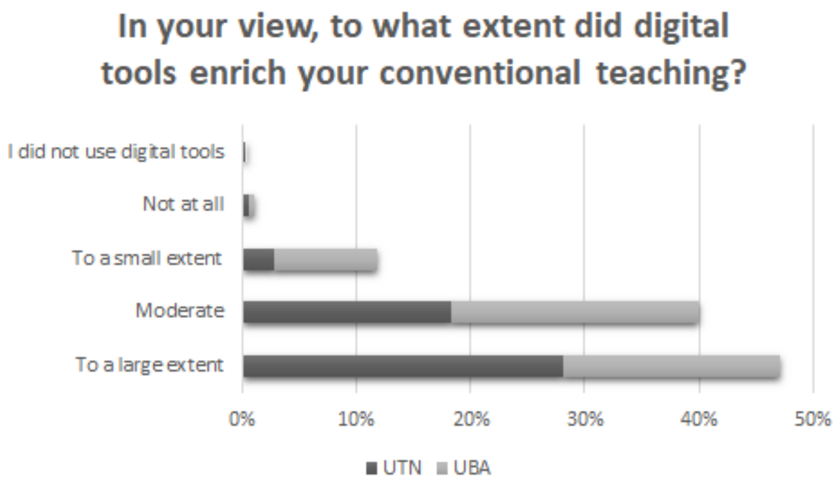

Fig. 1. About teaching with digital tools

In a regional study conducted by the IDB and the Monterrey Institute of Technology between February and March 2020, more than 800 university teachers were surveyed about the penetration of digital technologies in universities. According to the results of such study, 90% of the teachers considers that digital technologies are useful for improving learning processes. However, there are important challenges for the adoption thereof [18].

In teachers' words:

"We have to teach online, there is no choice. So, I have to look for the best tool which will not only allow me to do so but also be easy for students to use, especially if they are not familiar with it."

"I think I was able to rediscover the usefulness of the virtual campus or, actually, to enhance the use I make of it. Also, I incorporated resources such as videos and H5Ps that definitely help students understand certain contents and now I wonder: why didn't I incorporate them before? ... I think this pandemic is an opportunity to take advantage of the flexibilization of certain points of view, which have seen the usefulness of such tools."

"The positive side of this situation is that it forced us to use digital tools we already had but didn't devote the necessary time to learn about. The campus, for example, is an excellent tool that we were using very little and now is our main tool. This special situation compelled us to take a huge step in a very necessary area, considering that students use digital tools more and more every day, thus bridging that real gap in the use of technology."

4.2 Vision for change in teaching practices during and after the CRTS

Perceptions about technology tools and changes in teaching. The survey reveals that the transformation experience towards technology-mediated practices is regarded as a positive experience by 63.5% of the teachers and that 80% of them believe that their new experience with the use of digital tools will affect their pedagogic practice (Figure 2). In addition, they think that this experience has helped them to be prepared for future similar situations (62%). This implies that there is a vision for change in the pedagogic practices for the learning experience, but there are not any certainties that these changes will be reflected in higher education teaching practices in the future. This is something that will have to be studied in the coming years, verifying what has been learned and how this will affect future practices.

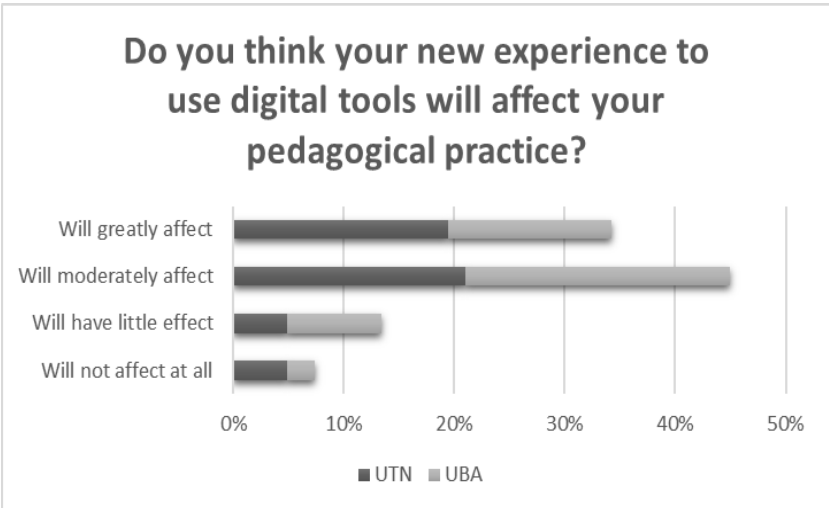

Fig. 2. About pedagogical practice

These results are in line with the situation observed in other countries, as shown by a survey recently conducted by the EDUCAUSE organization, which clearly indicates that most teachers agreed on the fact that they are now more prepared to teach online than before the pandemic and that online education in their institutions has improved considerably [19].

On the other hand, a trend is observed which shows that it has been a complex experience that required time, support, and teacher commitment.

In those disciplines oriented to professional practice, a point is recurrently made in relation to the difficulty regarding transfer to professional practice. Teachers, particularly in the areas of health and design, stress that there is practical knowledge which cannot be transmitted through digital technologies and pose a question as to which are the most valuable technology tools to articulate with practical knowledge (simulations? virtual reality?) Similar comments were made by technology teachers in relation to laboratory practices.

In teachers' words:

"It has been a complex experience, it requires more dedication than I expected, but it has been positive and inspirational. It demands much more dedication from the teacher, but it is very useful for those students who work and cannot attend lectures. In courses where practice is required, that laboratory practice part will remain pending because students need to acquire the abilities and behavioral content related to the laboratory setting."

"The class I teach is experimental and it focuses on students' work in the laboratory (drug manufacturing) (…) this was not a choice we had but a situation to which we had to adapt, although a good one, since we learned a lot from it."

"Of course, the essential practical learning that we will have to offer when we return to face-to-face teaching is lacking work in the laboratory, visits to industrial plants, etc."

"It is very complex to work remotely in design courses."

According to the information collected, there seems to be a certain difference regarding the type of discipline in question ...

In this sense, some distinctions are visualized in relation to the disciplinary fields and the implemented strategies that will have to be addressed in more detail in future studies.

Regarding the impact in the future, all the answers suggest that there will be a before and after as regards the way in which higher education will develop (Figures 3 and 4).

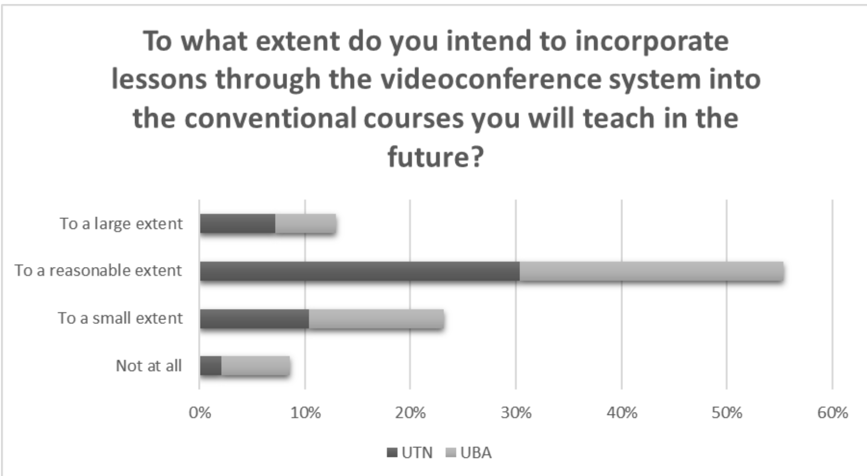

Fig. 3. About the future 1

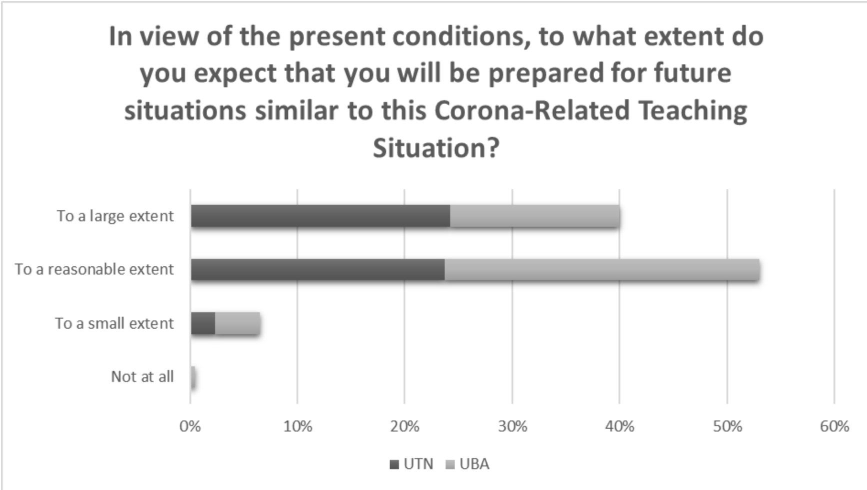

Fig. 4. About the future 2

When teachers were asked about the possibility of their courses becoming virtual in the future, the responses were not as categorical (Figure 5), but they show a trend that is much higher than what would have been if the consultation had been carried out before the experiences they are going through this year.

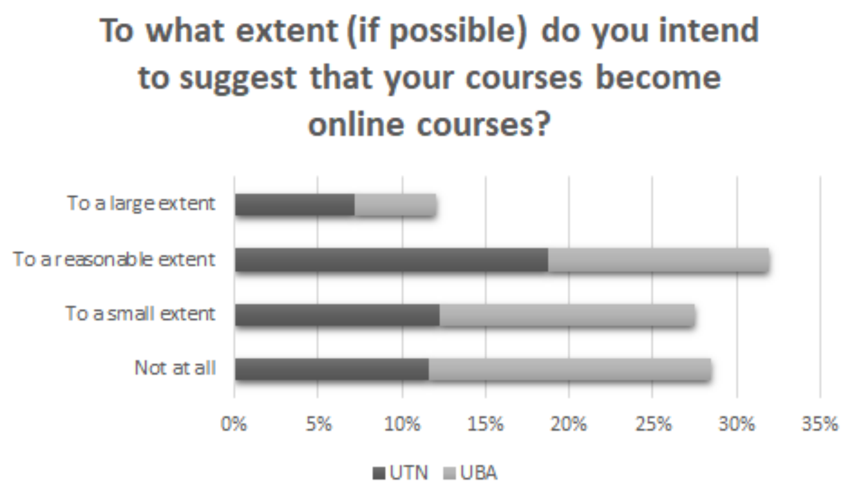

Fig. 5. About the future 3

Feelings. On the one hand, there is also a certain lack of knowledge in the use of these tools because there was no need to use them (prior to the CRTS).

In teachers' words:

“In the past, I did not use digital tools mainly due to unawareness and lack of familiarity with them. In addition, in most of the courses I participated, there was little encouragement to use digital tools."

“I used to teach face-to-face. I used - and considered - remote tools mainly as a complement, not as the core of a teaching system.”

"There was no tradition in the discipline, the use of technologies was not the rule."

On the other hand, there are feelings of ambivalence and stress:

“It is an ambivalent experience. On the one hand, it is a positive one since it was possible to establish contact with the students, creating a space for support and communication, but it has also generated frustration. A lot of work has been done creating content and planning it, knowing a priori that no resource is good or bad in itself but that it depends largely on how it is used. On the other hand, in the CBC (Common Basic Cycle), the virtual campus was not friendly in the beginning thus generating much back-and-forth communication with the students. To this, we had to add teaching with Zoom, which at times becomes complicated, from the technological aspect (Internet cuts out within minutes of starting classes) to the operational one: one speaks to a shared PowerPoint presentation or in the best of cases to a "small square" because many students disable the video."

Regarding feelings, there is variability in the responses:

"I lack personal contact with the students and being able to observe if they are understanding."

"I'm tired. The preparation of material in new formats and the acquisition of new habits, simultaneously with the permanent cohabitation with my family, means a great effort."

"I cannot yet define my feelings; they will depend on the result at the end of the course."

In summary, it could be said that the feelings expressed by teachers are a mixture of stress and overexertion largely generated by the unforeseen situation they had to face without adequate preparation and, on the other hand, the positive and encouraging experience of having been able to guarantee, to a lesser or greater extent, the continuity of the courses during the CRTS, discovering tools and methodologies in that process which, a priori, were alien or strange to them.

4.3 Strengths and weaknesses of distance education

In the case of the Universidad de Buenos Aires, the surveys reveal a critical look at institutional decisions. The same is not the case in UTN, in which 85.7% of those interviewed assure that the University is, to a large extent or to a moderate degree, prepared for a similar future crisis situation (Figure 6). This difference could be due to the fact that UTN began the conversion to virtual mode almost immediately after the quarantine started, which forced education institutions to close, while the UBA, on the other hand, took a few months to start that process.

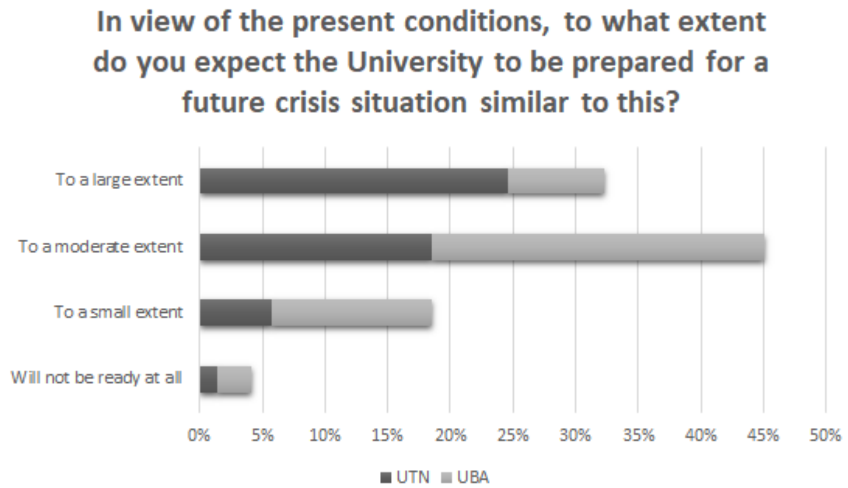

Fig. 6. About the future 4

On the other hand, they recuperate the specificity of online teaching and the challenges involved in teaching with technological mediation.

In teachers' words:

"The material, technical or environmental conditions are not suitable to do it. There is also practical knowledge that cannot be transmitted by ICTs."

"It is an opportunity to approach teaching in another way, perhaps face-to-face and online, a good resource to complement teaching and maintain a more personal interaction with the student."

"It is a greater effort because we did not have the materials ready. Furthermore, it is not feasible to teach some content online and it is impossible to organize any field trips; both things require to be completely redesigned in very little time."

"The impact of the experience in the future will depend on the possibility of reducing the demand for face-to-face lessons; otherwise it will be an overload for the students."

Regarding students' performance, the opinion is divided between higher and lower performance in comparison with face-to-face lessons. This ambivalence and duality may be due to the diversity of strategies implemented…

Those who assess their success in this transformation point out that it is due to the pedagogical support of their reference institution and not to their own technological skills.

5 Qualitative study

The qualitative study was carried out two months after the quantitative study was completed and five months after the ASPO began. The qualitative study provides a deeper insight into what was revealed in the quantitative study. In general terms, a feeling of exhaustion is perceived in relation to online tasks, follow up requirements and the design of materials in online teaching.

5.1 Context

Of a total of ten interviewees, in the case of UTN, one half belongs to the Department of Basic Sciences courses and the other to the engineering courses. Those belonging to the engineering courses Departments carry out activities in their profession outside the university. In the case of UBA, they are professors who work in different disciplinary fields.

Those who do not have an undergraduate degree in teaching have taken various teacher training courses during their professional career. In the case of UBA, the CITEP (Center for Innovation in Technology and Pedagogy) offers training in distance education and educational technology to the entire faculty of the University.

In teacher's words: *"Never has a course been more appropriate (speaking about a teacher training course developed in the second semester of 2019). If someone had told me that I would need to apply the tools that we worked on last year in such a vertiginous way, I would have asked them to stop fantasizing, and said that we must give time to time, but reality prevailed. It's been quite an experience."*

5.2 About the teaching practice

All interviewees responded that they consider themselves good teachers and justify their statement based both on the results of the student surveys and on their permanent professional updating.

With regard to the ways of teaching in this new context, all the interviewees use videoconferences via Meet or Zoom and complement their online lessons with other technological tools.

5.3 About the impact of distance education on teaching practices

In the case of the UTN, the teachers interviewed did not feel very affected in the new context because all of them had previously begun to use various technology tools in their lessons. Some highlighted that they feel satisfied with the recognition and appreciation that their previous practices acquire in this new context. In the case of UBA, there are variations in the responses, and these depended on the institutional support of each academic unit.

Although none of the interviewees stated having had much trouble with this new teaching method, some pointed out that their environment (family, children, lack of comforts at home, etc.) affected them and some suffer from severe muscle stiffness due to excessive use of the notebook.

UBA teachers agree on the fact that it has been a year in which they simplified the tasks because they did not manage to carry out proper student follow up. In this sense, unlike previous years, they incorporated self-assessment questionnaires and consultation forums.

On the other hand, they mention certain stress and fatigue, a day-to-day job, in which they had to resort to creativity and organization which they lacked in the department.

There were several examples of good practices, and the frustrations mainly had to do with the fact that the tool used (Moodle classroom, mathematical software, etc.) did not respond to their planning as well as they had expected and, in some cases, that the students did not respond, as planned by the teachers, to their various pedagogical proposals. In many cases, annoyance was manifested by the teachers due to the impossibility or refusal of the students to turn on their cameras. In other cases, there were difficulties in the organization of synchronous meetings due to the number of classes that the students have daily.

5.4 Institutional perspective

In the case of UTN, the interviewees highlighted the importance of the implementation of various online courses in the institutions to facilitate the use of new resources. Some point out that they felt a bit lonely and that they waited for the Department or Chair authorities to write to them individually to find out how their practices were developing and if they needed anything. On the contrary, in the case of UBA, we found that there was a disparity regarding institutional support, and this influenced remote work.

Regarding the question referring to whether they felt that they were able to work freely, some answered affirmatively and valued this circumstance, while others claimed that they wished that the Department Chair would have established the form of evaluation rather than leaving the decision on evaluation modality to the teachers.

5.5 Return to classroom activities

All those interviewed agree that the return to classroom activities will be a mix between online and face-to-face teaching and that this change will be promoted by both teachers and authorities and will also be driven by the students themselves.

This situation is presented, however, as an uncertainty and a redefinition of what "the new normality" will be like.

6 Conclusions and debates

The title of this work refers to the "Emergence of Emergency" since, in effect, the health emergency led, in the educational system, to the emergence of practices that had remained latent for a long time. Such is the case of the massive use of available technological resources and, fundamentally, of the development of teaching and learning modalities that until now had not been considered, especially in the field of Higher Education. The way in which the educational system has faced this emergency would not have been possible just a few decades ago because the technologies that available today simply did not exist. Clearly, what is still necessary, if not essential, is teacher training in the proper use of these technologies and, furthermore, improvements in terms of connectivity and availability of hardware resources for both students and teachers.

6.1 What are the changes brought about by the pandemic to higher education according to this study?

On the one hand, from the quantitative study, we can conclude that the use of technologies increased compared to what had been used before COVID 19. That is, the context forced the use of synchronous tools and virtual environments. At this point, we found that the support of the University was important for the feasibility of good practices through teacher training. In those cases, in which they were able to access tools and training, teachers recognized that they were able to carry out their task better. Moreover, we found that there was a high degree of adaptability despite not having chosen this modality. In addition, we found that many teachers consider that they have managed to improve their lessons with the inclusion of technologies and generated other bonds with their students. Finally, there is a recognition of diverse good practices according to each professional field. In the case of academic fields that require a high load of professional practice, working online has been more complex.

6.2 What are the changes that could occur in the future after the emergency is over?

It is difficult to determine whether the incorporation of technologies will remain as a learning experience in the coming years. The truth is that there is agreement on the need for a mixed modality that includes online and face-to-face teaching in its planning and didactic deployment. However, from the answers obtained, it is estimated that, in future lessons, virtuality will be present in the use of some tools that teachers have considered extremely useful: use of virtual environments; synchronous meetings to explain some topics; individualized follow up of students. As Manuel Castells expressed in a recent interview [3],, "the hybrid university is already the rule. Accepting that reality is a matter of time. The forced learning experience in this pandemic allows us to take a leap forward in the new pedagogical model".

It can be concluded then, following Franceso Tonucci[4], that "… the confinement shows "even more" that the school, as we know it today, is not effective. The crisis is rapidly approaching a different future in education."

We deeply believe that this emergency we are facing will facilitate, if properly managed, the emergence of the new educational system that the 21st century society has been demanding for a long time.

7 Note

This work is part of a wider and cross-cultural study on university teachers coping with a challenging situation, "The transition from conventional teaching to online

[3] https://www.publico.es/entrevistas/castells-hay-listos-establecer-ensenanza-evaluaciones-online-completo.html

[4] https://elpais.com/sociedad/2020-04-11/francesco-tonucci-no-perdamos-este-tiempo-precioso-dando-deberes.html

teaching: Organizational and pedagogical issues". The initiators of this study are Prof. G. Horenczyk and Dr. M. Dorfsman (Hebrew University, Israel); Dr. C. Lion (Universidad de Buenos Aires, Argentina); Prof. K. Göbel (Universität Duisburg-Essen, Germany); Prof. E. Makarova (Universität Basel, Switzerland); Dr. D. Birman (Miami University, USA).

8 References

[1] G. Marinoni, H. van't Land y T. Jense, «The Impact of COVID-19 on Higher Education Around the World,» International Association of Universities, Paris, 2020.
[2] M. Castells, La galaxia Internet, Barcelona: Areté, 2001.
[3] M. Castells, Comunicación y poder, Madrid: Alianza, 2009.
[4] R. Craig, College disrupted: the great unbundling of higher education, New York: Palgrave Macmillan Trade, 2015.
[5] M. Petit, Nuevos acercamientos a los jóvenes y la lectura, Mexico: Fondo de Cultura Económica, 1999.
[6] A. Piscitelli, El paréntesis de Gutenberg, La religión digital en la era de las pantallas ubicuas, Buenos Aires: Santillana, 2011.
[7] J. A. Cordón García, J. López Lucas, R. Gómez Díaz y J. Alonso Arévalo, Las nuevas fuentes de información. Información y búsqueda documental en el contexto de la web 2.0, Madrid: Pirámide, 2010.
[8] M. Serres, Pulgarcita, Buenos Aires: Fondo de Cultura Económica, 2012.
[9] M. Barbero, Cultura y nuevas mediaciones tecnológicas, Mexico: Fondo de Cultura Económica, 2014.
[10] M. Sharples, P. McAndrew, M. Weller, R. Ferguson, E. FitzGerald, T. Hirst, Y. Mor, M. Gaved y D. Whitelock, «Innovating Pedagogy 2012: Open University Innovation Report 1,» The Open University, Milton Keynes, 2012.
[11] M. Sharples, P. McAndrew, M. Weller, R. Ferguson, E. FitzGerald, T. Hirst, Y. Mor, M. Gaved y D. Whitelock, «Innovating Pedagogy 2013: Open University Innovation Report 2,» The Open University, Milton Keynes, 2013.
[12] M. Sharples, P. McAndrew, M. Weller, R. Ferguson, M. Gaved, D. Whitelock y A. Adams, «Innovating Pedagogy 2014: Open University Innovation Report 3,» The Open University, Milton Keynes, 2014.
[13] M. Sharples, A. Adams, P. McAndrew, M. Weller, R. Ferguson, M. Gaved y D. Whitelock, «Innovating Pedagogy 2015: Open University Innovation Report 4,» The Open University, Milton Keynes, 2015.
[14] C. Redecker, M. Leis, M. Leendertse, G. Gijsbers, Y. Punie, P. Kirschner, S. Stoyanov y B. Hoogveld, «The Future of Learning: New Ways to Learn New Skills for Future Jobs. Results from an online expert consultation,» Publications Office of the European Union, Luxembourg, 2010.
[15] B. Gros y I. Noguera, «Los sistemas de anotaciones como apoyo al aprendizaje colaborativo en entornos virtuales,» de *Entornos virtuales de aprendizaje: nuevas perspectivas de estudio e investigaciones*, Mendoza, Virtual Argentina, 2013, pp. 267-292.
[16] IESALC, «COVID-19 and higher education: Impact analysis, policy responses and recommendations,» 9 April 2020. [En línea]. Available: http://www.iesalc.unesco.org/en/wp-content/uploads/2020/04/COVID-19-EN-090420-2.pdf [Último acceso: 20 October 2020].
[17] OECD, «E-Learning in Higher Education in Latin America,» OECD Publishing, Paris, 2015.
[18] E. Arias, J. Escamilla, A. López y L. Peña, «Observatorio de Innovación Educativa del Tec de Monterrey,» 29 June 2020. [En línea]. Available: https://observatorio.tec.mx/edu-news/

encuesta-preparacion-digital-docentes-universitarios-america-latina [Último acceso: 20 October 2020].
[19] M. McCormack, «Educause Review,» 18 September 2020. [En línea]. Available: https://er.educause.edu/blogs/2020/9/educause-quickpoll-results-fall-readiness-for-teaching-and-learning [Último acceso: 20 October 2020].
[20] C. Hodges, S. Moore, B. Lockee, T. Trust y A. Bond, «EDUCAUSE,» 27 March 2020. [En línea]. Available: https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning [Último acceso: 20 October 2020].
[21] UNESCO International Institute for Higher Education in Latin America and the Caribbean, «COVID-19 and higher education: Today and tomorrow,» IESALC, Caracas, 2020.

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Evaluation and Measurement of Student Satisfaction with Online Learning Under Integration of Teaching Resources

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Abstract—The effective organization and integration of educational resources can solve the information confusion in online learning, and assist online teaching platforms in recommending multisource personalized learning resources. After the integration of teaching resources, the student satisfaction with online learning should be evaluated, setting the stage for the management and application of teaching resources, as well as the improvement of online teaching quality. Therefore, this paper evaluates and measures student satisfaction with online learning under the integration of teaching resources. Specifically, the name and descriptive features of the Japanese teaching resource library were extracted by the linguistic model, the class structure features and relationship attribute features of the library were learned by graph convolutional neural network (GCNN), and the corresponding eigenvectors were obtained. Next, the similarity of different features was calculated, the teaching resources were sorted, and the matching resources were selected, completing resource integration. After feature integration, the student satisfaction with online learning was evaluated, and a structural equation model (SEM) was established for the student satisfaction with online learning under the integration of teaching resources. The effectiveness of our model was proved through experiments.

Keywords—integration of teaching resources, online learning, learning satisfaction

1 Introduction

With the boom of education information technology, educational resources are shifting gradually from offline to online [1-5]. Due to online teaching activities, a huge amount of disorderly, scattered online educational resources have accumulated, resulting in information overload [6-8]. To solve the information confusion in online learning, it is necessary to clarify the distribution and form of educational resources, and organize and integrate educational resources effectively. This would also assist online teaching platforms in recommending multisource personalized learning resources [9-11], and provide a good way information organization for enhancing the correlations between educational resources [12-15]. The integration of teaching resources can effectively improve the utilization efficiency of online educational resources. After the integration of teaching resources, the student satisfaction with online learning should be evaluated, setting the stage for the management and application of teaching resources, as well as the improvement of online teaching quality [16-19].

With the development of science and technology, multimedia auxiliary teaching is increasingly important in practical teaching. The integration between multimedia technology and teaching is not only needed by current teaching, but also a demand by education development and reform. Lin [20] explored the integration of multimedia resources in college English teaching from the angle of artificial intelligence (AI). Firstly, the teaching features in the context of AI were analyzed, and the AI applications in college teaching were summarized. The traditional integration technology for online educational resources has errors in assessing educational resources, because it overlooks the variance contribution rate of online educational resource features. Zhao [21] proposed an online educational resource integration technology based on the scheduling of distance teaching information. According to the theory on the scheduling of distance teaching information, the value of online educational resource integration was quantified. In the era of the big data, the informatization of college English education calls for a simulated learning environment supported by massive information resources, which provides students with information and the chance of language practices. After analyzing the relevant concepts, Luo [22] expounded on the new problems of college English teaching in the background of big data, and presented strategies for integrating and optimizing the information resources of college English teaching in the context of big data, with the aim to enhance the efficiency and effect of college English education. Yuen et al. [23] put forward a growth model for belief and utilization to capture the dynamic changes in the belief and utilization of learning management system, and measure the influence of these changes over the system satisfaction. Their model adopts three longitudinal survey datasets, which cover random samples with different academic abilities from 25 junior high schools in Hong Kong. Chen et al. [24] extensively analyzed a large dataset containing more than 15,000 tutorial dialogs, which were generated by human tutors and students in the counseling services based on mobile apps. The dataset was analyzed to identify the factors related to student satisfaction in the online counseling system.

There are several problems with the research paradigm for the evaluation of student satisfaction with online learning: the satisfaction model is built by unscientific methods, the model is not widely applicable or highly adaptive, the students' self-expression and individualized development are often neglected, and the variation in student satisfaction with online learning after the integration of teaching resources is not fully considered. Taking Japanese teaching for example, this paper evaluates and measures student satisfaction with online learning under the integration of teaching resources. The main contents are as follows: (1) The linguistic model was adopted to extract the name and descriptive features of the Japanese teaching resource library, and trained iteratively to obtain the corresponding eigenvectors. (2) The graph convolutional neural network (GCNN) was employed to learn the class structure features and relationship attribute features of the library, and further acquire the corresponding eigenvectors. (3) The similarity of different features was calculated for Japanese teaching resources before sorting the resources, and the matching resources were selected to complete resource integration. (4) The student satisfaction with online learning was evaluated after integrating the features of Japanese teaching resources, and a structural equation model (SEM) was established for the student satisfaction with online learning under the integration of Japanese teaching resources. The effectiveness of our model was proved through experiments.

2 Feature extraction and integration

2.1 Feature extraction

In this paper, the term library refers to a database of various kinds of Japanese teaching resources. It mainly consists of the name, description, class, relationship, relationship attribute, and volume of Japanese teaching resources. The integration of teaching resources is premised on the matching between teaching resources. The purpose is to find the correlations of new teaching resources, according to the node information and correlations of the existing online teaching resources, and then match the teaching resources.

This paper firstly acquires the necessary information like the name, description, class, relationship, and volume from the Japanese teaching resources to be integrated. The acquired text information characterizes the relationship between teaching resources, and stores the class, relationship attribute, and volume of teaching resources in the teaching resource network. Then, multiple eigenvectors of the teaching resources were obtained, and the similarity between features was solved. After that, the weights corresponding to the similarity of different features of teaching resources were calculated by the learning to rank (LTR) algorithm. Finally, the teaching resources were integrated, and the similarity ranking and resource matching of the target teaching resources were obtained. In this paper, the linguistic model is adopted to extract the names and descriptive features of Japanese teaching resource library, and iterative model training was carried out to generate the corresponding eigenvectors. The name and descriptive feature extraction model is illustrated in Figure 1, where r is a teaching resource, and BI is the name and descriptive text of that resource.

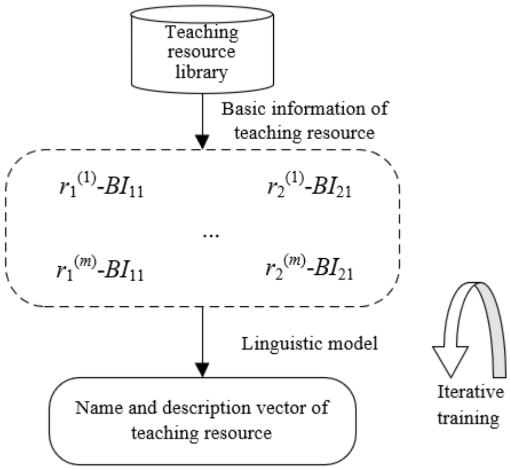

Fig. 1. The name and descriptive feature extraction model

This paper employs the GCNN to learn the class structure features and relationship attribute features of Japanese teaching resource library, and further derives the corresponding eigenvectors.

Figure 2 shows the class structure feature extraction model for teaching resources. During the acquisition of class-based structural feature, it is assumed that the connections between teaching resources are directional. In the teaching resource network, the diversity of relationship increases with the number of resource classes. When two teaching resources are connected to another teaching resource via different relationships, there will be a difference between the matching probabilities of the two teaching resources. Let HE be the number of initial teaching resources belonging to relationship s; TA be the number of final teaching resources belonging to relationship s; TR be the total number of resources belonging to relationship s. Then, two independent functions can be established to characterize the importance of each relationship:

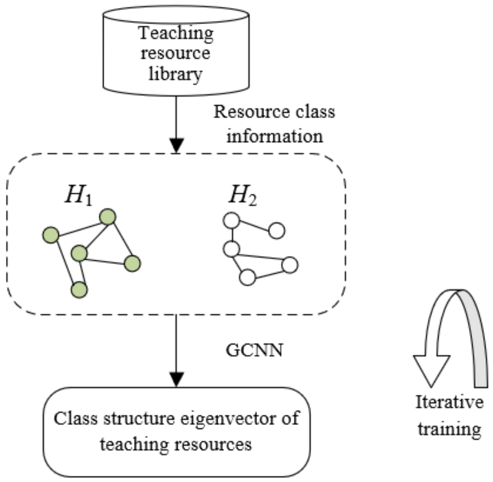

Fig. 2. Class structure feature extraction model

$$FU(s)=\frac{HE}{TR} \tag{1}$$

$$IF(s)=\frac{TA}{TR} \tag{2}$$

Under relationship s, two teaching resources r_i and r_j can be expressed as two triples $<r_i, s, r_j>$ and $<r_j, s, r_i>$, respectively. Let x_{ij} be the influence of the i-th teaching resource over the j-th teaching resource. Then, the relationship matrix X can be established as:

$$x_{ij}=\sum_{\langle r_i,s,r_j\rangle} IF(s)+\sum_{\langle r_j,s,r_i\rangle} FU(s) \tag{3}$$

Figure 3 shows the relationship attribute feature extraction model for teaching resources. During the acquisition of relationship attribute feature, it is assumed that the connections between teaching resources are non-directional. The relationship attributes of different teaching resources play different roles in the matching between teaching resources. To match teaching resources with a specific relationship attribute, this paper establishes a function to characterize the importance of the relationship attribute. Let x be a relationship attribute of a teaching resource r; RPV be the relationship attribute corresponding to attribute x of r. Then, we have:

$$Q(\beta,VA)=\frac{1}{\left|\left\{r:x(r,RPV)\right\}\right|} \tag{4}$$

A local weight needs to be assigned to any relationship attribute of the acquired teaching resource. Let y_{ij} be an element in the adjacency matrix Y, which represents the degree of correlation between the i-th teaching resource and the j-th attribute. Then, the discriminability of teaching resources by each relationship attribute in the teaching resource network can be calculated by:

$$y_{ij} = \frac{1}{\left|\left\{r_i : y_j\left(r_i, RPV\right)\right\}\right|} \tag{5}$$

The loss functions of the GCNN training model are defined as follows: The eigenvectors obtained by GCNN learning of two teaching resource networks correspond to two different spaces. To optimize the representation of eigenvectors, the model must be trained by the matched teaching resources. On this basis, the loss functions can be defined as formulas (5)-(7).

Based on a pair E of known teaching resources, the initial or final resource was replaced with a random resource, producing the set of negative samples E'. Let $u_{re}(r_1)$ and $u_{rx}(r_1)$ be the class structure eigenvector and relationship attribute eigenvector of teaching resource r_1, respectively; t_{re} and t_{rx} be the edge parameters of the samples matched with positive and negative teaching resources, respectively. Then, the loss functions for the class structure feature training and relationship attribute training can be respectively expressed as:

$$K_{re} = \sum_{(r_1,r_2)\in E} \sum_{(r'_1,r'_2)\in E'} \left(g\left(u_{re}\left(r_1\right), u_{re}\left(r_2\right)\right) - g\left(u_{re}\left(r'_1\right), u_{re}\left(r'_2\right)\right) + t_{re}\right) \tag{6}$$

$$K_{rx} = \sum_{(r_1,r_2)\in E} \sum_{(r'_1,r'_2)\in E'_{(r_1,r_2)}} \left(g\left(u_{rx}\left(r_1\right), u_{rx}\left(r_2\right)\right) - g\left(u_{rx}\left(r'_1\right), u_{rx}\left(r'_2\right)\right) + t_{rx}\right) \tag{7}$$

The distance between the two vectors can be calculated by:

$$g\left(a, b\right) = \left\|a - b\right\|_{K1} \tag{8}$$

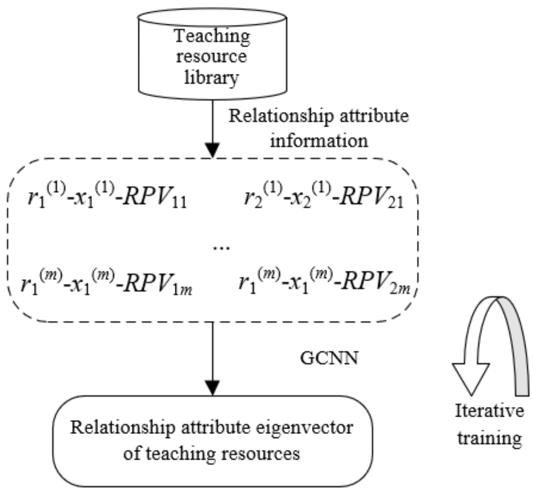

Fig. 3. Relationship attribute feature extraction model

Figure 4 explains the matching and integration steps of teaching resources. For the class structure features and relationship attribute features of teaching resources, this paper adopts cosine similarity to measure the resemblance of eigenvectors between different teaching vectors. In this way, the necessary eigenmatrix of teaching resources can be obtained.

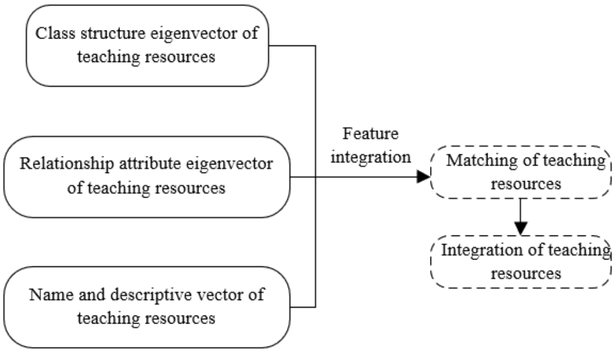

Fig. 4. Matching and integration steps of teaching resources

2.2 Feature integration

For the similarity integration of multiple teaching resource features, the manual assignment of feature weights lacks generalizability, and consumes too much time and efforts. Capable of multifeatured integration, common classifiers like support vector machine (SVM) and Bayesian classifier merely consider the relationship between independent pairs of teaching resources, without taking account of the relationship between teaching resources in a candidate set of teaching resources. Therefore, this paper chooses to compute the similarity of each feature of teaching resources, rank the said teaching resources, and select the matchable resources.

Let r be a teaching resource to be matched; m be the number of teaching resource pairs; c be the number of teaching resource features to be integrated. Then, the input of the LTR algorithm can be viewed as a c-dimensional space vector $u \in R^{m\times c}$. The classifier is constrained by the condition that: the evaluation score of the correct teaching resource containing r should be higher than that of any other teaching resource containing r. Let $g(q, t)$ be the loss function of the weight characterizing the feature to be integrated; θ be the slack variable of a teaching resource; D be the penalty factor; r_1 be the teaching resource to be matched in teaching resource network H_1; r_2 be the teaching resource in teaching resource network H_2, which can be matched with r_1; r_2' be the other candidate resources in teaching resource network H_2 for matching with r_1. Then, the optimization function can be established as:

$$Min: g\left(q,\theta\right)=\frac{1}{2}q*q+D\theta_{r_1,r_2},\tag{9}$$

The corresponding constraint can be expressed as:

$$s.t: q\left(u\left(r_1,r_2\right)-u\left(r_1,r_2'\right)\right)\geq 1-\theta_{r_1,r_2'} \tag{10}$$

$$\theta_{r_1,r_2'}\geq 0 \tag{11}$$

3 Satisfaction evaluation and measurement

Based on multisource online educational resources, this paper extracts the characteristic information and relationships from various kinds of educational resources, and integrates the resources into a resource network. Online learning platforms should collect, analyze, and organize massive educational resources, such that the students can learn all knowledge units of the curriculum system independently and methodically, and select learning resources with a clear purpose. Owing to the fast update of online educational resources, the effective integration of teaching resources provides students with the latest knowledge of the selected disciplines, which improves the experience and satisfaction of online learning.

This paper evaluates the online learning satisfaction after the integration of teaching resources. Figure 5 shows the student satisfaction evaluation and measurement model after the integration of teaching resources. Six variables were selected for the evaluation, namely, diversity of teaching resources, innovativeness of teaching resources, novelty of teaching resources, selectivity of teaching resources, quality of teaching resources, and gap between learning effect and ideal level. Based on the selected variables, the authors built up the SEM for student satisfaction with online learning, facing the integration of teaching resources.

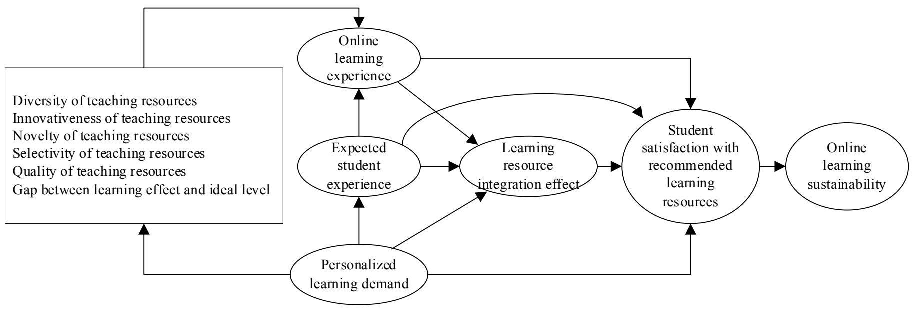

Fig. 5. Student satisfaction evaluation and measurement model after the integration of teaching resources

The exponent of evaluation index refers to the score of a student against an evaluation index. The exponent value reflects the student satisfaction with that index. There are two exponents of student satisfaction index: latent variable exponent and explicit variable exponent. Let λ be the overall score of exogenous latent variables; μ_i be the loading coefficient corresponding to these variables; a_{1i} be the mean of the latent variables; u_σ be the overall score of students given for the σ-th endogenous latent variable;

σ be the σ-th endogenous latent variable; $\xi_{\sigma i}$ be the loading coefficient corresponding to the σ-th endogenous latent variable; $b_{\sigma i}$ be the explicit variable corresponding to $t\sigma$ endogenous latent variables; l be the number of explicit variables corresponding to endogenous variables. The latent variable of an evaluation index can be calculated by:

$$\lambda = \sum_{i=1}^{l} \mu_i a_{1i}, u_\sigma = \sum_{i=1}^{l} \xi_{\sigma i} b_{\sigma i} \tag{12}$$

Let QH_η and QH_α be the exponents of exogenous and endogenous latent variables, respectively; $R[\lambda]$ and $R[u_\sigma]$ be the mean overall scores of exogenous and endogenous latent variables, respectively; $min[\lambda]$ and $min[u_\sigma]$ be the minimum overall scores of exogenous and endogenous latent variables, respectively; $max[\lambda]$ and $max[u_\sigma]$ be the maximum overall scores of exogenous and endogenous latent variables, respectively. The variable exponents can be calculated by:

$$\begin{aligned} QH_\eta &= \frac{R[\lambda] - min[\lambda]}{max[\lambda] - min[\lambda]} \times 100 \\ QH_\alpha &= \frac{R[u_\sigma] - min[u_\sigma]}{max[u_\sigma] - min[u_\sigma]} \times 100 \end{aligned} \tag{13}$$

$min[\lambda]$ and $max[\lambda]$ can be calculated by:

$$min[\lambda] = \sum_{i=1}^{l} \mu_i min(a_{1i}), max[\lambda] = \sum_{i=1}^{l} \mu_i max(a_{1i}) \tag{14}$$

$min[u_\sigma]$ and $max[u_\sigma]$ calculated by:

$$min[u_\sigma] = \sum_{i=1}^{l} \xi_{\sigma i} min(b_{\sigma i}), max[u_\sigma] = \sum_{i=1}^{l} \xi_{\sigma i} max(a_{\sigma i}) \tag{15}$$

The exponents of exogenous and endogenous latent variables can be simplified as:

$$\begin{aligned} QH_\eta &= \frac{\sum_{i=1}^{l} \mu_i A_{1i} - \sum_{i=1}^{l} \mu_i}{4\sum_{i=1}^{l} \mu_i} \times 100 \\ QH_\alpha &= \frac{\sum_{i=1}^{l} \xi_{\sigma i} b_{\sigma i} - \sum_{i=1}^{l} \xi_{\sigma i}}{4\sum_{i=1}^{l} \xi_{\sigma i}} \times 100 \end{aligned} \tag{16}$$

Let a_{1i} be the i-th exogenous explicit variable; μ_i be the loading coefficient corresponding to the exogenous explicit variable; $b_{\sigma i}$ be the i-th explicit variable corresponding to the σ-th endogenous latent variable; $\xi_{\sigma i}$ be the loading coefficient corresponding to the endogenous latent variable. Then, the explicit variable exponents can be calculated by:

$$QH_{a_{1i}} = \frac{\mu_i a_{1i} - \mu_i}{4\mu_i} \times 100$$
$$QH_{b_{\sigma i}} = \frac{\xi_{\sigma i} b_{\sigma i} - \xi_{\sigma i}}{4\xi_{\sigma i}} \times 100 \quad (16)$$

4 Experiments and results analysis

Table 1 presents the reliability test results on student satisfaction indices after the integration of teaching resources. The reliability was tested by Cronbach's alpha and split-half reliability. It can be seen that the reliability coefficients of all factors, including diversity of teaching resources, innovativeness of teaching resources, novelty of teaching resources, selectivity of teaching resources, quality of teaching resources, and gap between learning effect and ideal level, were greater than 0.82. Thus, the proposed evaluation index system is reliable enough for further analysis.

Table 2 displays the total variance explained by the measurement and evaluation system for student satisfaction after the integration of teaching resources. The initial eigenvalues of the six indices were 36.185, 8.192, 8.374, 5.629, 3.281, and 2.936, all of which was greater than 1. In addition, after the integration of teaching resources, the six indices of the measurement and evaluation system cumulatively explained 68.419% of the total variance. The percentage was greater than 60%, the threshold for scientific education and teaching. Therefore, after the integration of teaching resources, the measurement and evaluation system for student satisfaction has an overall good explanatory power of the relevant data.

Table 1. Reliability test results on student satisfaction indices after the integration of teaching resources

Variable	Cronbach's alpha	Split-half reliability
Diversity of teaching resources	0.917	0.935
Innovativeness of teaching resources	0.973	0.968
Novelty of teaching resources	0.958	0.908
Selectivity of teaching resources	0.961	0.913
Quality of teaching resources	0.829	0.846
Gap between learning effect and ideal level	0.975	0.933

Table 2. Total variance explained by the measurement and evaluation system

Compo-	Initial variance			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	*% of variance*	*Cumulative %*	*Total*	*% of variance*	*Cumulative %*	*Total*	*% of variance*	*Cumulative %*
1	18.246	36.185	34.528	18.158	37.126	38.415	8.629	15.269	13.427
2	4.205	8.192	45.636	4.627	8.936	45.128	7.158	12.085	32.528
3	4.369	8.374	55.907	4.824	8.742	53.629	7.052	10.062	46.057
4	2.741	5.629	56.127	2.618	5.281	58.152	5.139	9.158	55.169
5	2.306	3.281	63.174	2.041	3.905	62.157	2.751	4.329	57.421
6	1.846	2.936	68.419	1.294	2.738	67.362	1.862	3.749	68.293

This paper adopts two datasets of teaching resources, none of which contain many long-tail resources. Table 3 shows the statistical features of the two teaching resources datasets. To verify its effectiveness, our feature extraction algorithm was compared with four classic entity matching algorithms, including TransH (1), TransR (2), TransD (3), and TransSpare (4). The performance was measured by the percentage of the matchable resources whose ranking is no greater than 1, the percentage of the matchable resources whose ranking is no greater than 10, and the reciprocal of mean ranking.

As shown in Table 4, the traditional entity matching algorithms are limited. Our algorithm fully utilizes the name and description feature, class structure feature, and relationship attribute feature of teaching resources, and carries out weighted fusion between the three kinds of features. Then, the linguistic model and GCNN are adopted to enhance the matching and integration effects of teaching resources through iterative training. That is why our algorithm outperformed the traditional entity matching algorithms in all three performance metrics.

Table 3. Statistical features of the integrated teaching resources datasets

Dataset	Number of resources	Class structure	Class structure triple	Relationship attribute	Relationship attribute triple
1	16025	261	36298	352	72153
	14528	153	42153	664	152456
2	13629	224	35084	332	68592
	16284	36	33291	214	23157

Table 4. Experimental results on different datasets

Algorithm	Dataset 1			Dataset 2		
	Ranking ≤ 1	***Ranking ≤ 10***	***Reciprocal of mean ranking***	***Ranking ≤ 1***	***Ranking ≤ 10***	***Reciprocal of mean ranking***
Algorithm 1	0.251	0.528	0.336	0.284	0.512	0.361
Algorithm 2	0.294	0.562	0.384	0.249	0.574	0.382
Algorithm 3	0.236	0.597	0.352	0.277	0.539	0.348
Algorithm 4	0.148	0.301	0.241	0.183	0.427	0.281
Our algorithm	0.816	0.864	0.862	0.926	0.974	0.964

Next, the effectiveness of our iterative model training was verified through an experiment on the prior data percentage, using 10%-90% of known matched teaching resources. The results in Table 5 show that the three performance indices of the linguistic model and GCNN increased continuously, with the rising proportion of prior data. That is, the matching effect of teaching resources became better and better. Therefore, more known matched teaching resources help the proposed model acquire the features of teaching resources, which in turn improves the matching effect of teaching resources.

Table 5. Test results on the effectiveness of iterative model training

Prior data proportion		10%	20%	30%	40%	50%	60%	70%	80%	90%
Linguistic model	Ranking≤1	0.728	0.715	0.762	0.784	0.815	0.843	0.859	0.805	0.926
	Ranking≤10	0.802	0.836	0.847	0.869	0.937	0.963	0.918	0.985	0.973
	Reciprocal of mean ranking	0.862	0.892	0.815	0.847	0.836	0.829	0.861	0.842	0.869
GCNN	Ranking≤1	0.715	0.769	0.825	0.862	0.819	0.847	0.836	0.829	0.872
	Ranking≤10	0.862	0.816	0.872	0.884	0.895	0.952	0.961	0.968	0.974
	Reciprocal of mean ranking	0.813	0.828	0.809	0.836	0.817	0.829	0.816	0.889	0.861

Table 6 compares the satisfaction of students in different grades for each evaluation index. It can be seen that the student learning satisfaction with diversity of teaching resources, innovativeness of teaching resources, novelty of teaching resources, selectivity of teaching resources, quality of teaching resources, and gap between learning effect and ideal level was higher among grade 1 and grade 2 students than that among grade 3 and grade 4 students. On the selectivity of teaching contents, the difference between the satisfaction of students in different grades widened with the F-score.

Table 6. Satisfaction of students in different grades with each evaluation index

Index	Grade	Mean	Standard deviation	F-score	Significance
Diversity of teaching resources	Grade 1	2.5	1.30258	4.85	0.025
	Grade 2	2.4853	0.91842		
	Grade 3	1.8517	0.74851		
	Grade 4	1.962	1.26359		
Innovativeness of teaching resources	Grade 1	2.748	0.68521	4.97	0.026
	Grade 2	2.3628	0.91847		
	Grade 3	1.7482	0.74812		
	Grade 4	1.92	1.06258		
Novelty of teaching resources	Grade 1	2.6851	0.91847	4.58	0.036
	Grade 2	2.36248	0.96285		
	Grade 3	1.8459	0.75182		
	Grade 4	1.748	0.81547		
Selectivity of teaching resources	Grade 1	2.8	1.30625	6.35	0.028
	Grade 2	2.3262	0.91487		
	Grade 3	1.8459	0.62854		
	Grade 4	1.6258	0.92847		
Quality of teaching resources	Grade 1	2.215	0.5774	5.12	0.025
	Grade 2	2.625	0.68451		
	Grade 3	1.589	0.59748		
	Grade 4	1.516	1.0594		
Gap between learning effect and ideal level	Grade 1	2.544	1.3542	4.65	0.019
	Grade 2	2.3691	0.9644		
	Grade 3	1.6482	0.7587		
	Grade 4	1.5614	1.2455		

5 Conclusions

This paper mainly explores the evaluation and measurement of student satisfaction with online learning under the integration of teaching resources. Based on the linguistic model, the authors extracted the name and descriptive features of the Japanese teaching resource library. Then, the GCNN was adopted to learn the class structure features and relationship attribute features of the library. The corresponding eigenvectors were further obtained. Next, the similarity of each kind of features was computed, and the teaching resources were thus ranked. The matchable resources were then selected to complete resource integration. After integrating the features of teaching resources, the authors evaluated the student satisfaction with online learning, and built an SEM for student satisfaction with online learning, facing the integration of teaching resources. Through experiments, the reliability of the evaluation and measurement indices for student satisfaction was tested after the integration of teaching resources. The total variance explained by the evaluation and measurement system was obtained, revealing that the measurement and evaluation system for student satisfaction has an overall good explanatory power of the relevant data. Further, the proposed feature extraction algorithm was proved effective through experiments on different datasets. In addition, the effectiveness of our iterative model training was verified through an experiment on the prior data percentage, using 10%-90% of known matched teaching resources. The results show that our algorithm outperformed the traditional entity matching algorithms in all three performance metrics. Finally, the authors compared the satisfaction of students in different grades for each evaluation index.

6 References

[1] Álvarez, R., Vergara, D. (2022). Natural resources and educational attainment: Evidence from Chile. Resources Policy, 76: 102573. https://doi.org/10.1016/j.resourpol.2022.102573

[2] Wang, J., Tigelaar, D.E., Admiraal, W. (2019). Connecting rural schools to quality education: Rural teachers' use of digital educational resources. Computers in Human Behavior, 101: 68-76. https://doi.org/10.1016/j.chb.2019.07.009

[3] Grami, G.M. (2020). An Evaluation of Online and Automated English Writing Assistants: Collocations and Idioms Checkers, International Journal of Emerging Technologies in Learning,15(4): 218-226. https://doi.org/10.3991/ijet.v15i04.11782

[4] Hua, S.Y., Ren, Z.W. (2020). "Online + Offline" Course Teaching Based on Case Teaching Method: A Case Study of Entrepreneurship Education Course, International Journal of Emerging Technologies in Learning,15(10): 69-85. https://doi.org/10.3991/ijet.v15i10.13999

[5] Zhou, N., Zhang, Z.F., Li, J. (2020). Analysis on course scores of learners of online teaching platforms based on data mining. Ingénierie des Systèmes d'Information, 25(5): 609-617. https://doi.org/10.18280/isi.250508

[6] Sun, Z., Wang, K., Li, Z. (2019). Construction of educational resources and design of learning activities in facilitating museum education. In 2019 International Joint Conference on Information, Media and Engineering (IJCIME), 414-418. https://doi.org/10.1109/IJCIME49369.2019.00090

[7] Wijayati, P.H., Kharis, M., Hidayat, E., Ardiyani, D.K., Ebner, M., Schön, S. (2022). Teaching German as a foreign language with open educational resources (OER): Implementation in and experiences from an Indonesian university. International Journal of Emerging Technologies in Learning, 17(4): 225-238. https://doi.org/10.3991/ijet.v17i04.23225
[8] Li, S.L., Chai, H.Q. (2021). Recognition of teaching features and behaviors in online open courses based on image processing. Traitement du Signal, 38(1): 55-164. https://doi.org/10.18280/ts.380116
[9] Wen, J., Wei, X.C., He, T., Zhang, S.S. (2020). Regression analysis on the influencing factors of the acceptance of online education platform among college students. Ingénierie des Systèmes d'Information, 25(5): 595-600. https://doi.org/10.18280/isi.250506
[10] Jackson, D.M. (2017). Establishing an instructor YouTube channel as an open educational resource (OER) supplementing general and organic chemistry courses. In Teaching and the Internet: The Application of Web Apps, Networking, and Online Tech for Chemistry Education, 115-135. https://doi.org/10.1021/bk-2017-1270.ch007
[11] Liu, Y., Yang, H., Sun, G.X., Bin, S. (2020). Collaborative filtering recommendation algorithm based on multi-relationship social network. Ingénierie des Systèmes d'Information, 25(3): 359-364. https://doi.org/10.18280/isi.250310
[12] Escudeiro, N., Escudeiro, P., Remenyi, D.B.E. (2009). Organizing web educational resources according to specific user needs. In 8th European Conference on e-Learning, 189-195.
[13] Encheva, S.B., Tumin, S. (2005). Sharing protected web resources among independent educational organizations. In IICAI, 2505-2520.
[14] Kirpotin, S., Cheglokov, E., Moskvitina, N., Letuvninkas, A. (2001). About the necessity of organizing the regionalacademical educational and informational analytical centre for environmentaleducation and natural resources management. In 5th Korea-Russia International Symposium on Science and Technology. Proceedings. KORUS 2001, 2: 117-120. https://doi.org/10.1109/KORUS.2001.975198
[15] Sun, G., Cui, T., Beydoun, G., Chen, S., Xu, D., Shen, J. (2017). Organizing online computation for adaptive micro open education resource recommendation. In International Conference on Web-Based Learning, 177-182. https://doi.org/10.1007/978-3-319-66733-1_19
[16] Conrad, C., Deng, Q., Caron, I., Shkurska, O., Skerrett, P., Sundararajan, B. (2022). How student perceptions about online learning difficulty influenced their satisfaction during Canada's Covid-19 response. British Journal of Educational Technology, 53(3): 534-557. https://doi.org/10.1111/bjet.13206
[17] Alkhateeb, M.A., Abdalla, R.A. (2021). Factors influencing student satisfaction towards using learning management system moodle. International Journal of Information and Communication Technology Education (IJICTE), 17(1): 138-153. https://doi.org/10.4018/IJICTE.2021010109
[18] Amalita, N., Fitria, D. (2021). Analysis of student's satisfaction to academic service in FMIPA universitas negeri Padang. In Journal of Physics: Conference Series, 1742(1): 012008. https://doi.org/10.1088/1742-6596/1742/1/012008
[19] Kazim, I., Janjua, U.I. (2021). Factors influencing student satisfaction in distance learning environment: A systematic literature review. In 2021 4th International Conference on Computing & Information Sciences (ICCIS), 1-5. https://doi.org/10.1109/ICCIS54243.2021.9676373
[20] Lin, R. (2021). Integration of university foreign language teaching and multimedia resources in artificial intelligence vision. In 2021 4th International Conference on Information Systems

and Computer Aided Education, 1214-1217. https://doi.org/10.1145/3482632.3483117
[21] Zhao, K. (2021). A novel method for integration of online educational resources via teaching information remote scheduling. Mathematical Problems in Engineering, 2021: 4553872. https://doi.org/10.1155/2021/4553872
[22] Luo, G. (2020). Integration and optimization of college English teaching information resources in the context of big data. In International Conference on Machine Learning and Big Data Analytics for IoT Security and Privacy, 264-270. https://doi.org/10.1007/978-3-030-62743-0_37
[23] Yuen, A.H., Cheng, M., Chan, F.H. (2019). Student satisfaction with learning management systems: A growth model of belief and use. British Journal of Educational Technology, 50(5): 2520-2535. https://doi.org/10.1111/bjet.12830
[24] Chen, G., Ferreira, R., Lang, D., Gasevic, D. (2019). Predictors of student satisfaction: a large-scale study of human-human online tutorial dialogues. International Educational Data Mining Society, 19-28.

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Effectiveness of Collaborative Constructivist Strategies to Minimize Gaps in Students' Understanding of Biological Concepts

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Abstract—This study aimed to test how the collaborative constructivist learning strategies can reduce the gap in students' understanding of biological concepts, compared to Novick's constructivist strategies, and student team achievement divisions (STAD) collaborative strategies. Six classes of tenth graders consisted of 12 upper and lower academic students each were randomly placed into three learning strategy treatment groups: Collaborative constructivist, Novick's constructivist, and STAD. Students were given essay to tests their biological concepts understanding before and after treatment. The difference in students' understanding and the gaps in understanding between UA and LA students were analyzed. The results showed no difference in students' understanding if treated with Novick's and collaborative constructivist. Differences in students' understanding were found in the treatment of STAD. Students' understanding was higher if treated with collaborative constructivist and Novick's constructivist than STAD. Collaborative constructivist strategies can reduce the gap in students' understanding and optimize gain in students' understanding to the other two strategies.

Keywords—conceptual understanding, constructivist, collaborative

1 Introduction

Bibliographic studies showed many studies have examined the effectiveness of Biology learning strategies on students' conceptual understanding. But only a small number of them focused on how to minimize the gap in understanding between upper academic students (UA) and lower-academic students (LA) [1]. Many studies showed various learning strategies affect students' understanding. But when observed, they were always distributed in a normal curve consisting of students with high, medium, and low conceptual understanding based on variations in students' academic abilities[2]–[4]. Learning strategies do not necessarily reduce the gaps in students' conceptual understanding [1], [5]. Innovative biology learning strategies that can improve students' conceptual understanding and reducing the gap in students' conceptual understanding are needed.

Understanding the concepts is one goal of learning [6]. Conceptual understanding is the ability to re-explain what has been learned [7]. Indicators of concept understanding include the ability to restate the learned concepts, evaluate concept attributes, apply concepts, present concepts, and elaborate on various concepts [6], [8]. Students' conceptual understanding can be categorized into four: no understanding (NU), alternative conceptions (AC), partial understanding (PU), and sound understanding (SU). NU is characterized by the absence of answers, no-idea answers, or irrelevant answers. The AC is characterized by the attempt to explain the concept but not following the established scientific conception. The PU is characterized by responses that contain at least one component of scientific conception. The SU is characterized by responses that are entirely following scientific conceptions [8].

Conceptual understanding is the result of a student's active knowledge construction while interacting with the learning environment [9], [10]. Conceptual understanding is also gained from the interaction between the initial schema and knowledge with the new ones [11], [12]. Schema is the mental structure that will adapt to the learning experience [13]. Interaction between the initial schemas with the new ones causes an imbalance in the cognitive structure [14]–[16]. The assimilation and accommodation led to the formation of new schemes [17]. Assimilation is a cognitive process by which old schemes are integrated with new perceptions, concepts, or experiences [14]. Assimilation does not cause schematic changes but develops new schematics [18]. Accommodation forms new scheme or changing the old scheme, due to new experiences or concepts that cannot be assimilated into the old scheme. Accommodation also occurred if new concepts do not match with the old ones [15], [19], [20]. Schemata resulting from assimilation and accommodation are the representation of the conceptual understanding [21].

One of the learning strategies developed from constructivism theory and widely used in classroom learning is Novick's constructivist strategy [15], [22]. It consists of three stages: Stage 1: Exposing alternative framework, creating cognitive conflict, and encouraging cognitive accommodation. Students are activated schematically initially relating to the new knowledge being learned. Stage 2: Students' initial schemes are conflicted with new phenomena and concepts, resulting in schematic imbalances in their cognitive structure. Stage 3: students undertake assimilation and accommodation activities until a new schematic (new concept) is formed on their cognitive structures [15], [22], [23]. Many studies convince the application of Novick's constructivist strategies to influence the understanding of student concepts [22], [23].

Many studies concluded that students' conceptual understanding was correlated with students' stage of cognitive development [16]. Students who have reached the formal operational thinking were easier to understand concepts [10], [24]. Unfortunately, many studies showed that students' biological age does not always align with the ideal stage of cognitive development. Not all students can reach the formal operational thinking stage when they reach adolescence [24]. It can be concluded that this phenomenon causes the gap in conceptual understanding between UA and LA students. Therefore, constructivist learning strategies in the classroom with diverse students' cognitive development may cause a gap in conceptual understanding between UA and LA students.

If students are distributed normally based on their talents, then given the same quality of learning and study time in the classroom, their conceptual understanding will be distributed based on their talents [25]. Talented students (UA students) have a higher conceptual understanding than less talented ones (LA students) [25], [26]. However, many studies concluded that talent is not an index of abilities but rather a measure of learning rate [25], [27]. Students with high talent need a shorter study time to understand concepts than students who have low talent. Students with low talent can understand concepts as high-talented students if given study time as needed [26], [28], [29]. Therefore, to minimize the gap in students' conceptual understanding, study time must be allocated according to the students' needs [25].

The problem is, in Indonesian schools students are distributed based on their biological age, and then they are given the same quality of learning and study time, thus the gaps in students' learning outcomes are inevitable [30] . In addition, some studies concluded that the proper study time allocation does not necessarily improve students' understanding [31], [32]. LA students at some point have learning difficulties that they are unable to complete. Vygotsky calls this the actual zone [20]. To help LA students pass through the actual zone to the proximal development zone, scaffolding from others is needed, such as from teachers and friends who know better [12], [31].

Learning strategies that can facilitate scaffolding well are collaborative-based [33]–[35]. The collaborative learning strategy ensures UA students provide scaffolding to LA students, and they also get scaffolding from teachers [30]. Collaborative strategies can facilitate students to learn according to their time needs [33]. Some research shows that collaborative strategies can reduce the gap in students' understanding between UA and LA students [36]. Our bibliometric study concluded that one of the most widely used collaborative strategies in research is STAD. STAD consists of the following steps: (1) Teacher presentation: teachers explain the concepts that students will learn. (2) Collaborative group discussion: students discuss the assignments in collaborative groups. (3) Class presentation: student groups present their results in class seminars. (4) Individual test: students are given individual tests to measure their mastery of concepts. (5) Team recognition: recognition of student groups for their collaborative work. Some studies concluded that STAD can reduce the gap in students' learning outcomes [32], [37].

Some studies stated that STAD is less constructivist because teachers still position themselves as learning centers and sources of information rather than as facilitators [32]. Learning activities in STAD starts from the transfer of knowledge by teachers followed by discussions on the application of knowledge by students in collaborative groups [32], [37], [38]. This learning is widely assessed by constructivists as less meaningful learning, thus potentially leading to low-level understanding, retention, and students' learning outcomes [13]. Some empirical research corroborates this opinion [32], [38].

To improve students' concept mastery and minimize the gap in students' understanding, collaborative constructivist learning strategies were developed. This strategy was developed based on Piaget's constructivism theory which carries the concepts of schematics, assimilation, and accommodation. It also accommodates Vygotsky's constructivism theory that carries the concept of actual zones, potential zones, proximal development zones, and scaffolding [12], [20]. Collaborative constructivist strategy consists of six stages: (1) Collaborative team formation and learning contracts: students are formed into heterogeneous groups based on academic ability and are explained about the rules of collaborative work. (2) Initial schematic activation: students' initial schemes are activated by teachers, (3) Creation of cognitive conflicts: initial schematics are to be conflicted with the new phenomena and concepts. (4) Concept formation: students construct new concepts in collaborative groups. (5) Class presentation: students present the results of their concept construction in a class seminar. (6) Individual tests and group recognition: students take tests and group recognition. However, whether the collaborative constructivist learning strategies will improve students' understanding and reducing the gap in students' conceptual understanding compared to Novick and STAD will be answered in this research.

Based on the explanations above, the questions to be answered in this study were as follows: (1) Are there any differences in conceptual understanding between students learning using collaborative, constructivist Novick, and STAD strategies? (2) Are there any differences in students' conceptual understanding between UA and LA students? (3) What is the most optimal strategy to improve students' conceptual while reducing the gap in understanding between UA and LA students?

2 Research methodology

2.1 General background

This was a quasi-experiment with a 3 × 2 factorial design. Six classes of tenth graders (12 UA and LA students) were randomly placed into three strategy treatment groups: collaborative constructivist, Novick constructivist, and STAD. The research was conducted at one of the high schools in Karanganyar, Indonesia. The Animalia were concepts to be learned by students. Treatments were carried out in six meetings, 2 × 45 minutes each. Before and after treatment students were given tests to assess their understanding. P-rates and the homogeneous samples were used to control the extraneous variables before and during treatment. Before treatment, partner teachers were trained to implement those learning strategies. Training ensure accuracy and consistency in implementing learning strategies. The design was visualized in Table 1.

Table 1. Factorial design group 3 × 2

Factor B: Students' Academic Ability	Factor A: Learning Strategy		
	Collaborative Constructivist (A1)	***Constructivist Novick (A2)***	***Collaborative STAD (A3)***
Upper Academic (B1)	A1 B1	A2 B1	A3 B1
Lower Academic (B2)	A1 B2	A2 B2	A3 B2

2.2 Participans

The population was all tenth-grade students in one of the high schools in Karanganyar, Indonesia (266 students) distributed in seven classes. Each class contains 38 students. Six classes were randomly assigned to participate in the study. In each class, upper and lower academic students were selected. Students were categorized based on their report grades in the previous semester. Thirty percent of students above and below averages were designated as the sample of UA and LA group respectively. Thus, in each class 12 UA and 12 LA students were selected. Six classes were chosen in this research. Thus, the total participants were 144 students consisting of 72 UA and 72 LA students. All students and teachers have committed their consents.

2.3 Instrument and procedures

Students' conceptual understanding was assessed using an essay test. Indicators of conceptual understanding include the ability to restate concepts, evaluate concept attributes, apply concepts, present concepts, and elaborate between concepts [8]. To maintain logical validity, the rubrics were arranged concerning the topics and concept constructions. The test was equipped with a rubric to maintain objectivity. The validity was tested by three experts who assessed the accuracy of the content and the concept construction. The reliability was measured 0.78 on Cronbach's alpha test (high). Treatment procedures were described as follows.

Collaborative constructivist. Stage 1: Heterogeneous groups were formed based on variations in students' academic abilities. Students were explained that they were assessed for the development of their achievements. Students' achievements were used as the basis for the group ranking. The development of individual achievements was measured from the difference in pretest and post-test. The results were used to determine students' development scores. For example, if the students get a perfect score, then their development score is 30 points, if the student obtains 1–10 points above the initial score then the development score is 15 points. The accumulation of individual development scores becomes the basis for determining the achievements of groups that were categorized as good, great, and super. Stage 2: Students' initial schematic students related to the concepts to be studied were activated. For example, on the sub-topic of Aves, students' initial knowledge of Aves as animals that can fly, beaked, and two-legged. Stage 3: Students' initial schematics were conflicted with new phenomena. For example, students were shown to the various animals such as butterflies, dragonflies, bats as animals that can fly but are not called Aves, cassowaries cannot fly but are called Aves, humans are two-legged but not called Aves, Platypus are beaked but not called Aves. This cognitive conflict triggers imbalances in students' cognitive structures. Stage 4: Students in groups perform concept construction through direct observation, literature studies, and video observations. Stage 5: Students present the results of their construction at class seminars. Stage 6: Tests were conducted to assess students' conceptual understanding and calculate individual developmental scores and groups reward as described in Stage1.

Novick's Constructivist. Stage 1: Students' initial schematics were activated. Stage 2: Cognitive conflicts were initiated. Stage 3: Students in groups construct knowledge by conducting direct observations, literature studies, and video observation, followed by class presentations. Stage 4: Reinforcement and correction. Stage 6: Post-test.

Collaborative STAD. Stage 1: Concepts of the topic to be studied were explained by teachers. Stage 2: Heterogeneous groups were formed based on students' academic ability, and the rules were explained. Students' groups were assigned to discuss problems related to the topic. Stage 3: Students present the results of their discussions in class. Stage 4: Post-test, individual developmental scores were calculated, and group's reward was given.

2.4 Data analysis

Data were analyzed using ANCOVA with pre-test scores as covariate. Before ANCOVA, data normality tests, and variant homogeneity tests were performed. Data normality was tested using Kolmogorov Smirnov test. The results obtained the pre-test data of 0.200 and post-test 0.198 or greater than the α: 0.05; thus the data have a normal distribution. Variant homogeneity was tested using Levene's test. The results obtained the value of 0.254 or greater than α: 0.05 so the variants between data groups were homogeneous. Significance differences in variable average values were tested using the Tukey post-hoc test. Statistical calculations were done with IBM SPSS at a sig. level of 0.05.

3 Research results

ANCOVA was used to test the students' biological concepts understanding based on three treatments of learning strategies and academic ability and their interactions. The results were visualized in Table 2.

Table 2. Influence of strategy, academic, and interaction on understanding of concepts

Source	Sum of Squares	dF	Mean Square	F	Sig.
Corrected Model	1908.328	6	318.055	11.204	.000
Intercept	2349.895	1	2349.895	82.780	.000
Pretest	3.114	1	3.114	.110	.742
Learning strategy	1472.591	2	736.295	25.938	.000
Academic	325.495	1	325.495	11.466	.001
Learning strategy * Academic	96.413	2	48.207	1.698	.191
Error	1845.173	65	28.387		
Total	310906.432	72			
Corrected Total	3753.501	71			

a. R Squared = .508 (Adjusted R Squared = .463)

The results showed that the learning strategy got the sig. value of .000 < α: .050. It was concluded that there was a significant difference in students' understanding due to different treatments in learning strategies. The post-hoc test was also done and visualized in Table 3.

Table 3. Post-hoc tests of differences in students' biological concepts understanding

Learning strategies	Pre-test	Post-test	Δ	Mean	Notations
STAD	25.005	59.234	34.229	59.196	a
Novick's Constructivist	26.414	66.649	40.235	66.739	b
Collaborative-Constructivist	24.955	70.059	45.104	70.009	b

The results showed that students who were treated with collaborative constructivist strategies and Novick constructivists have no significant differences in their conceptual (indicated by notation b). But they have significant differences from students who were given STAD (indicated by notation a). Conceptual understanding treated with Novick's and collaborative constructivist strategies was significantly higher than students who were given STAD (notations a and b).

ANCOVA results also showed that the students' academic ability got the sig. Value of .001 <α: .050. It was concluded that there was a difference in students' biological concepts understanding between UA and LA students. The corrected mean score of UA students was 67.510, higher than LA students' (63.119). The difference in understanding of biological concepts between UA and LA students was visualized in Table 4.

Table 4. Differences in understanding of biological concepts between UA and LA students

Academic Abilities	Pre-test	Post-test	Δ	Corrected Mean
Upper Academic (UA)	26.029	67.457	41.428	67.510
Lower Academic (LA)	24.290	63.173	38.883	63.119

ANCOVA results also showed that the interactions between learning strategies and students' academic ability got sig. Value of .191> α: .005. Thus, there were no interactions between learning strategies and students' academic ability toward students' biological concepts understanding. A post-hoc test was also done and the results were visualized in Table 5.

Table 5. Differences in students' concepts understanding between UA and LA students

Learning strategy	Academic	Pre-test	Post-test	Δ	Mean	Notations
STAD	LA	24.401	57.680	33.279	57.576	a
STAD	UA	25.709	60.793	35.084	60.815	a
Novick's Constructivist	LA	26.362	62.823	36.461	62.907	ab
Collaborative Constructivist	LA	25.912	69,017	43.105	68.874	bc
Novick's Constructivist	UA	26.467	70.476	44.009	70.572	c
Collaborative Constructivist	UA	23,998	71,100	47.102	71.143	c

The results showed no significant differences in students' biological concepts understanding between UA and LA students treated with collaborative constructivist strategy and UA students treated with Novick constructivist strategy (notation c). There were no significant differences in students' biological concepts understanding between LA students treated with collaborative and LA students treated with Novick's Constructivist (notation b). There was a difference in students' biological concepts understanding between UA and LA students treated with Novick's strategy (notation c and b). There was no difference in students' biological concepts understanding between LA students treated with Novick strategy and UA and LA students treated with STAD (notation a). There was a difference in students' biological concepts understanding between UA and LA students treated with collaborative constructivist strategy and AA students treated with Novick's and UA and LA students treated with STAD (notation c and a). There were no differences in students' biological concepts understanding between UA and LA students treated with STAD (notation a).

Table 5 showed that biological concepts of UA and LA students treated with collaborative constructivist strategy and AA students treated with Novick were highest compared to LA students treated with Novick's constructivist and UA and LA students treated with STAD. The lowest gains in concepts understanding were experienced by UA and LA students treated with STAD. These findings showed that: (1) Collaborative constructivist and STAD were proven to minimize the gaps in biological concepts understanding between UA and LA students. (2) Novick's constructivism causes gaps in biological concepts understanding in UA and LA students. (3) Biological concepts understanding of UA and LA students treated with collaborative constructivist strategy and Novick's were higher than the students with STAD. (4) Collaborative constructivist strategies were proven to improve the students' biological concepts understanding, and Novick's constructionist can reduce the gap in students' biological concepts understanding between UA and LA students

4 Discussion

The results showed differences in biological concepts understanding between students who were treated with collaborative constructivist strategies, Novick's constructivists, and STAD. The lowest score in biological concepts understanding was found in students treated with STAD. They were in line with constructivism theory which states the concept should be constructed by students independently [11]. In concept building, students must match the perception and experience of the object studied with their initial schematic in their cognitive structures. If the perception and experience were in line with their initial schematic, then they will assimilate them into their initial schematic into a more developed schematic [11], [16], [39]. If their initial schematics did not correspond to the new perceptions and experiences, then there will be an imbalance in their cognitive structure. Students must decide whether the initial schemata need to be replaced with the new ones or the schematic is maintained by the student. If the initial schematics were to be replaced, then students will gain an understanding of the new concepts [10], [13], [14].

Novick's collaborative and constructivist learning steps were developed by accommodating key concepts in constructivism theory [15], [22]. The teachers position themselves as facilitators that ensure the students' concept construction process runs optimally. Both strategies begin with the activation of the students' initial schematic related to the object studied, then continued with the teachers presenting cognitive conflicts such as new perceptions and experiences that contradict the students' initial schematic. Cognitive imbalances are to be expected to arise. Then, learning activities continued with the construction of new knowledge through assimilation and accommodation by students [15], [23]. Novick's collaborative and constructivist strategies ensure more meaningful learning. Many studies concluded that constructivist-based learning strategies were effective in improving the students' conceptual understanding [13]. In STAD, learning started from the presentation of concepts by teachers, followed by collaborative group discussions. STAD has a lower level of constructivism compared to the other two strategies [1], [32]. STAD views that knowledge can be replicated from the teachers' minds to the students'. On the other hand, many studies convinced teacher-centered learnings were less effective at improving students' conceptual understanding [13].

The results also showed differences in biological concepts understanding between UA and LA students. Variations in students' academic abilities occurred because they were not always a linear correlation between students' biological age of students with their mental ages. Eleven-year-old students or above were not necessarily can think at the formal operations level, even more, students have not reached it [24]. Distributing students in a uniform biological age with diverse cognitive developments resulted in stratifications of students' academic abilities: Upper (UA), Middle (MA), and Lower (LA) academic students [26].

Students' biological concepts understandings were influenced by internal and external factors. Internal factors come from within the student such as talent, perseverance, and cognitive capacity. External factors come from outside such as the quality of teachers and the learning process, and the time allocation given to students [25], [27]. If the student is distributed in a normal curve on their internal factors then given the same treatment on their external factors, then their understanding will follow the normal curve distribution according to their talent [25]. If students were distributed normally in talent, perseverance, the cognitive capacity, then given the same quality of learning and study time, their conceptual understanding will follow the distribution of their talents and will be stratified into UA, MA, and LA. Those explanations confirmed various research findings that significant differences in concepts understanding between UA and LA students were observed.

The results also showed that collaborative constructivist strategies can minimize the gap in students' biological concepts understanding that not present in Novick's constructivist, and can improve students' biological concepts understanding that cannot be found in STAD. The collaborative constructivist learning strategy can improve students' conceptual understanding and reduce the gap between UA and LA students compared to the other two strategies.

Collaborative constructivist strategies such as Novick's constructivist strategies were developed based on constructivism, and have been shown to improve the students' conceptual understanding [11], [40]. This study's findings showed that the understanding of students who were treated with these two strategies was highest than students treated with STAD. UA and LA students who were treated with collaborative constructivist strategies have no significant differences in their conceptual understanding. UA and LA students treated with Novick's have significant differences in their conceptual understanding. These findings indicated that although both strategies are constructivist-based, they have different characters. The collaborative-constructivist strategy was developed by the author by integrating Piaget's constructivism theory and Vigotsky's theory of collaborative learning. Collaborative activities are considered able to minimize the gap in conceptual understanding between UA and LA students. Academic abilities (talent) are not an index of students' abilities but rather a measure of learning rate [25]. UA students take a shorter time than LA students in understanding the same concept. If LA students were given study time as they needed, then they will have the same conceptual understanding as UA students [25], [38]. Collaborative work provides the flexibility of study time according to the diversity of students' time needs. Collaborative work facilitates LA students to go through their actual zone to their proximal development zone with proper scaffolding [18], [33], [41]. Collaborative characters can minimize the gap in conceptual understanding between UA and LA students.

The collaborative-constructivist strategy has both constructivist and collaborative characters so it can improve the students' conceptual understanding and reduce the gap in conceptual understanding between UA and LA students compared to Novick or STAD. Novick's constructivist strategy was developed based on the theory of competitive personal constructivism [38]. Despite working in groups, students will competing to be the best, thus scaffolding does not run optimally. Group formation and group work rules on Novick's constructivist strategy are not as designed to facilitate proper scaffolding as in collaborative-constructivist strategies.

Novick's constructivist strategy does not accommodate students' diverse study time needs and is less able to facilitate students entering their proximal development zone. As the results, study findings suggested that Novick's constructivist strategy resulted in a gap in conceptual understanding between UA and LA students, although overall students' conceptual understanding was no different from collaborative-constructivist strategy.

STAD was developed based on tabula rasa theory and collaborative learning theory [32]. The tabula theory believes that concepts can be replicated from the teachers' minds to the students'. The first phase of STAD was the explanation of concepts by teachers followed by collaborative discussions by students about the issue related to the topics [42]. STAD has considered still as teacher-centered learning [32], [38]. Many studies concluded that teacher-centered learning strategies lead to low students' conceptual understanding [13]. Collaborative character in the STAD can facilitate the diversity of students' learning time needs, and ensure scaffolding runs well so that students can enter their proximal development zone. The study findings showed that STAD resulting the lowest gain in students' biological concepts understanding compared to the other two strategies. But this strategy can reduce the gap in conceptual understanding between UA and LA students.

5 Conclusions and implications

This research provided strong evidence that constructivist-based learning strategies such as Novick's constructivist and collaborative-constructivist strategies were effective in enhancing students' understanding of biological concepts. The study findings showed that there were differences in conceptual understanding between students treated with collaborative-constructivist and Novick strategies compared to students treated with STAD. STAD was considered as a less constructivist learning strategy. The results confirmed that collaborative learning can reduce the gap in conceptual understanding between UA and LA students. Effective scaffolding on collaborative group work can usher LA students into their proximal development zone. The results showed that the collaborative constructivist and STAD can reduce the gap in conceptual understanding between UA and LA students. The results proved that the integration of constructivist and collaborative characters in optimal learning strategies improves the students' conceptual understanding and reduces the gap in conceptual understanding between students. Teachers were advised to combine constructivist strategies with collaborative strategies. Future research should modify competitive constructivist strategies by incorporating potential collaborative characters.

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7 References

[1] B. A. Prayitno and Suciati, "Narrowing the gap of science students' learning outcomes through INSTAD strategy," *New Educ. Rev.*, vol. 50, no. 4, pp. 123–133, 2017. https://doi.org/10.15804/tner.2017.50.4.10

[2] Y. Dan and R. Todd, "Examining the mediating effect of learning strategies on the relationship between students' history interest and achievement," *Educ. Psychol.*, vol. 34, no. 7, pp. 799–817, 2014. https://doi.org/10.1080/01443410.2013.792331

[3] F. Demie, C. McLean, and E. R. and S. U. Lambeth (London, *Narrowing the achievement gap for disadvantaged pupils : good practice in schools*. London: Lambeth, 2018.

[4] Misrahudin, R. Situmorang, H. Muchtar, Y. Dan, and R. Todd, "Examining the mediating effect of learning strategies on the relationship between students' history interest and achievement," *Int. J. Recent Technol. Eng.*, vol. 34, no. 2 Special Issue 9, pp. 799–817, 2014. https://doi.org/10.1080/01443410.2013.792331

[5] N. I. Noviyanti, S. Mahanal, W. R. Mukti, I. D. Yuliskurniawati, S. Zubaidah, and D. Setiawan, "Narrowing the gaps of scientific argumentation skills between the high and low academic achievers," *AIP Conf. Proc.*, vol. 2330, no. March, pp. 1–9, 2021. https://doi.org/10.1063/5.0043308

[6] A. Ayas, H. Özmen, and M. Çalik, "Students' conceptions of the particulate nature of matter at secondary and tertiary level," *Int. J. Sci. Math. Educ.*, vol. 8, no. 1, pp. 165–184, 2010. https://doi.org/10.1007/s10763-009-9167-x
[7] İ. Morgİl and N. Yörük, "Cross-age study of the understanding of some concepts in chemistry subjects in science curriculum," *Turkish Sci. Educ.*, vol. 3, no. 1, pp. 1–15, 2006, [Online]. Available: https://www.tused.org/index.php/tused/article/download/457/393
[8] M. R. Abraham, V. M. Williamson, and S. L. Westbrook, "A cross-age study of the understanding of five chemistry concepts," *J. Res. Sci. Teach.*, vol. 31, no. 2, pp. 147–165, 1994. https://doi.org/10.1002/tea.3660310206
[9] M. Pande and S. V. Bharathi, "Theoretical foundations of design thinking – A constructivism learning approach to design thinking," *Think. Ski. Creat.*, vol. 36, no. October 2019, p. 100637, 2020. https://doi.org/10.1016/j.tsc.2020.100637
[10] T. Stoltz, "Consciousness in Piaget: possibilities of understanding," *Psicol. Reflex. e Crit.*, vol. 31, no. 1, 2018. https://doi.org/10.1186/s41155-018-0110-3
[11] M. Bächtold, "What do students 'construct' according to constructivism in science education?," *Res. Sci. Educ.*, vol. 43, no. 6, pp. 2477–2496, 2013. https://doi.org/10.1007/s11165-013-9369-7
[12] R. Van der Veer, "Vygotsky and Piaget: A collective monologue," *Hum. Dev.*, vol. 39, no. 5, pp. 237–242, 1996. https://doi.org/10.1159/000278473
[13] N. Gunduz and C. Hursen, "Constructivism in teaching and learning: Content analysis evaluation," *Procedia - Soc. Behav. Sci.*, vol. 191, no. 392, pp. 526–533, 2015. https://doi.org/10.1016/j.sbspro.2015.04.640
[14] H. B. Bormanaki and Y. Khoshhal, "The role of equilibration in piaget's theory of cognitive development and its implication for receptive skills: A theoretical study," *J. Lang. Teach. Res.*, vol. 8, no. 5, pp. 996–1005, 2017. https://doi.org/10.17507/jltr.0805.22
[15] J. Nussbaum and S. Novick, "Alternative frameworks, conceptual conflict and accommodation: Toward a principled teaching strategy," *Instr. Sci.*, vol. 11, no. 3, pp. 183–200, 1982. https://doi.org/10.1007/BF00414279
[16] M. Shahsavari, "Jean Piaget's ideas about foundations of education," *Aust. J. Basic Appl. Sci.*, vol. 6, no. 5, pp. 185–188, 2012, [Online]. Available: http://ajbasweb.com/old/ajbas/2012/May/185-188.pdf
[17] S. Janjai, "Improvement of the ability of the students in an education program to design the lesson plans by using an instruction model based on the theories of constructivism and metacognition," *Procedia Eng.*, vol. 32, pp. 1163–1168, 2012. https://doi.org/10.1016/j.proeng.2012.02.072
[18] L. O. Kang, S. Brian, and B. Ricca, "Constructivism in pharmacy school," *Curr. Pharm. Teach. Learn.*, vol. 2, no. 2, pp. 126–130, 2010. https://doi.org/10.1016/j.cptl.2010.01.005
[19] Y. Karagiorgi and L. Symeou, "Translating constructivism into instructional design: Potential and limitations," *Educ. Technol. Soc.*, vol. 8, no. 1, pp. 17–27, 2005, [Online]. Available: https://www.researchgate.net/publication/220374356_Translating_Constructiv–ism_into_Instructional_Design_Potential_and_Limitations
[20] O. Lourenço, "Piaget and Vygotsky: Many resemblances, and a crucial difference," *New Ideas Psychol.*, vol. 30, no. 3, pp. 281–295, 2012. https://doi.org/10.1016/j.newideapsych.2011.12.006
[21] G. Unal and E. Akpinar, "To what extent science teachers are constructivist in their classrooms?," *J. Balt. Sci. Educ.*, vol. 2, no. 10, pp. 40–50, 2006, [Online]. Available: http://www.scientiasocialis.lt/jbse/files/pdf/vol5/40-50.Unal_JBSE_Vol.5_No.2.pdf
[22] B. K. Lim, "Motion under gravity: A creative lesson from the paradigm of constructivism," *Asian J. Univ. Educ.*, vol. 7, no. 1, pp. 53–67, 2011, [Online]. Available: https://www.

researchgate.net/publication/275893613_Motion_Under_Gravity_A_Creative_Lesson_From_The_Paradigm_of_Constructivism_Introduction_Galileo_and_Thought_Experiment
[23] B. K. Lim, "The theme park experience of teaching science from the constructivist paradigm," *Procedia - Soc. Behav. Sci.*, vol. 123, pp. 12–19, 2014. https://doi.org/10.1016/j.sbspro.2014.01.1392
[24] Z. H. Babakr, P. Mohamedamin, and K. Kakamad, "Piaget's cognitive developmental theory: Critical review," *Educ. Q. Rev.*, vol. 2, no. 3, pp. 517–524, 2019. https://doi.org/10.31014/aior.1993.02.03.84
[25] J. B. Carrol, B. S. Bloom, and P. W. Airasiian, *Mastery learning: Theory and practice*, 1st ed. New York: Rinehart and Winston, 1971.
[26] O. Benjamin and O. Clement, "Effect of mastery learning approach on senior secondary school students ' achievement in geometry," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 4, no. 3, pp. 293–302, 2008. https://doi.org/10.12973/ejmste/75352
[27] M. S. Lipsky and C. J. Cone, "A review of mastery learning: The roseman model as an illustrative case," *Educ. Heal. Chang. Learn. Pract.*, vol. 31, no. 1, pp. 39–42, 2018. https://doi.org/10.4103/1357-6283.239045
[28] S. A. Adeyemo and V. F. T. Babajide, "Effects of mastery learning approach on students' achievement in physics," *Int. J. Sci. Eng. Res.*, vol. 5, no. 2, pp. 910–920, 2014, [Online]. Available: https://www.ejmste.com/download/effects-of-mastery-learningapproach-on-secondary-schoolstudents-physics-achievement-4118.pdf
[29] M. Siddaiah-Subramanya, S. Smith, and J. Lonie, "Mastery learning: How is it helpful? an analytical review," *Adv. Med. Educ. Pract.*, vol. 8, no. May, pp. 269–275, 2017. https://doi.org/10.2147/AMEP.S131638
[30] B. A. Prayitno and Suciati, "Narrowing the gap of science students' learning outcomes through INSTAD strategy," *New Educ. Rev.*, vol. 50, no. 4, pp. 123–133, 2017. https://doi.org/10.15804/tner.2017.50.4.10
[31] N. R. Azizah, M. Masykuri, and B. A. Prayitno, "Scaffolding as an effort for thinking process optimization on heredity," in *Journal of Physics: Conference Series*, 2018, vol. 1006, no. 1. https://doi.org/10.1088/1742-6596/1006/1/012017
[32] B. K. B. Putra, B. A. Prayitno, and Maridi, "The effectiveness of guided inquiry and instad towards students' critical thinking skills on circulatory system materials," *J. Pendidik. IPA Indones.*, vol. 7, no. 4, 2018. https://doi.org/10.15294/jpii.v7i4.14302
[33] E. Haataja, E. Garcia Moreno-Esteva, V. Salonen, A. Laine, M. Toivanen, and M. S. Hannula, "Teacher's visual attention when scaffolding collaborative mathematical problem solving," *Teach. Teach. Educ.*, vol. 86, p. 102877, 2019. https://doi.org/10.1016/j.tate.2019.102877
[34] L. Moccozet, W. Opprecht, and M. Léonard, "A Collaborative Training Platform for Peer-Based Co-Construction of Knowledge and Co-Tutoring," *Int. J. Emerg. Technol. Learn.*, vol. 4, no. 7, p. 40, 2009. https://doi.org/10.3991/ijet.v4s3.1100
[35] D. Hasanuddin, Emzir, and S. Akhadiah, "Improving students' scientific writing ability through blended learning-based collaborative learning," *Int. J. Emerg. Technol. Learn.*, vol. 14, no. 20, pp. 34–43, 2019. https://doi.org/10.3991/ijet.v14i20.11457
[36] S. Swestyani, M. Masykuri, B. A. Prayitno, Y. Rinanto, and S. Widoretno, "An analysis of logical thinking using mind mapping," in *Journal of Physics: Conference Series*, 2018, vol. 1022, no. 1. https://doi.org/10.1088/1742-6596/1022/1/012020
[37] P. S. Garcha, "Effectiveness of student team achievement division (STAD) on achievment of secondary school students," *Indian Streams Res. J.*, vol. 3, no. 10, pp. 4–11, 2013. http://dx.doi.org/10.13140/RG.2.2.24935.09121

[38] B. A. Prayitno and Suciati, "Narrowing the gap of science students' learning outcomes through INSTAD strategy," *New Educ. Rev.*, vol. 50, no. 4, 2017. https://doi.org/10.15804/tner.2017.50.4.10
[39] E. M. DeRobertis, "Piaget and Husserl: Comparisons, contrasts, and challenges for future research," *Humanist. Psychol.*, no. April, 2020. https://doi.org/10.1037/hum0000183
[40] O. Matanluk, B. Mohammad, D. N. A. Kiflee, and M. Imbug, "The effectiveness of using teaching module based on radical constructivism toward students learning process," *Procedia - Soc. Behav. Sci. Behav. Sci.*, vol. 90, no. 1, pp. 607–615, 2013. https://doi.org/10.1016/j.sbspro.2013.07.132
[41] E. Hendarwati, L. Nurlaela, B. S. Bachri, and N. Sa'ida, "Collaborative Problem Based Learning Integrated with Online Learning," *Int. J. Emerg. Technol. Learn.*, vol. 16, no. 13, pp. 29–39, 2021. https://doi.org/10.3991/ijet.v16i13.24159
[42] M. Tiantong and S. Teemuangsai, "Student team achievement divisions (STAD) technique through the moodle to enhance learning achievement," *Int. Educ. Stud.*, vol. 6, no. 4, pp. 85–92, 2013. https://doi.org/10.5539/ies.v6n4p85

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A Ubiquitous Learning Model for Education and Training Processes Supported by TV Everywhere Platforms

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Abstract—Advances in technology and digital convergence, for example Netflix, enable users to view TV and video without time or place restrictions. These advances can be applied in education and training processes to enable ubiquitous learning (u-learning). However, a literature review (of the years 2002 to 2018) on u-learning models yielded scarce information about its implementation, specifically demonstrating a lack of application alternatives that could provide access to TV regardless of place and device. To contribute to this and other challenges in education, the objective of this study is to propose a reference model for u-learning implementation involving cloud-supported TV/video platforms. The model was validated in a university context by a group of experts and applied through a prototype in a real setting with students, and it showed favourable results and improvement in student performance.

Keywords—u-learning, multiscreen, model, TV everywhere, cloud computing

1 Introduction

U-learning is a broad approach that encompasses various means and enables learning experiences linked to each person's place, pace, and setting. In ISO/IEC [1], u-learning is defined as learning that is stimulated and supported through various means and is always readily accessible. U-learning is not limited to a single place, which allows the expansion of learning experiences [2]. Students can access learning resources in an easier and more convenient way [3]. As El Guabassi *et al.* [4] outline, the system is ubiquitous if it is able to adapt to its context (user, platform, environment, device, etc.). According to Moreno Lopez *et al.* [5], u-learning is an ecosystem that fosters or complements learning beyond the traditional classroom. Through a convergence of technologies, it facilitates access to the right services anywhere and at any time. These services, in the most transparent and simplest way possible, provide individuals with a sense of continuous learning and motivation immersed in everyday life to learn and connect with the setting in which they develop.

Through the use of technology, u-learning seeks to bring learning closer to the places learners reside, where networks of students, faculty, and experts interact both synchronously and asynchronously without relying on specific schedules and places [6]. According to [7], ubiquitous learning allows access to educational resources with full mobility and system adaptation to the students' computational context. In general, as Shapsough and Zualkernan [8] indicated in the literature, u-learning is defined as learning anything, anywhere, and at any time.

U-learning itself benefits from broad technology development, digital convergence, increased bandwidth, content delivery networks (CDNs), adaptive bitrate (ABR) technologies, cloud computing, and ubiquitous computing, among others. For example, Cisco [9] projects that by 2023 there will be 29.3 billion networked devices, of which machine to machine (M2M), smartphones, connected TVs, PCs, and tablets are highlighted. In this scenario, video is projected to become the most popular content, representing 82% of all IP traffic by 2022. Video learning is becoming an increasingly important part of contemporary education [10].

Against this backdrop, video content can be adapted to any Internet-connected screen (PC, smartphone, tablet, smart TV). A new generation of cloud-supported and software-defined TV is emerging—the notion of TV Everywhere (TVE), which refers to deployed video content that can be viewed everywhere on a variety of Internet-connected screens [11]. Initially, when cable operators began to use it to offer online television programming, TVE was technically known as multi-channel video programming distributors (MVPD) [12]. There are several terms related to TVE, such as software-defined TV, Cloud TV, TV streaming, Over-the-Top (OTT) TV, multi-screen TV, software-defined video processing, and TV as a Service (TVaaS). Based on the premise of ubiquity, ubiquitous TV is presented as television that is supported by a convergence of technologies and connectivity, which can be seen everywhere, at any time, and on any screen. These terms are covered under software-defined everything, which, according to Virmani [13], refers to a varied group of software-defined computing technologies within a general framework and design. In addition, cloud computing service models serve as a deployment reference: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS), as well as essential features, namely, on-demand self-service, extensive network access, resource pooling, rapid elasticity, and measured service [14]. A highly-used term is video streaming, a technique that allows customers to start playing a video without having to download the entire file [15]. For example, Netflix is one of the world's leading streaming platforms [16], [17].

While u-learning models have been well defined in the literature, there is a particular lack of cloud-supported TV technologies, greater model detail, and consideration from a pedagogical approach (for instance, in instructional design theory), and universities rarely adopt them. The motivation behind this study is to project the applicability of TVE platforms that enable video adaptation and delivery to different types of screens, with a link to the u-learning approach. Therefore, this paper proposes a u-learning model backed by TVE platforms and provides the results of a systematic literature review as well as illustration and validation of a prototype.

2 Method

The adopted research paradigm was post-positivism, which is flexible and seeks objectivity. The research approach was quantitative [18], [19]. In general, the design-based research [20] methodology was applied, which seeks to improve educational practices through iterative analysis, design, development, and implementation.

The research design had two scenarios (Figure 1): one non-experimental model assessment with a group of educational technologies experts and a quasi-experimental model that explored prototype application in real courses. In both, the sample was targeted and the data analysis was descriptive and factorial. In the quasi-experimental model, a pre-test/post-test design was also implemented [21] to evaluate students' academic performance. There was a control group (traditional lecture) and an experimental group (u-learning and TVE). Afterwards, the experimental group evaluated a prototype called "Aprenutvi" by answering a survey.

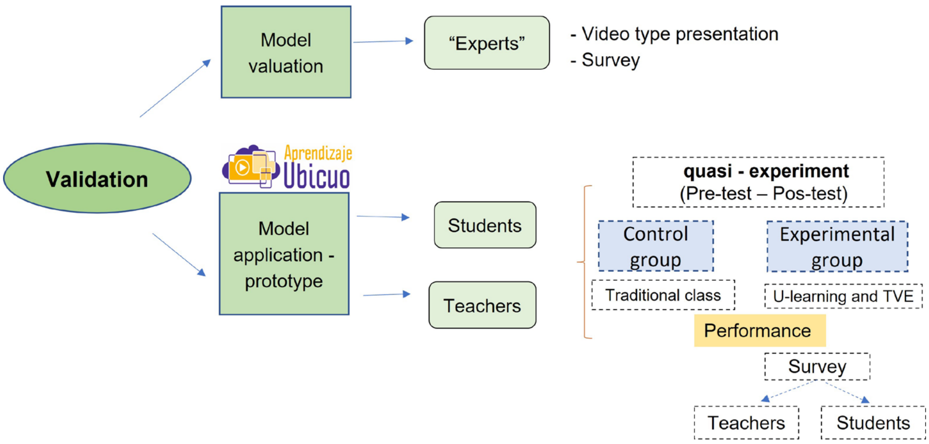

Fig. 1. Validation process summary

2.1 Sample

For the model evaluation, 19 experts from 17 universities fully completed a survey, out of approximately 65 individuals who responded to an e-mail request. These data were collected from May 2018 to May 2019. The implementation and evaluation of the Aprenutvi prototype was conducted during the second semester of 2018 and the first semester of 2019 in the Algorithms and Coding course (Faculty of Engineering, Politécnico Jaime Isaza Cadavid [Poli JIC]) with 44 students (22 in each control and experimental group), and in the History and Theory 2 course (School of Architecture, Universidad Nacional de Colombia [UNAL Medellín]) with 43 students (control group: 21, experimental group: 22).

2.2 Tools

For the model evaluation by the group of experts, a survey-type tool (in Google forms) was developed that consisted of a 15-item Likert scale containing five response alternatives (1 = Strongly Disagree to 5 = Strongly Agree). It was also based on some of the ISO/IEC 25010:2011 standard indicators for a product or system evaluation in the areas of quality in use and product quality [22]. Another indicator is the intention of use [23], as shown in Table 1.

Table 1. Reference indicators for evaluation provided by the group of experts

Indicator	Characteristic	Items
Usability in use	Satisfaction – usefulness	9
Product usability	Appropriateness recognizability Learnability Operability Accessibility	1 2 1 1
Intention of use		1

In the prototype assessment, an instrument was also created, consisting of a 23-item, Likert-type scale, as shown in Table 2. Another indicator is performance (pre-test and post-test); the UNAL and Poli JIC professors develop the tests, the presentation of the theme, and then do a video recording.

Table 2. Reference indicators for prototype evaluation

Indicator	Characteristic	Items
Usability in use	Effectiveness, efficiency, satisfaction (usefulness, trust, pleasure, comfort)	7
Context coverage	Flexibility, context completeness	2
Functional suitability	Functional correctness	1
Product usability	Appropriateness recognizability, learnability, operability, user error protection, user interface aesthetics, accessibility	9
Portability	Adaptability	1
Reliability	Availability	1
Intention of use		2

2.3 Procedure

For the model evaluation by the group of experts, a request was sent to them via an e-mail containing the online survey. During the prototype evaluation, the professors of both courses first conducted the pre-test. Then, the traditional lecture was presented to the control group and the implementation of cloud TV-based u-learning was carried out with the experimental group. Subsequently, the professors conducted the post-test for both groups. Finally, only the experimental group took the online survey in order to evaluate the experience.

3 Results

3.1 Literature review

The systematic literature review process was based on the work of Kitchenham and Charters [24], which has three phases: planning, execution, and review reporting. During this process, 4,868 articles were obtained (from the years 2002 to 2018), 4,767 of which were discarded since the titles did not make any reference to a u-learning model. During this stage, 101 items were obtained. Only articles from journals or books were kept, resulting in 53 items being discarded. Of the remaining 48 articles, duplicate articles were discarded, and upon conducting a more complete literature review, those that did not involve the implementation of a u-learning model were also discarded. From this review, 17 articles were left for further analysis, as outlined in Figure 2.

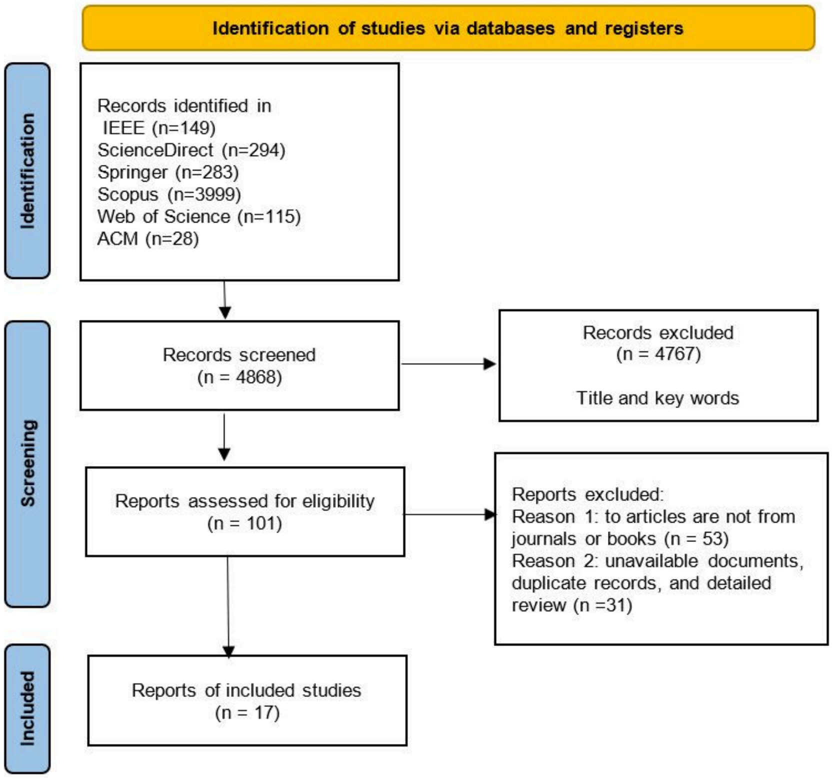

Fig. 2. Summary of the literature selection process

Following a review of relevant literature on u-learning models, several details were noted. With the exception of Zhao and Okamoto [25], very few studies mention the use of multiple devices. To some extent, several models present good information [25], [26], [27], [28], [29], [30], [31], [32] and [33]. Certain studies reflected the possibility of using other information and communication technology (ICT) resources [34], [35], [36], [25], [27], [37]. As for the degree of coverage or improvement, some authors project it to be broader, such as [37], [38], on campus [27], [28], [29], [39], in the classroom [40] and in simulations [31], [26], [35]. Regarding context awareness, most implement this feature through, for example, employing RFID sensors [39] and WSN sensors [29]. In terms of main infrastructure/technology, several authors use a server client, as in the case of Shih *et al.*[39] through the use of RFID, tablet, PC and wireless sensors [25], while other authors use PC and mobile sensors [35], XML, ASP.net, and mobile sensors [34], and mobile and WSN sensors [29]. Tortorella *et al.* [32] use a Raspberry Pi 2-based system, and Rabello *et al.*[31] use agents. With regard to real deployment tests, several studies have conducted them, such as Tortorella *et al.* [32], who applied them to driving training. With respect to application domain, some are specific, for example plant education [27], teacher training [28], mathematics [39], use of text messages [2], driving training [32], computer science, and smart cities [33]. Some are implemented on campus (school, classroom), others are generic, and still others generally have a university application [37], [38]. The following table shows the general findings of the analysis of selected articles, according to certain defined characteristics.

Table 3. General findings of the analysis of selected articles

Characteristic	**Finding**	
	Notes	***Percentage***
Degree of detail in model	From a more comprehensive perspective, more elements are necessary to guide its implementation.	12% Low 82% Average 6% Broad
Multi-screen deployment	Only one study suggests that the solution can be deployed across multiple devices.	6% Yes
Main use of video	None have it as a primary resource.	0%
Incorporates more ICT resources	Six studies generally have them, others regularly, and others minimally or not at all.	35% Yes 24% Regularly 18% Minimally 23% No
Degree of coverage	Only three have a broad approach; most of them have a mid-range approach since they focus on one campus, while others are simulated.	18% Broad 23% None 12% Limited 47% Mid-Range
Pedagogical orientation	Connected theory, constructivism, project-based learning, and collaborative learning approaches.	0% Instructional design theory
Context awareness	Over half of them consider it.	65% Yes 29% No
Main infrastructure/technologies	Client-server infrastructure, mainly use mobile, PC devices. Some have sensors and agents.	0% Cloud supported/screen diverse
Real deployment test	On average, they conduct real deployment tests. Some are limited in terms of coverage and devices.	41% Yes 53% No 6% Simulated
Application domain	Some are specific. On campus. Generic. Schools. Scarce in university settings.	(18%) Application in a university

The complete details of the analysis of the selected articles can be reviewed in the following link figshare.

3.2 U-learning model with TV everywhere platforms

The model is developed referencing the Analyze, Design, Develop, Implement, and Evaluate (ADDIE) instructional design approach because it is widely accepted and functional as well as easy to use [41], [42]. The model is defined as an ecosystem in which multiple items factor in and, to a certain degree, contribute to the u-learning solution. It has several levels, each of which has a group of factors and components, as shown in Figure 3.

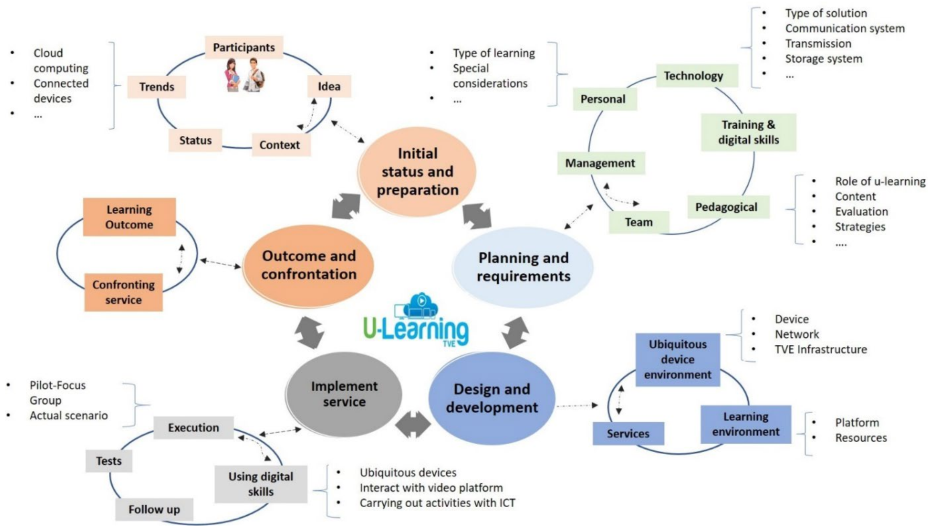

Fig. 3. U-learning model

The first phase, initial status and preparation, includes the idea of u-learning and multi-screen TV. It considers technology trends, application context (e.g., university), and participants, with students as the main actors. In the second phase, planning and technological requirements are defined (technologies that enable TVE, communication systems among participants, modes of interaction, storage, etc.). From a pedagogical standpoint, factors such as the role of u-learning (complementary, face-to-face, and virtual), content, activities, and strategies such as flipped classroom or gamification, among others, are projected. According to Collazos Ordóñez *et al.* [43], u-learning not only implies technological changes but also requires methodological and didactic changes to enhance learning, including establishing an interdisciplinary team (lecturer, multimedia developers, engineers, etc.), identifying personal needs and management-related factors, and defining training needs or areas for strengthening digital skills. In the third phase of design and development, the u-learning solution, content, and activities, among others, are outlined. The platform, resources, services, content, and others are configured or developed, and the video pre-production, production, and post-production are studied. The main components are the ubiquitous device environment (screens, Internet, TVE infrastructure), a learning platform, and services. The fourth phase of the u-learning service implementation aims to confirm the platform's functionality, execute it in real scenarios or focus groups, and track and make wide use of it. Finally, in the fifth phase, the learning outcome and service are evaluated, at which time the experience, impact, and teaching/learning process enhancement are reviewed.

Among the various forms of u-learning with TVE characteristics, the following are proposed: accessibility, immediacy, interactivity, functionality, context sensitivity, safety, scalability, flexibility, customizability, usability, learnability, interconnectivity, daily ubiquity, portability, measurable, manageable and multi-factored (plus other factors, e.g., multimodal or multi-screen). When some or all of these are connected, they foster a suitable u-learning ecosystem.

Figure 4 illustrates u-learning projections using cloud-based TV/video platforms and the use of various ICT resources complementing the solution.

Fig. 4. U-learning plan with TV streaming

3.3 Prototype

The u-learning and TVE prototype was defined considering the proposed model, called "Aprenutvi" (aprendizaje ubicuo basado en la nube y televisión/video [cloud-based ubiquitous learning with television/video]). Figure 5 shows an illustration of the prototype supported on the video platform Vimeo that is linked to the aprenutvi.co domain, through which the video portfolios for the courses are also linked.

Fig. 5. U-learning and TVE prototype illustration

3.4 Model validation and prototype implementation

The model was evaluated by a group of 19 experts: 11 men (57.9%) and 8 women (42.1%). In general, the perception about the u-learning and TVE model and concept is positive. Table 4 presents a summary of the most notable responses. For example, in the usability-in-use assessment, which measures user satisfaction, the fact that 63.2% strongly agree that TVE platforms are useful and benefit u-learning implementation is highlighted. The instrument in general has an internal consistency of 0.946, according to Cronbach's alpha [44].

Table 4. Overall results of the expert group evaluation

Indicator	Characteristic	Outstanding results
Usability in use	Satisfaction - usefulness	63.2% (SA) and 31.6% (A), TVE utility for u-learning. 47.4% (A) and 36.8% (SA), model elements First level - 42.1% (SA) participants, 52.6% trends, 63.2% context Second level - 63.2% (SA) work team, 52.6% technological, 73.7% pedagogical Third level - 78% (SA) learning environment Fourth level - 68.4% (SA) service monitoring Fifth level - 57.9% (SA) service impact
Product usability	• Appropriateness recognizability • Learnability • Operability • Accessibility	52.6% (A) and 26.3% (SA) 36.8% (A) and 57.9% (SA) 63.2% (A) 73.7% (A)
Intention of use		31.6% (A) and 63.2% (SA) in employing TVE for educational use

(SA): Strongly Agree. (A): Agree

Five factors were obtained from the exploratory factor analysis and were validated via structural equations [45], as depicted in Figure 6. Factor (F1) has a high correlation with the idea component (u-learning and TVE). Factors 2, 3, and 4 are directly associated with the first-level components of the model related to participating actors (such as students), process expectation, and the usefulness of the model and application in any institution, respectively.

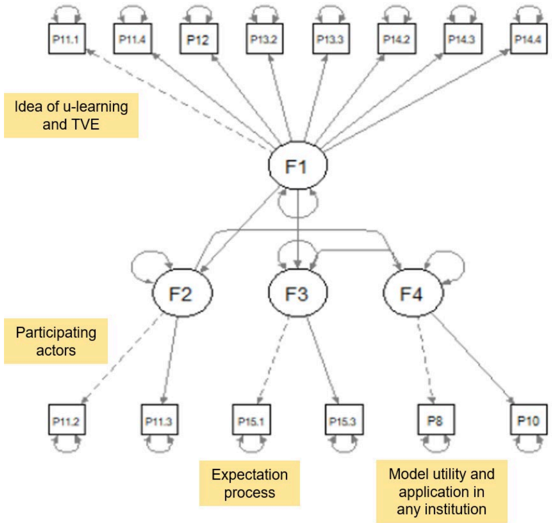

Fig. 6. Result of expert group evaluation of structural equations

Another scenario validates the application of the model using the prototype. As for the academic performance indicator, it is shown that when implementing u-learning and TVE, there is an overall improvement in results (see Table 5).

Table 5. Results of student performance tests

Subject	Group	Number	Pre-test average	Post-test average
History and Theory 2 (UNAL)	Experimental	21	4.0	4.5
	Control	22	4.5	4.5
Algorithms and Coding (Poli JIC)	Experimental	22	2.3	3.5
	Control	22	2.1	2.8

Table 6 shows the results of the statistical analysis of the grades obtained in the experimental and control groups using the chi squared test. The data obtained from UNAL have statistically significant differences since the p-values for each of the groups were lower than the significance level, while the data obtained from the Poli JIC experimental group did not provide sufficient evidence to establish a statistically significant difference.

Table 6. Results of statistical analysis of student performance tests

University	Experimental Group	Control Group
UNAL	0.0006074	0.006482
Poli JIC	Statistically non-significant	0.05657

Twenty-two students from the Algorithms and Coding course (Poli JIC) and 24 students from the History and Theory 2 course (UNAL) participated in the survey. In general, a positive perception from the students who participated in the prototype was observed, as illustrated in Table 7, which provides response highlights. For instance, in the usability-in-use evaluation (the indicator of satisfaction-utility), a notable 68.2% of respondents from Poli JIC and 79.2% of UNAL strongly agreed that they would recommend that universities implement video platforms to support ubiquitous learning. Overall, the instrument's reliability was 0.928 and 0.933 for Poli JIC and UNAL, respectively.

Table 7. Overall results of the student evaluation

Indicator	Characteristic	Outstanding Results (%)			
		Poli JIC		***UNAL***	
		A	SA	A	SA
Usability in use	Effectiveness	50	36.4	50	36.5
	Efficiency	45.5	54.5	54.2	45.8
	Satisfaction (usefulness)	31.8	68.2	16.7	79.2
	Satisfaction (trust)	63.6	9.1	58.3	33.3
	Satisfaction (pleasure)	68.2	13.6	65.2	29.2
	Satisfaction (comfort)	68.2	9.1	65.2	29.2
Context coverage	Flexibility	36.4	50	37.5	54.2
	Context completeness	59.1	22.7	8.3	41.7
Functional suitability	Functional correctness	40.9	54.5	66.7	33.3
Product usability	Appropriateness recognizability	59.1	27.3	41.7	37.5
	Learnability	36.4	63.6	37.5	54.2
	Operability	50	50	25	66.7
	User error protection	36.4	4.5	25	8.3
	User interface aesthetics	68.2	9.1	37.5	25
	Accessibility	68.2	18.2	37.5	50
Portability	Adaptability	63.6	18.2	33.3	50
Reliability	Availability	54.5	31.8	41.7	45.8
Intention of use		22.7	72.7	50	50

Note: (SA): Strongly Agree. (A): Agree

Four factors were obtained from the exploratory factorial analysis and validated via structural equations (see Figure 7). For example, for Poli JIC students (Figure 7-a), of note are factor one (F1), which has a high correlation for usability in use (effectiveness), factor four (F4) satisfaction (trust), factor three (F3) product usability (learning capacity), and factor two (F2) reliability (availability).

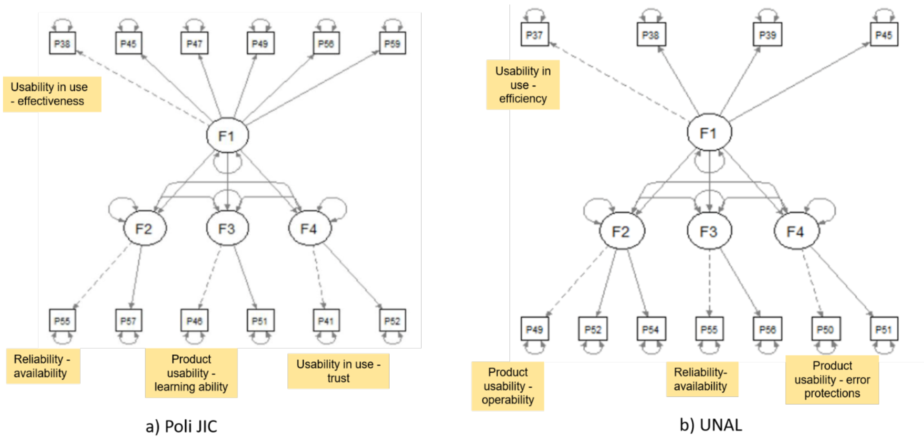

Fig. 7. Results of structural equations for Poli JIC and UNAL students

The three professors who participated in the implementation of the prototype also evaluated the subject and activity positively. For example, 66.7% strongly agree on the usefulness of TVE platforms and their benefit for u-learning, in addition to the usefulness of the model and implementation in any institution. They are all strongly in favour of the technological components and the need for digital skills training or strengthening.

The full data of the survey results can be accessed from the following repository figshare.

4 Conclusion

The study endeavoured to present a u-learning model with TVE platforms evaluated by a group of experts and to observe the impact of its application in a real-world scenario by means of a prototype. Overall, the results were satisfactory. On the one hand, the use of the u-learning application supported by streaming TV has favourable effects on students' performance. According to the evaluation, it can be concluded that there is a positive perception of the model as it relates to how it can contribute to the learning process.

The u-learning approach with TVE platforms assumes a scenario where Internet, technologies, and platforms that enable content can be shown on any screen. The applicability of u-learning is enhanced by a multi-screen TV. TVE platforms have a high potential for resource optimization because they are based on cloud computing, which allows for on-demand access to computing and infrastructure resources. When conducting experimental testing, the results demonstrated that the implementation was fast and the performance of the video platform was satisfactory. In terms of its applicability in an educational context, it can help solve issues related to flexibility and coverage, among others. Moreover, it makes it possible to employ other strategies such as flipped classroom or gamification.

The model's aim is to promote comprehensive consideration of the u-learning solution. Several stages were proposed in which factors and elements, to some degree, contributed to the implementation of u-learning. While it involved using cloud-based TV/video platforms, defining ICT implementation options or other resources remains open to individuals' discretion. From a comprehensive perspective, it involves not only having the technologies but also thinking about pedagogical issues, among others. As Holland and Judge [46] indicated, a successful combination of technology with innovative pedagogical practices is necessary.

There were elements that stood out when comparing the model and topic presented in this document with those of several authors: multi-screen visualization, detailed information for implementation, video as main content, and the use of convergent technology such as cloud computing, CDNs, and TVE. In addition, the model suggests working on acquiring digital skills that expand the possibility of learning, working, and sharing in the digital ecosystem, and it falls within the framework of instructional design theory known as ADDIE. It can be applied in colleges and other settings.

A big challenge in educational institutions is the shift in paradigm. According to Virtanen *et al.* [47], the teaching methods found in many universities continue to be conventional and strongly professor-based. As Liu *et al.* [30] indicate, u-learning facilitates a student-centred learning experience by allowing the student to define the time, place, and ICT resources. Gaining a better subject understanding is possible through video, and it is useful in complementing laboratory practices and improving training in equipment management. According to Strecker *et al.* [48], the learning experience is improved through abundant resources, including videos.

To a certain extent, TVE-based u-learning can contribute depending on the different learning styles or rhythms. Videos can be paused and re-watched to bolster understanding. Immersive experiences can be achieved via videos, and thus, as Lui and Slotta [49] state, allow for different perception, reflection, or integration opportunities of scientific understanding. Hung *et al.* [50] indicate that levels of reflection are improved when videos are used. In addition, students' communication skills can be improved [51]. Authors like Brame [52] claim that videos are a highly effective educational tool, integrating cognitive load, student engagement, and active learning. Li [53] emphasizes that playing the questions in the learning video can enable to students to review and consolidate their knowledge over time and improve learners' learning experience and learning effect to a certain extent.

As a future study, application and projection of the model is proposed in other scenarios in populations with diverse needs for systematization of the model, development of specific applications, adding technological elements, such as artificial intelligence (e.g., for smart information searches), or expanding context-sensitive applications. Moreover, pedagogical components (support, follow-up, and personalized and adaptive learning) track technological trends such as guidelines, and research and application of emerging technologies (immersive content, applying virtual reality [VR], mixed reality [MR], augmented reality [AR], or haptic technologies) or other technologies such as computer vision and speech recognition are proposed.

Competing interests

The authors declare that they have no competing interests.

Data availability statement

The dataset that supports the findings of this study are openly available in figshare at https://figshare.com/s/7720653edb0c70e33047.

Supplemental online material

The complete details of the analysis of the selected articles can be reviewed in the following link figshare.

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6 References

[1] ISO/IEC, "ISO/IEC TS 29140-2:2011(en), Information technology for learning, education and training — Nomadicity and mobile technologies — Part 2: Learner information model for mobile learning," *ISO*, 2011. https://www.iso.org/obp/ui/#iso:std:iso-iec:ts:29140:-2:ed-1:v1:en (accessed May 31, 2018).

[2] K. Umam, S. N. S. Mardi, and M. Hariadi, "Ubiquitous learning model using interactive internet messenger group (IIMG) to improve engagement and behavior for smart campus," *J. Phys. Conf. Ser.*, vol. 801, p. 012083, Jan. 2017. https://doi.org/10.1088/1742-6596/801/1/012083

[3] S. Kanagarajan and S. Ramakrishnan, "Ubiquitous and ambient intelligence assisted learning environment infrastructures development - a review," *Educ. Inf. Technol.*, vol. 23, no. 1, pp. 569–598, Jan. 2018. https://doi.org/10.1007/s10639-017-9618-x

[4] I. El Guabassi, Z. Bousalem, M. Al Achhab, I. Jellouli, and B. E. EL Mohajir, "Personalized adaptive content system for context-aware ubiquitous learning," *Procedia Comput. Sci.*, vol. 127, pp. 444–453, 2018. https://doi.org/10.1016/j.procs.2018.01.142

[5] G. A. Moreno Lopez, J. A. Jimenez Builes, and S. C. Bernal Villamil, "Overview of u-learning. Concepts, characteristics, uses, application scenarios and topics for research," *IEEE Lat. Am. Trans.*, vol. 14, no. 12, pp. 4792–4798, Dec. 2016. https://doi.org/10.1109/TLA.2016.7817013

[6] C. I. Báez Pérez and C. E. Clunie Beaufond, "Una mirada a la Educación Ubicua," *RIED Rev. Iberoam. Educ. Distancia*, vol. 22, no. 1, p. 325, Jan. 2019. https://doi.org/10.5944/ried.22.1.22422

[7] S. Dutra Piovesan, M. Hoff do Amaral, C. Priscila Barbosa Arenhardt, and R. Duarte Medina, "U-SEA: A learning environment ubiquitous using cloud computing," *Int. J. Emerg. Technol. Learn. IJET*, vol. 7, no. 1, p. 19, Feb. 2012. https://doi.org/10.3991/ijet.v7i1.1838

[8] S. Shapsough and I. A. Zualkernan, "IoT for ubiquitous learning applications: Current trends and future prospects," in *Ubiquitous Computing and Computing Security of IoT*, vol. 47, N. Jeyanthi, A. Abraham, and H. Mcheick, Eds. Cham: Springer International Publishing, 2019, pp. 53–68. https://doi.org/10.1007/978-3-030-01566-4_3

[9] CISCO, "Cisco Annual Internet Report - (2018–2023) White Paper," *Cisco*, Mar. 09, 2020. https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html (accessed Jun. 11, 2020).
[10] M. Giannakos, L. Jaccheri, and J. Krogstie, "Looking at MOOCs rapid growth through the lens of video-based learning research," *Int. J. Emerg. Technol. Learn. IJET*, vol. 9, no. 1, p. 35, Feb. 2014. https://doi.org/10.3991/ijet.v9i1.3349
[11] G. A. M. López, J. A. J. Builes, and W. P. Plaza, "Ubiquitous learning based on platform of TVE as a service. uLTVEaaS model," in *2016 8th IEEE Latin-American Conference on Communications (LATINCOM)*, Nov. 2016, pp. 1–7. https://doi.org/10.1109/LATINCOM.2016.7811596
[12] E. Sanz and T. Crosbie, "The meaning of digital platforms: Open and closed television infrastructure," *Poetics*, vol. 55, pp. 76–89, Apr. 2016. https://doi.org/10.1016/j.poetic.2015.11.002
[13] M. Virmani, "Understanding DevOps & bridging the gap from continuous integration to continuous delivery," in *Innovative Computing Technology (INTECH), 2015 Fifth International Conference on*, 2015, pp. 78–82. Accessed: Apr. 04, 2017. https://doi.org/10.1109/INTECH.2015.7173368
[14] P. Mell and T. Grance, "The NIST Definition of Cloud Computing." Sep. 2011. https://doi.org/10.6028/NIST.SP.800-145
[15] V. Krishnamoorthi, "Efficient HTTP-based adaptive streaming of linear and interactive videos," Department of Computer and Information Science. Linköping University, Faculty of Science & Engineering., Linköping, Sweden, 2018. https://doi.org/10.3384/diss.diva-143802
[16] M. Au-Yong-Oliveira, M. Marinheiro, and J. A. Costa Tavares, "The power of digitalization: The Netflix story," *Trends Innov. Inf. Syst. Technol. WorldCIST 2020 Adv. Intell. Syst. Comput.*, vol. 1161 AISC, pp. 590–599, 2020. https://doi.org/10.1007/978-3-030-45697-9_57
[17] M. Fudurić, E. C. Malthouse, and M. H. Lee, "Understanding the drivers of cable TV cord shaving with big data," *J. Media Bus. Stud.*, vol. 17, no. 2, pp. 172–189, 2020. https://doi.org/10.1080/16522354.2019.1701363
[18] E. N. Asencio, E. J. García, S. R. Redondo, and B. T. Ruano, *Fundamentos de la investigación y la innovación educativa*, Primera. La Rioja, España: UNIVERSIDAD INTERNACIONAL DE LA RIOJA, 2017. [Online]. Available: www.unir.net
[19] R. Hernández Sampieri and C. P. Mendoza Torres, *Metodología de la investigación. Las rutas cuantitativa, cualitativa y mixta*, Primera edición. México: McGRAW-HILL, 2018.
[20] F. Wang and M. J. Hannafin, "Design-based research and technology-enhanced learning environments," *Educ. Technol. Res. Dev.*, vol. 53, no. 4, pp. 5–23, 2005, [Online]. Available: http://www.jstor.org/stable/30221206
[21] N. M. Seel, "Experimental and quasi-experimental designs for research on learning," *Encyclopedia of the Sciences of Learning*. Springer, Boston, MA, pp. 1223–1228, 2012. [Online]. Available: https://doi.org/10.1007/978-1-4419-1428-6_716
[22] ISO, "ISO/IEC 25010:2011 - Systems and software engineering -- Systems and software Quality Requirements and Evaluation (SQuaRE) -- System and software quality models," Mar. 2011. https://www.iso.org/standard/35733.html (accessed Jul. 01, 2017).
[23] V. Venkatesh and H. Bala, "Technology acceptance model 3 and a research agenda on interventions," *Decis. Sci.*, vol. 39, no. 2, pp. 273–315, May 2008. https://doi.org/10.1111/j.1540-5915.2008.00192.x
[24] B. Kitchenham and S. Charters, "Guidelines for performing systematic literature reviews in software engineering version 2.3," Keele University And University of Durham, UK, Jul.

09, 2007. [Online]. Available: https://www.elsevier.com/__data/promis_misc/525444systematicreviewsguide.pdf

[25] X. Zhao and T. Okamoto, "Adaptive multimedia content delivery for context-aware u-learning," *Int. J. Mob. Learn. Organ.*, vol. 5, no. 1, pp. 46–63, 2011, Accessed: Mar. 14, 2015. [Online]. Available: http://inderscience.metapress.com/index/A185755566V30860.pdf

[26] Y. Atif, S. S. Mathew, and A. Lakas, "Building a smart campus to support ubiquitous learning," *J. Ambient Intell. Humaniz. Comput.*, vol. 6, no. 2, pp. 223–238, Apr. 2015. https://doi.org/10.1007/s12652-014-0226-y

[27] M. Chen, S. Q. Yu, and F. K. Chiang, "A dynamic ubiquitous learning resource model with context and its effects on ubiquitous learning," *Interact. Learn. Environ.*, vol. 25, no. 1, pp. 127–141, Jan. 2017. https://doi.org/10.1080/10494820.2016.1143846

[28] M. Chen, F. K. Chiang, Y. N. Jiang, and S. Q. Yu, "A context-adaptive teacher training model in a ubiquitous learning environment," *Interact. Learn. Environ.*, vol. 25, no. 1, pp. 113–126, Jan. 2017. https://doi.org/10.1080/10494820.2016.1143845

[29] H. Kim, R. D. Caytiles, and T. Kim, "Design of an effective WSN-based interactive u-learning model," *Int. J. Distrib. Sens. Netw.*, vol. 8, no. 1, p. 12, Jan. 2012. https://doi.org/10.1155/2012/514836

[30] G. zen Liu, T. Chien Liu, C. Chung Lin, Y. Ling Kuo, and G. Jen Hwang, "Identifying learning features and models for context-aware ubiquitous learning with phenomenological research method," *Int. J. Mob. Learn. Organ.*, vol. 10, no. 4, p. 238, 2016. https://doi.org/10.1504/IJMLO.2016.079501

[31] S. Rabello, J. Oliveira, A. Wagner, J. Barbosa, and D. Barbosa, "CoolEdu - A collaborative multiagent model for decentralized ubiquitous education environments," *IEEE Lat. Am. Trans.*, vol. 10, no. 6, pp. 2273–2279, Dec. 2012. https://doi.org/10.1109/TLA.2012.6418132

[32] R. A. W. Tortorella, D. Kinshuk, and N.-S. Chen, "Framework for designing context-aware learning systems," *Educ. Inf. Technol.*, vol. 23, no. 1, pp. 143–164, Jan. 2018. https://doi.org/10.1007/s10639-017-9591-4

[33] A. Wagner, J. L. V. Barbosa, and D. N. F. Barbosa, "A model for profile management applied to ubiquitous learning environments," *Expert Syst. Appl.*, vol. 41, no. 4, pp. 2023–2034, Mar. 2014. https://doi.org/10.1016/j.eswa.2013.08.098

[34] D. Casey and J. Fraser, "A framework for developing and implementing u-learning models," in *Handbook of Research on Human Performance and Instructional Technology*, United States of America: Information Science Reference - IGI Global, 2010, ch. 19, pp. 310–323. https://doi.org/10.4018/978-1-60566-782-9.ch019

[35] R. Mehmood, F. Alam, N. N. Albogami, I. Katib, A. Albeshri, and S. M. Altowaijri, "UTiLearn: A personalised ubiquitous teaching and learning system for smart societies," *IEEE Access*, vol. 5, pp. 2615–2635, 2017. https://doi.org/10.1109/ACCESS.2017.2668840

[36] H. Zhang and T. Maesako, "A framework of learner development ecosystem for designing a ubiquitous educational informational infrastructure," *J. Softw.*, vol. 4, no. 2, p. 8, Apr. 2009. https://doi.org/10.4304/jsw.4.2.124-131

[37] C. M. Zea Restrepo, J. G. Lalinde Pulido, R. Aguas Nuñez, and J. D. Restrepo Díaz, "Educational model for scenarios of ubiquitous," *Ubiquitous Learn. Int. J.*, vol. 7, no. 1, 2015. https://doi.org/10.18848/1835-9795/CGP/v07i01/40403

[38] M. Coto, C. A. Collazos, and S. Mora-Rivera, "Modelo colaborativo y ubicuo para apoyar los procesos de enseñanza-aprendizaje a nivel Iberoamericano," *Rev. Educ. Distancia RED*, no. 48, Jan. 2016. https://doi.org/10.6018/red/48/10

[39] S.-C. Shih, B.-C. Kuo, and Y.-L. Liu, "Adaptively ubiquitous learning in campus math path," *Educ. Technol. Soc.*, vol. 15, no. 2, p. 11, 2012.

[40] R. Caceffo and H. Vieira da Rocha, "Design and model of a ubiquitous classroom response system through context factors," *Ubiquitous Learn. Int. J.*, vol. 4, no. 3, pp. 61–72, 2012. https://doi.org/10.18848/1835-9795/CGP/v04i03/40337
[41] C. Peterson, "Bringing ADDIE to life: Instructional design at its best," *J. Educ. Multimed. Hypermedia*, vol. 12, no. 3, pp. 227–241, 2003.
[42] N. Asriati, M. Thoharudin, Syamsuri, and D. Dike, "Implementation of 4d learning and ADDIE model to increase entrepreneurship competencies," *Int. J. Adv. Sci. Technol.*, vol. 29, no. 8, pp. 854–861, 2020.
[43] C. A. Collazos Ordóñez, J. L. Jurado Muñoz, and L. M. Paredes, *Entornos ubicuos y colaborativos (u-CSCL) para ambientes de enseñanza-aprendizaje de competencias profesionales*. Cali: Bonaventuriana, 2016.
[44] L. J. Cronbach, "Coefficient alpha and the internal structure of tests," *Psychometrika*, vol. 16, no. 3, pp. 297–334, Sep. 1951. https://doi.org/10.1007/BF02310555
[45] T. Asparouhov and B. Muthén, "Exploratory structural equation modeling," *Struct. Equ. Model. Multidiscip. J.*, vol. 16, no. 3, pp. 397–438, Jul. 2009. https://doi.org/10.1080/10705510903008204
[46] C. Holland and M. Judge, "Future learning spaces: The potential and practice of learning 2.0 in higher education," in *Social Media and the New Academic Environment: Pedagogical Challenges*, IGI Global., 2013, pp. 1–25. https://doi.org/10.4018/978-1-4666-2851-9.ch001
[47] M. A. Virtanen, E. Haavisto, E. Liikanen, and M. Kääriäinen, "Ubiquitous learning environments in higher education: A scoping literature review," *Educ. Inf. Technol.*, vol. 23, no. 2, pp. 985–998, Mar. 2018. https://doi.org/10.1007/s10639-017-9646-6
[48] S. Strecker, D. Kundisch, F. Lehner, J. M. Leimeister, and P. Schubert, "Higher education and the opportunities and challenges of educational technology," *Bus. Inf. Syst. Eng.*, vol. 60, no. 2, pp. 181–189, Apr. 2018. https://doi.org/10.1007/s12599-018-0522-8
[49] M. Lui and J. D. Slotta, "Immersive simulations for smart classrooms: exploring evolutionary concepts in secondary science," *Technol. Pedagogy Educ.*, vol. 23, no. 1, pp. 57–80, Jan. 2014. https://doi.org/10.1080/1475939X.2013.838452
[50] I.-C. Hung, X.-J. Yang, W.-C. Fang, G.-J. Hwang, and N.-S. Chen, "A context-aware video prompt approach to improving students' in-field reflection levels," *Comput. Educ.*, vol. 70, pp. 80–91, Jan. 2014. https://doi.org/10.1016/j.compedu.2013.08.007
[51] V. Reher, G. Rehbein, and P. Reher, "Integrating video recording and self-reflection to enhance communication skills training for dental students," in *7th International Conference on the Development of Biomedical Engineering in Vietnam (BME7)*, Singapore, Jun. 2019, vol. 69, pp. 715–719. https://doi.org/10.1007/978-981-13-5859-3_120
[52] C. J. Brame, "Effective educational videos," 2015. http://cft.vanderbilt.edu/guides-sub-pages/effective-educational-videos/ (accessed Aug. 15, 2019).
[53] Z. Li, "Influence of online learning behavior and video playing questions on students' learning effect," *Int. J. Emerg. Technol. Learn. IJET*, vol. 17, no. 02, pp. 223–238, Jan. 2022. https://doi.org/10.3991/ijet.v17i02.28535

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Effects and the Analyzing of E-Learning on Higher Education During COVID-19 Period Time – Case Study University "Ukshin HOTI" Prizren

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Abstract—The challenges and problems that the educational programs are facing nowadays are those that previously have not been present, therefore, the solutions of these concerns should be compatible and reasonable in order to have a complete function of the educational institutions, especially the universities that are in transition such as University 'UH' of Prizren. The main reasons for addressing this topic through this paper are the ongoing discussions from students for not being able to learn enough during classes lectured by different professors in the Faculty of Economics. In order to get the most reliable results, this paper used the statistical program SPSS v.26 in which various methods such as descriptive statistics, factor analysis, reliability, linear regression, and One-Way ANOVA analysis are implemented. Moreover, this study shows the analysis of the connection and comparison of these methods. The results of this research are sustainable of e-learning services and the form of generating of the quality model. Further, the relationship of these models highlights among factors and provides a research foundation for elaboration in other contexts.

Keywords—eLearning, Covid 19, SPSS, university, student

1 Introduction

During the last year, one of the major problems was the COVID-19 pandemic that affected all spheres of our lives. Therefore, as part of University staff, this paper tries to show the effects of this pandemic and the impact that the use of electronic platforms has reached. Moreover, this study shows how many students and professors have achieved random requirements by diving them into four sections explained in methodology.

The main focus of this research is to indicate problems of online learning during the pandemic period by using e-learning services by the students and academic staff and also showing the dissatisfaction of these parts of research who have been the most affected ones. This shows the best that during recent months, there has been an important increase in infections of Covid-19, and the world has witnessed the way how this pandemic has affected a significant number of individuals all around the world.

Although the statistics are not certain yet, some studies have been reporting that this issue may exist in about three more years [1], [2]. So, the main purpose of this paper is to show the effects of E-learning on higher education specifically at the University of Prizren "Ukshin HOTI". This analysis is done with online surveys including three generations, first, second and third year of study. Furthermore, different subjects taught by many professors at the University of Prizren are included.

This pandemic has impacted various aspects of tuition, for instance, the formal model and traditional design of the academic and professional education programs by dividing them and by also bringing new challenges [3]. Suddenly, teachers were compelled to transfer to an electronic form of education, and this is reported by [4], in his research. The abrupt transition to online learning on an unexpected and not experimented extent caused disorder and uncertainty in numerous schools since they were not prepared and there was not enough time to do so [5], [6], [7]. E-learning was one possible learning approach that could be applied to conduct the educational procedure online during the COVID-19 pandemic. E-learning may help the education process since it can be accessed at any time and from any location without being limited by place or time. However, using this platform contains some disadvantages, too.

The main problems that students and teachers may encounter are the students' lower motivation, no proper students' engagement, and the missing communication between students and teachers. If carefully examined, all students have risen their ability to take decision behind the choice of an e-Learning platform and to gain more knowledge at the same time [8]. Another main problem of using the platform of online learning is the family conditions for which students depend on. It has been shown that there are two aspects of family concerns when its members have to use e-Learning.

Firstly, the financial conditions and incomes that deal with their ability of having the devices needed to join virtual classes, and secondly, the space they use during online learning that may be insufficient or small for students as well as facing internet connection problems [9]. E-learning platform has developed the facilities like chatting, screen sharing, and recording by making the video conferencing systems able to offer online communication for audio gatherings, video chat, and presentations.

For instance, universities and colleges in Kosovo have been holding the courses online while utilizing a range of video conferencing systems, including Google Meet, Zoom, Blue Jeans, and BigBlueButton [10].

This paper is organized as follows. In Section II, the research methodology which is divided in some different part of explanation will be discussed. The discussion of literature review is written in section III. In section IV, results and discussions of the paper are shown, and lastly, the paper finishes with the conclusion.

2 Literature review

In the literature, several studies have addressed the challenges associated with the introduction of e-Learning. According to Emmanuel Aboagye, et al [11], although engaging students in this pandemic era can be appropriate to keep them active and busy with studies, there are a lot of other challenges that should have been addressed before the pandemic era. Even the most powerful educational institutions and their students were forced to accept the new forms of learning by challenging themselves into adopting the online platform which was not used at such a high level of usage before, this problem is also identified by [12]. In different places, this pandemic has affected routines of activities, for instance, the Philippines Universities have been affected by this pandemic for which according to Ronnie E. Baticulon et al. [13], it has been shown that medical students, like students of other major confronted technological, individual, domestic, institutional, and community barriers were influenced as they tried to adapt to online learning. Some of these barriers are transient and expected to resolve with the global health crisis, others may persist or have long-term repercussions. Joi L. Moore et al. [14], propose an implementation of a mixed-method analysis of research articles to find out how they define the learning environment. To show the achieved results, 43 people have been survived and they discovered that there was inconsistent use of terminology for different types of delivery modes. In addition, the results revealed that there are different expectations and perceptions of learning environment labels such as distance learning, e-Learning, and online learning. Other research analyses propose to use different platforms such as Google Meet and Quiz Application to make learning more attractive for students. This happened for other levels of education such as elementary schools. Moreover, the authors used Indonesia, as a study case, which during the pandemic period time has encouraged students to learn more by having teachers or professors using quizzes applications to measure the knowledge of students even when it runs with any problem [15]. According to [16], it is shown that learners who were required to instantly adjust to distance education in the unexpected situation may be unaware of cyber security for which did not have enough time to adapt changes on their protecting way from this threat. E-learning enables teachers to reach a wider audience and deliver a more consistent message to their intended audience by making all students acquire the same information. Nonetheless, notwithstanding the growing spread of virtual learning, this method of acquiring knowledge has its drawbacks, too. A particular number of people tend to not use this method. Moreover, the highest proportion of students chooses classroom learning considering it more realistic and being able to communicate and talk with each other when they are in class [17]. Furthermore, distance education during an emergency may be extremely stressful for learners. However, there are various methods that can be used by learners so they achieve success in learning while facing this crisis. Some aspects of adapting the methods that appeared are having a good space and timing to learn, supporting each other, meditating or praying, working skills, reaching educators, and so on [18]. Moreover, according to the participants' results, the Coronavirus pandemic had a negative impact on learners' participation during e-learning due to the emergency situation characterized by various difficulties throughout the education process. For instance, some of the obstacles faced at this period were the issues related to infrastructure, culture, and digital inequality. Additionally, there were issues related to digital privacy that resulted in a negative impact on student participation in emergent distant education [19]. In order for these obstacles to be solved appropriately, it has been suggested that regulators, especially schools, need to develop broad programs in order to inform and educate learners on how to use e-learning [20]. Finally, the suggestions given to the management team are to establish knowledge on the significance of E-service, content, and use quality, as well as user satisfaction to effective use of virtual learning platform [21].

3 Methodology

This study used the quantitative method in which students have been able to evaluate each question by giving a certain weight to the answers provided by them known as the Likert scale method. The survey was prepared by using Google Forms that was shared through official e-mail addressed to all learners who study in University "Ukshin HOTI", Prizren. To analyze the results, the statistical program SPSS v.26 has been used in which various methods such as descriptive statistics, factor analysis, reliability, linear regression, and One-Way ANOVA analysis will be taken to analyze the data from the shared questionnaire.

3.1 Research questions

To be more accurate, several research questions have been increased. These questions will be answered in the results and experiments part and then compared. These two research questions are given below:

- R1: Do students differ based on their academic level and does age impact it?
- R2: Given the social impact that the C-19 has had so far, has it made the difference between students, knowledge of technology, and the academic preparation that students can have?

3.2 Hypotheses

According to the literature review and the papers, in this reviewed process, we increase four hypotheses and they will be proven (accepted, supported or rejected through different techniques based on the achieved results.

- H1: The academic part affects the effectiveness of online learning;
- H2: The technological part affects the effectiveness of online learning;
- H3: The social part affects the effectiveness of online learning;
- H4: The academic part, the technological part, and the social part have a mutual effect on the effectiveness of online learning;

Initially, the descriptive analysis will be used to describe the sample as well as to find basic statistics such as mean standard deviation for all variables.

3.3 Primary data

The primary data is the questionnaire prepared on the use of digital platforms at the University "Ukshin HOTI", Prizren. The questionnaire is based on Emmanuel Aboagye et al. [11], however, these questions are appropriately adapted for students of the University of Prizren.

The questionnaire is divided into four parts such as Effectiveness of Online Learning, Academic Part, Technological part, and Social Part. In focus, we have addressed the challenges of using services such as Google Meet, SMU (University Management System), Google Classroom, Google Calendar, and other web services which are mainly used for quizzes, tests, and other forms depending on the teachers.

A total of 26 questions were asked and out of these questions, we have 198 respondents, both male and female gender from different ages within the bachelor studies.

Except for demographic information, all other questions are measured according to the Liker scale.

3.4 Secondary data

In order to show the real situation, we will use different research, for example, scientific papers, research, reports, and different results which will have a foundation with the developed material. These materials will focus on the most powerful and credible databases so that the research to present the real situation. Also, the reports issued by the University itself will be taken as a basis of the development process in this time period.

This will help us generate the current state or state-of-the-art. The extracted materials will be mainly focused on getting them in databases such as ACM, IEEE, Scopus, Web of Science, Scopus, DOAJ, etc. Moreover, we will try to get away from sources that are not secure and that are published on platforms that do not have a secure source. This will help us to generate more accurate and clear information, and also data in our work.

4 Findings and analysis

In this section, we have shown the results are gained by using SPSS. Moreover, we have tested the hypotheses and the results are shown below. As mentioned in the methodology part, we used linear regression technique, factor analysis, and One-Way ANOVA to see if the hypotheses are supported, accepted, or rejected. The questionnaire is divided into four parts such as Effectiveness of Online Learning, Academic Part, Technological Part, and Social Part.

4.1 Descriptive statistics

Table 1 presents the frequency distribution for gender and age. In total, 198 students have participated in our research. Of all students, 13.1% are males and 86.9% are females. 76.3% of students are under 22 years old, 16.2% of them belong to 22-27 years interval and only 7.6% are older than 27 years.

Table 1. Frequency distribution (n=198)

Variables		Frequency	Percent
Gender	Male	26	13.1
	Female	172	86.9
Age	Under 22	151	76.3
	22-27	32	16.2
	Over 27	15	7.6

Source: Authors'

In order to test the validity and reliability of the scale, we have performed factor analysis and reliability analysis. Table 2 provides the results of factor analysis. The value of KMO of 0.938 shows that the data set is suitable for running the factor analysis. Total Explained Variance is 68.025 and this value is high enough. Our scale consisted of 26 questions, but two of them were removed due to low factor loadings. Therefore, factor analysis proceeded with 24 items.

When using the varimax method, four factors were obtained at the end of the factor analysis. The first factor has 9 items, for instance, "Online learning cannot achieve student objectives", "Online learning environment is not motivating", etc. and these items are related to the effectiveness of online learning. Therefore, the first factor is named "Effectiveness of Online Learning", then, the second factor has 7 items, for instance, "Course materials are unclear and submitted late", "Professors are not trained to teach online", etc.

These items are related to the academic part of the professors, therefore, this factor is named as "Academic Part". The third factor has 4 items such as "The technology that has been used has serious problems in access, and it is often unavailable", "Problems with the operation/access to lectures", and so on. These questions are related to the technological part of online learning, therefore, this factor can be named as the "Technological part". Finally, the fourth factor also has 4 items. Two of them are "Online learning is very personal", and "Lack of communication between students". These questions are related to the social part of the interaction between students, so this factor is named as "Social Part".

The Reliability Statistics in Table 3 shows the reliability coefficient of the study. The Alpha coefficient for the overall scale that includes all questions is 0.952 and this value indicates that the scale used is very reliable. Furthermore, the reliability of each factor obtained from the factor analysis is tested. The Alpha reliability coefficient for the Effectiveness of the Online Learning Factor is 0.928 indicating that this factor is reliable to a high degree. The reliability coefficient for the Academic Part Factor is 0.895 and this value indicates that this factor is very reliable.

The reliability coefficient for the Technological Part Factor is 0.903, and this indicates that this factor is very reliable. The reliability coefficient for the Social Part Factor is 0.764 and this value indicates that the reliability of this factor is quite high. Hence, we can say that our scale is valid and reliable at the same time.

Table 2. Factor analysis results

KMO	.938			
Total Explained Variance	68.025			
	1	***2***	***3***	***4***
Learning on internet cannot achieve student objectives	.775			
The online learning environment is not motivating	.771			
Online lectures are as not effective as physicall lectures	.767			
I miss the personal motivation to learn on internet/ online	.766			
Online lectures are boring for me	.742			
I preferer that learning through internet to stop	.729			
From the begining of pandemic, my average mark is decreased due to online learning	.646			
I prefer the semester to postpone	.600			
Made students more isolated during the online learning period	.559			
Course materials unclear and submitted late		.779		
Professors are not trained for online learning		.720		
Lack of reading skills during online learning		.698		
Professors have troubles providing online learning assistance		.678		
Lack of good writing skills		.677		
Lack of effective communication skills during online learning		.600		
Low quality of online materials		.478		
The technology used has serious access problems and is often unavailable			.801	
Problems with functioning / access to lectures.			.788	
Some accessories (phones or laptops) are not suitable			.777	
Accessing problems to teaching materials			.678	
Learning online is very personal				.764
Lack of communication between students				.632
Lack of group discussions when solving tasks				.596
Learning online is incredibly indirect				.557

Table 3. Reliability analysis results

	Cronbach's Alpha	**N of Items**
Overall reliability	.952	24
Effectiveness of Online Learning	.928	9
Academic Part	.895	7
Technological Part	.903	4
Social Part	.764	4

4.2 Hypotheses testing

H1: The academic part affects the effectiveness of online learning. To test this hypothesis, we have used linear regression analysis. The model summary (R2=0.483) in Table 4 shows that the Academic Part (AP) explains 48.3% of the change in Effectiveness of Online Learning (EOL) and this regression model is significant (F=183.249, p=0.000). The coefficient of AP has a significant effect on EOL (ß=0.797, p=0.000). Consequently, we support our first hypothesis.

Table 4. Results of regression analysis for effect of AP on EOL

Dependent Variable	Independent Variables	B		T	p	F	Model (p)	R	R^2
EOL	Constant	.956		5.289	.000	183.249	.000	.695	.483
	AP	.797		13.537	.000				

H2: The technological part affects the effectiveness of online learning. For the second hypothesis, we have used regression analysis, too. The model summary (R2=0.411) in Table 5 shows that Technological Part (TP) explains 41.1% of the change in Effectiveness of Online Learning (EOL) and the regression model is significant (F=135.506, p=0.000). The coefficient of TP has a positive and significant effect on EOL (ß=0.669, p=0.000). On account of this result, the second hypothesis is supported.

Table 5. Results of regression analysis for effect of TP on EOL

Dependent Variable	Independent Variables	β	t	p	F	Model (p)	R	R^2
EOL	Constant	1.096	5.582	.000	135.506	.000	.641	.411
	TP	.669	11.684	.000				

H3: The social part affects the effectiveness of online learning. Similarly, to test the third hypothesis, we have used regression analysis. The model summary of regression analysis (R2=0,390), in Table 6, shows that Social Part (SP) explains 39% of the change in Effectiveness of Online Learning (EOL) and the model is significant as a whole (F=125.203, p=0,000). The coefficient of Beta shows that Social Part has an effect of 78.9% on the Effectiveness of Online Learning and this effect is significant (p=0,000).

Table 6. Results of regression analysis for effect of SP on EOL

Dependent Variable	Independent Variables	β	t	p	F	Model (p)	R	R^2
EOL	Constant	.796	3.460	.001	125.203	.000	.624	.390
	SP	.759	11.189	.000				

H4: The academic part, the technological part and the social part have a mutual effect on the effectiveness of online learning. After testing the individual effect of three factors on EOL, we tested the interaction of the three factors at once using regression analysis. The mode summary in Table 7 shows that AP, TP, and SP explain 59.2% of the change on EOL (R2=0.592) and this model is significant (F=93.888, p=0,000). When we check the coefficients, we see that AP has an effect of ß=0.432, p=0.000, TP has an effect of ß=0.262, p=0.000, and SP has an effect of ß=0.329, p=0.000. Accordingly, the fourth hypothesis is supported.

Table 7. Results of regression analysis for the mutual effect on EOL

Dependent Variable	Independent Variables	β	t	p	F	Model (p)	R	R^2
EOL	Constant	.089	.440	.660	93.888	.000	.770	.592
	AP	.432	5.882	.000				
	TP	.262	4.036	.000				
	SP	.329	4.640	.000				

4.3 Differences on factors by gender and age

To test whether there is any difference in the factors obtained from factor analysis by gender, we have performed independent samples t-test. Table 8 provides the statistics of this test. Based on T and Sig values, we can see that only the Technological Part (TP) factor significantly differs according to gender (t=-2.029, p=0.044). If we compare the means for this factor, the mean of males is 2.8462 and the mean of females is 3.3110. This difference shows that female students have been facing more technical issues than male students. Therefore, only the hypothesis. ?? qka only ?

H: Technological part differs by gender is supported.

Table 8. Results of t-test for the differences on factor by gender

Factor	Gender	Mean	Std. Deviation	t	Sig.
EOL	Male	3.2607	1.24640	−.044	.965
	Female	3.2713	1.13389		
AP	Male	2.9725	.95620	.382	.703
	Female	2.8920	1.00777		
TP	Male	2.8462	1.22898	−2.029	.044
	Female	3.3110	1.06714		
SP	Male	3.2788	1.08242	.123	902
	Female	3.2544	.92262		

To test the differences in factors according to age, we have used One-Way ANOVA. For the first factor, EOL, there is a significant difference between students under 22 years old and students over 27 years old (F=8.115, p=0.000). The mean difference is 1.06824 for p=0.001. This difference shows that students under 22 years have greater effectiveness of online learning than students over 27 years old. To this end, hypothesis ***H: Effectiveness of online learning differs by students' age is successfully accepted.***

For the second factor, there is a significant difference between students under the age of 22 years and students over 27 years old (F=3.723, p=0.026). The mean difference is 0.72785 for p=0.019. This difference shows that students under 22 years have greater academic part issues than students over 27 years old. In consequence, hypothesis ***H: The academic part differs by students' age*** is supported.

For the third factor, there is a similar difference between the upper groups and also a difference between students of age 22-27 and over 22 years old (F=11.516, p=0.000). The mean difference for the first group is 1.30894 for p=0,000 and for the second group is 0.93906, p=, 0.12. These differences show that students over 27 years old have greater issues on technological part than students under 22 years and 22-27 years. In as much as, the hypothesis ***H: The technological part differs by students'*** age is supported.

Finally, the results of One-Way ANOVA show that social part factor does not differ by age (F=1,903, p=0,152). In this case, hypothesis ***H: The social part differs by students' age*** is rejected.

Table 9. Results of one-way ANOVA for the differences on factor by age

Factor	F	Sig.	Difference	Mean Difference	Sig
EOL	8.115	.000	Under 22 years & Over 27 years old	1.06824	.001
AP	3.723	.026	Under 22 years & Over 27 years old	.72785	.019
TP	11.516	.000	Under 22 years & Over 27 years old 22-27 years & Over 27 years old	1.30894 .93906	.000 .012
SP	1.903	.152	/	/	/

4.4 Comparison of evaluation of two forms of learning

In order to achieve different statements that are divided into two forms of learning, online and physically, the results are taken just to compare in one subject (Human Resource Management).

The difference between the two parts of students is immense enough due to several cases which are explained in the analysis. If carefully analyzed, the students who failed the exam when doing it in the online form are 41, whereas there are 10 students who got the six mark, 8 of them got seven, 10 students got eight, 13 students got nine, and only 2 students got the higher mark. If we compare with physical learning, this one has more students who have achieved the higher mark. There are 7 out of 84 students who got ten, 6 students got nine, eight students got 8, 23 students got seven, and 9 of them go six. In addition, out of 84 students, 31 failed this exam.

As seen in Table 10, the level of pass ability in physical form is better than in electronic form. Figure 1 visually shows that the average passing rate for students who have attended online form is 6.40 indicating that it is a general passing grade. On the other hand, the average grade of students who learned in face-to-face form is 6.64 while having the same syllabus and teacher or assistant. Although this was a small difference, yet, this shows that students have managed to gain more knowledge based on the semester evaluation obtained according to the final evaluation.

Table 10. Marks from two forms learning, e-learning and physically

(Marks)	Online	(Face-to-Face)
5	41	31
6	10	9
7	8	23
8	10	8
9	13	6
10	2	7

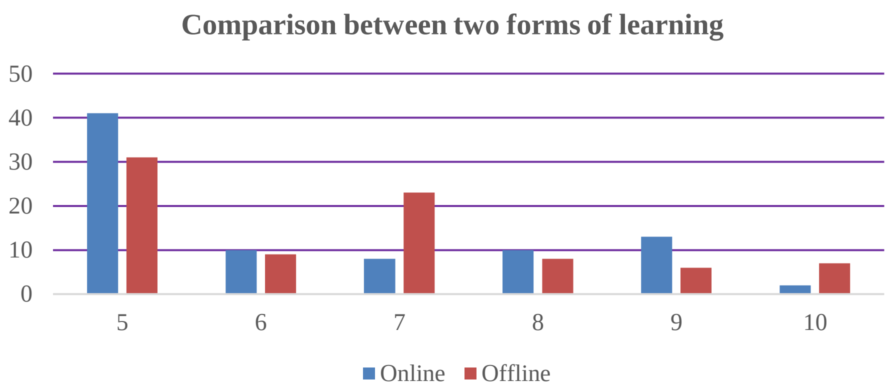

Fig. 1. Comparison between two forms of learning at University "Ukshin HOTI" Prizren

5 Conclusion

The current situation and the consequences that we carry as a society will continue to be present either in the emotional perspective or in the challenges that we continue to have in the recovery of the problems created so far. As a result, higher education institutions in the Republic of Kosovo have not been less affected in this regard, which have managed to create solutions to various current situations and then modify them as longer-term solutions, according to the experience that has been achieved in this direction. Although e-Learning used to be just evolving, with the pandemic situation, it got a very big boost and its use was a must for everyone. Students and teachers were very skeptical about this form of teaching, as the challenges were too great and the adaptation of teachers who were not familiar with the technology was an essential problem.

The present study analyses the perception of university students of the e-Learning form of learning before and during the COVID-19 pandemic. After testing the individual effect of three factors on EOL, we tested the interaction of the three factors at once using regression analysis. AP, TP, and SP explain 59.2% of the change on EOL

($R2=0.592$) and this model is significant ($F=93.888$, $p=0,000$). When we check the coefficients, we see that AP has an effect of ß=0.432, p=0.000, TP has an effect of ß=0.262, p=0.000, and SP has an effect of ß=0.329, p=0.000. If carefully seen, after evaluation of dataset, the factors obtained from factor analysis by gender we have performed independent samples t-test. This difference shows that female students have been facing more technical issues than male students. Besides, there is a significant difference between students under 22 years old and students over 27 years old. The mean difference is 1.06824 for p=0.001. This difference shows that students under 22 years have greater effectiveness of online learning than students over 27 years old. These differences show that students over 27 years old have greater issues on technological part than students under 22 years and 22-27 years.

Further, academic issues relationship between students of the age under 22 years and students over 27 years old show a significant difference. The mean difference is 0.72785 for p=0.019. This difference shows that students under 22 years have greater academic part issues than students over 27 years old. However, this is not the same in the technological part as the technological relationship between these age domains. Experience makes a person achieve things in a more professional way most of the time because he has gone through those stages and this gives the best results. Since there is a similar difference between the upper groups and also a difference between students of age 22-27 and over 22 years old ($F=11.516$, $p=0.000$). The mean difference for the first group is 1.30894 for p=0,000, and for the second group is 0.93906, p=, 0.12. These differences show that students over 27 years old have greater issues on technological part than students under 22 years and 22-27 years.

The findings of this study reflect the relationship of four models and how they can differ considering the results before (physically) of Covid-19 and during (e-Learning) this period. If we look at the results of students who have attended face-to-face learning, there is a better average of 6.64% out of 84 students who have been evaluated for each year. Whereas, if we look at students who have continued their activities in virtual form, there is a general decrease in the total assessment of an average of 6.40, this total value derived from the same number as physically.

The implication of the study shows a relationship between opportunities to learn remotely and using in the best form these tools. This form helps students and teachers to save their time and to do the same thing. It is clear that the way you can teach students in physical form, in the same way, you can use the same tools to teach them online, nothing can stop you from sharing the main information for what you plan to do on that day. Technology, in general, has impacted our daily lives even more by the methods and techniques of learning. Therefore, it is crucial that the whole society advances the knowledge on technology and on how we should use it.

Moreover, this paper contributes its most to show how the institution which we have taken as a case study has faced this period of time. Additionally, this is a good example of comparison with other different institutions on how to manage the "damages" of this experience that has never challenged us previously.

The limitations of this study were the lack of research and the form of presenting the results by using advanced software. Moreover, it is significantly important to mention that one of the main goals of this research's results was on getting correct answers from more respondents since in online mode everyone tries to finish the surveys, however, they are less likely to read it carefully and fulfill it.

In the future work, we plan to show the results of before, during the pandemic, and post-pandemic, the impact the form of learning and teaching in this and other public institutions had, and draw a comparison between them.

6 References

[1] Stephen M. Kissler et al.,, "Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period," *Science,* vol. 368, no. 6493, pp. 860--868, 2020. https://doi.org/10.1126/science.abb5793

[2] Siham Tabik et al., , "COVIDGR dataset and COVID-SDNet methodology for predicting COVID-19 based on Chest X-Ray images," *IEEE journal of biomedical and health informatics,* vol. 24, no. 12, pp. 3595--3605, 2020. https://doi.org/10.1109/JBHI.2020.3037127

[3] Rachel Hilburg et al.,, "Medical education during the COVID-19 pandemic: learning from a distance," *Advances in Chronic Kidney Disease,* vol. vol: 27, no. 5, pp. 1--17, 2020. https://doi.org/10.1053/j.ackd.2020.05.017

[4] S. Dhawan, "Online learning: A panacea in the time of COVID-19 crisis," *Journal of Educational Technology Systems,* vol. vol: 49, no. 1, pp. 5--22, 2020. https://doi.org/10.1177/0047239520934018

[5] J. Daniel, "Education and the COVID-19 pandemic," *Prospects,* vol. vol: 49, no. 1, pp. 91--96, 2020. https://doi.org/10.1007/s11125-020-09464-3

[6] R. ElSaheli-Elhage, "Access to students and parents and levels of preparedness of educators during the COVID-19 emergency transition to e-learning," *International Journal on Studies in Education,* vol. vol: 3, no. 2, pp. 61--69, 2021. https://doi.org/10.46328/ijonse.35

[7] Simon Burgess and Hans Henrik Sievertsen, "Schools, skills, and learning: The impact of COVID-19 on education," voxeu.org, 2020.

[8] Arghya Raya et al.,, "Exploring values affecting e-Learning adoption from the user-generated-content: A consumption-value-theory perspective," *Journal of Strategic Marketing,* vol. 29, no. 5, pp. 1--23, 2020. https://doi.org/10.1080/0965254X.2020.1749875

[9] Luciana Oliveira et al.,, "Emergency Remote Learning during COVID-19: socio-educational impacts on Portuguese students," *Educating Engineers for Future Industrial Revolutions,* vol. 1328, no., pp. 303--314, 2021. https://doi.org/10.1007/978-3-030-68198-2_28

[10] Ereza Baftiu and Krenare Pireva Nuci, "The transformation process from in-campus classes into online classes due to the COVID-19 situation--the case of higher education institutions in Kosovo," *arXiv preprint arXiv:2104.03896,* pp. 1--12, 2021.

[11] Emmanuel Aboagye, et al, "COVID-19 and E-Learning: the Challenges of Students in Tertiary Institutions," *Social Education Research,* pp. 1-8, 2020. https://doi.org/10.37256/ser.212021422

[12] Mohammed Arshad Khan et al., "Students' Perception towards E-Learning during COVID-19 Pandemic in India: An Empirical Study," *Sustainability,* vol. 13, no. 57, pp. 1-14, 2021. https://doi.org/10.3390/su13010057

[13] Ronnie E. Baticulon et al., "Barriers to Online Learning in the Time of COVID-19: A National Survey of Medical Students in the Philippines," *Medical Science Educator, Springer,* pp. 1-12, 2021. https://doi.org/10.1007/s40670-021-01231-z

[14] Joi L. Moore et al., "e-Learning, online learning, and distance learning environments: Are they the same?," *Internet and Higher Education, Science Direct, Elsevier,* pp. 1-7, 2011.

[15] Atika Rahmah Nasution, Asep Bayu Dani Nandiyanto, "Utilization of the Google Meet and Quiziz Applications in the Assistance and Strengthening Process of Online Learning

during the COVID-19 Pandemic," *Indonesian Journal of Educational Research and Technology*, pp. 31-34, 2021. https://doi.org/10.17509/ijert.v1i1.33367

[16] Erwin Rotas and Michael Cahapay , "Does threat knowledge influence protective behaviors of students in the context of cyber security in remote learning amid COVID-19 crisis?," *Journal of Pedagogical Sociology and Psychology*, vol. 3, no. 1, pp. 45--53, 2021. https://doi.org/10.33902/JPSP.2021167595

[17] Rajapandian Radha et al.,, "E-Learning during Lockdown of Covid-19 Pandemic: A Global Perspective," *International journal of control and automation*, vol. 13, no. 4, pp. 1088--1099, 2020.

[18] Erwin Rotas and Michael Cahapay, "From stress to success: Exploring how Filipino students cope with remote learning amid COVID-19 pandemi," *Journal of Pedagogical Sociology and Psychology*, vol. 3, no. 1, pp. 27--35, 2021. https://doi.org/10.33902/JPSP.2021366608

[19] Zuheir N. Khlaif et al.,, "Emergency remote learning during COVID-19 crisis: Students' engagement," *Education and information technologies*, vol. 26, no. 3, pp. 1--23, 2021. https://doi.org/10.1007/s10639-021-10566-4

[20] Abdulsalam Almanthari et al.,, "Secondary school mathematics teachers' views on e-learning implementation barriers during the COVID-19 pandemic: The case of Indonesia," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 16, no. 7, pp. 1--9, 2020. https://doi.org/10.29333/ejmste/8240

[21] Arfan Shahzad et al.,, "Effects of COVID-19 in E-learning on higher education institution students: the group comparison between male and female," *Quality & Quantity*, vol. 55, no. 3, pp. 805--826, 2021. https://doi.org/10.1007/s11135-020-01028-z

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Feasibility Analysis of Visual Interaction Mode in Digital Art Design Teaching

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Abstract—The visual presentation of teaching contents facilitates students to master the relevant knowledge and skills of digital art design (DAD). The existing studies focus on the construction of traditional classroom teaching and interaction strategies, but rarely tackle the visual interaction (VI) technology of synchronous online classroom. This paper analyzes the feasibility of VI mode in DAD teaching. Firstly, the authors detailed the realization steps for teacher-student VI in the DAD teaching process control platform, and constructed the topology of VI system in DAD teaching. After a data analysis on VI flow, the authors parsed the VI flow data, and encoded the teacher-student VI involved in DAD teaching. Based on the improved neural network, a model was established to predict the degree of realization for course goals of DAD teaching. Through experiments, the teacher-student VI in DAD teaching was described statistically, and the relevant analysis results were obtained, which verify the effectiveness of our prediction model.

Keywords—visual interaction (VI), digital art design (DAD), feasibility analysis

1 Introduction

The effectiveness of teacher-student interaction directly affects the effect of classroom teaching [1-8]. The visualization of text, image, and video data has been widely applied in various industries and social groups, and can be introduced to the teaching of design courses [9-15]. Compared with traditional offline classroom, the synchronous online classroom of digital art design (DAD) involves highly complex teacher-student interactions. It is extremely difficult to realize high-quality teaching in the virtual scenario [16-20]. The visual presentation of teaching contents facilitates students to master the relevant knowledge and skills of DAD. To apply and promote visual interaction (VI) mode to DAD teaching, it is important to observe the records, process, interaction problems, and causes of these problems of DAD course teaching.

Massive open online courses (MOOCs) lack the sense of immersion. To solve the problem, Zhang et al. [21] explored the key techniques, constructed an interactive MOOC system based on virtual reality (VR), and improved the system to enhance the immersive and interactive feelings of users in virtual scenes. Qi [22] introduced a case study on providing an interactive and collaborative environment for remote teaching, reviewed the existing multi-user collaboration environments, summarized the requirements of supporting remote teaching with collaborative environment, and analyzed how the open platform of Wonderland satisfies these requirements. It was learned that such an environment fully supports the entire learning process. Open educational resources (OER) have been successfully applied to teaching challenging disciplines. Cacho et al. [23] proposed a new virtual memory teaching method, which simulates the main elements of the memory hierarchy, and described the classroom plan and its application in OER Amnesia. The results show that the improvements of up to 180% in scores of students when they use Amnesia to learn virtual memory. Tourou et al. [24] discussed the current development trend of e-learning, such as virtual experiments and remote experiments in electronic engineering education, introduced a network-based wind energy conversion and control learning module, detailed graphic user interface and experimental operations, and talked about different learning goals and interaction possibilities. Ding and Li [25] proposed an interactive teaching mode based on the Proteus virtual laboratory. This teaching model helps stimulate students' learning interest, improve their learning efficiency and practical ability, and promote the teaching curriculum reform of single-chip machines.

The existing studies on teaching interaction emphasize the construction of traditional classroom teaching and interaction strategies over the VI technology of synchronous online classroom. Therefore, this paper analyzes the feasibility of VI mode in DAD teaching. The main contents are as follows: (1) Detailing the realization for teacher-student VI in the DAD teaching process control platform; (2) Constructing the topology of VI system in DAD teaching; (3) Analyzing the data of VI flow, and encoding the teacher-student VI involved in DAD teaching; (4) Building a prediction model for the degree of realization for course goals of DAD teaching, based on the improved neural network: the realization degree was predicted with teacher-student VI behaviors VI1-18 as the model inputs. Finally, experiments were carried out to describe the teacher-student VI in DAD teaching statistically, produce the relevant analysis results, and verify the effectiveness of our prediction model.

2 VI realization

In DAD teaching, the VI aims to display the design process and aesthetic laws of many aspects of DAD, including design environment, visual principles, application range, and basic elements, to students via the visual system. On the DAD teaching process control platform, the visual display of DAD results is the goal for the transmission and conversion of teacher-student interaction information. Facing different types of student needs, the teaching process control platform properly presents the DAD images recommended by teachers. Then, the students feed back the acquired information to teachers and the platform, wrapping up the teaching process control. Figure 1 shows the topology of the VI system in DAD teaching. This paper details the realization steps of teacher-student VI on DAD teaching process control platform.

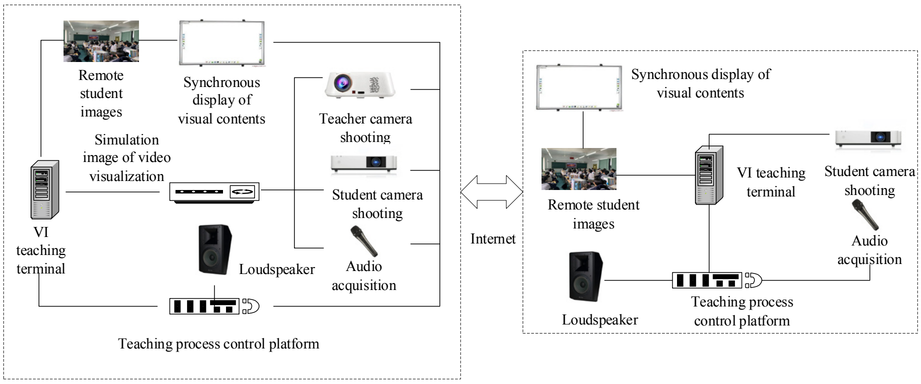

Fig. 1. Topology of VI system in DAD teaching

During DAD teaching, there are many kinds of image data requiring teacher-student VI. If the visual contents (e.g., tables, images, videos, and three-dimensional (3D) models) are selected blindly, it would be impossible to establish effective teacher-student VI, but impede the teaching process. Thus, it is important to choose the visual contents properly, according to the personalized needs of students. The contents can be selected and classified using the mind map, after analyzing the functions and applicable scenarios of mainstream visual presentation techniques.

To visualize DAD teaching process, it is necessary to analyze the students' interaction needs during DAD teaching, and complete VI according to the personalized needs of the students. This section defines several subjects in DAD teaching, including students, platform administrators, and teachers, and completes VI in the light of the VI needs of each kind of subjects.

To realize coordinated, efficient cooperation between students, platform administrators and teachers, this paper groups the students by interaction needs, and designs the visual display of images for each group. The grouping improves the display effect and accuracy. From the angle of teaching process, a complete DAD teaching process should begin with the teachers' definition of DAD teaching goals, and preparation of global teaching plan for the goals. Based on each link of the global teaching plan, phased teaching goals should be determined, and specific classroom teaching plans should be formulated. The students participate in the teaching process, and enter VI with teachers and other students. In this way, they learning the relevant knowledge of DAD, and acquire the ability to complete DAD independently. The students' evaluation of VI teaching provides a reference for platform administrators and teachers to management and push information, and reflect on teaching.

For DAD teaching process control, an important step is to display the key visual contents of DAD teaching process. The key visual contents of teaching should be determined, according to the specific needs of each student group.

Platform administrators intend to grasp the overall DAD teaching process, and recommend visual contents more accurately, such that the students in different groups can learn with the least difficulty. Institutive visual images should be presented directly to illustrate the steps of DAD. To implement VI, platform administrators need to fulfil three tasks: visualization of overall teaching progress, visualization of the completion degree of teaching goals, and the execution flow of the platform.

During the VI, teachers attempt to teach the relevant knowledge of DAD, and know the level of knowledge mastery of students through the interaction. Based on the interactive performance and evaluation of students, the teachers should adjust the execution of DAD teaching process. To implement VI, teachers need to visualize teaching traces, and visualize DAD tasks.

3 Data analysis on VI flow

This paper mainly analyzes the VI data on the platform, including the students' mastery of DAD knowledge, degree of realization of teaching goals, and execution progress of DAD teaching. The VI data were collected from DAD teaching, and preprocessed before being entered into the evaluation matrix.

Suppose there are m teaching links $X_i(0<i<=m)$. The score proportion of X_i in the DAD course is denoted as P_i. Each teaching link X_i contains s items $X_{ij}(0<j<=s)$. The score that should be obtained on each item is denoted as B_{ij}. Let g be the goals of the DAD course. The goal of each teaching link is denoted as Y_n. Then, the proportion of goal Y_n in each item of teaching link X_i is denoted as S_{ijn}. The actual score of students for each item of teaching link X_{ij} is denoted as A_{ij}. The actual total score of goal Y_n in teaching link X_i is denoted as A_{ni}. The score that should be obtained on link X_i is denoted as R_{ni}. The realization degree of the goal of link X_i, and that of the overall goal are denoted as U_{ni}, and U_n, respectively. Then, we have:

$$R_{ni} = \sum_{j=1}^{s} B_{ij} O_{ijn} \tag{1}$$

$$A_{ni} = \sum_{j=1}^{s} A_{ij} O_{ijn} \tag{2}$$

$$U_{ni} = \frac{A_{ni}}{R_{ni}} \tag{3}$$

$$U_{ni} = \frac{\sum_{i=1}^{m} A_{ni} P_i}{\sum_{i=1}^{m} R_{ni} P_i} \tag{4}$$

The realization degree of DAD teaching goals can be solved by the above formulas. To solve the overall realization degree of DAD course goals, the realization degrees of all students corresponding to the preprocessed data should be averaged. Then, the behaviors of the students with weak interests in VI and low realization degree of DAD course goals were mined and analyzed to identify the problematic teaching links, in order to improve the VI contents and modes. The flow of VI data analysis is displayed in Figure 2.

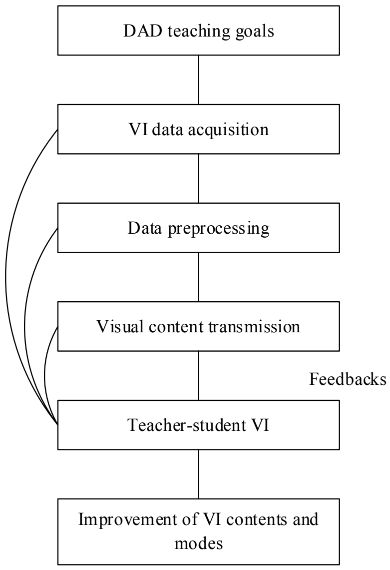

Fig. 2. Flow of VI data analysis

This paper encodes the teacher-student VI behaviors involved in DAD teaching. The following VI behaviors of teachers were encoded as VI1-8: acknowledgement of student performance, praise of student performance, acceptance of interaction request, raising questions about visual contents, raising summative questions, explaining visual contents, guiding the understanding of visual contents, and criticizing student performance. The following VI behaviors of students were encoded as VI9-13: collective response to teacher interaction, active individual response to teacher interaction, passive individual response to teacher interaction, raising questions about visual contents, and participating the themed discussion of visual contents. The following non-interactive course states were encoded VI14-16: chaotic state, student reflection or autonomous learning, and DAD practice. In addition, the following VI techniques were encoded VI17-18: teacher operation technology, and student operation technology.

Then, the proportion of verbal behaviors in teachers' VI can be calculated by:

$$\delta_1 = \frac{\sum_{i=1}^{8} VI_i}{\sum_{i=1}^{13} VI_i} \tag{5}$$

The proportion of raising questions in teachers' VI can be calculated by:

$$\delta_2 = \frac{\sum_{i=4}^{5} VI_i}{\sum_{i=1}^{13} VI_i} \tag{6}$$

The proportion of lecturing in teachers' VI can be calculated by:

$$\delta_3 = \frac{VI_6}{\sum_{i=1}^{8} VI_i} \tag{7}$$

The proportion of raising questions about visual contents in teachers' VI can be calculated by:

$$\delta_4 = \frac{VI_4}{VI_4 + VI_5} \tag{8}$$

The proportion of raising summative questions in teachers' VI can be calculated by:

$$\delta_5 = \frac{VI_5}{VI_4 + VI_5} \tag{9}$$

The ratio of indirect effect to direct effect in teachers' VI can be calculated by:

$$\delta_6 = \frac{\sum_{i=1}^{5} VI_i}{\sum_{i=6}^{8} VI_i} \tag{10}$$

Then, the proportion of verbal behaviors in students' VI can be calculated by:

$$\delta_7 = \frac{\sum_{i=9}^{13} VI_i}{\sum_{i=1}^{13} VI_i} \tag{11}$$

The proportion of non-interactive course states can be calculated by:

$$\delta_8 = \frac{\sum_{i=14}^{16} VI_i}{\sum_{i=1}^{13} VI_i} \tag{12}$$

The proportion of VI technology usage can be calculated by:

$$\delta_9 = \frac{VI_{17} + VI_{18}}{\sum_{i=1}^{13} VI_i} \tag{13}$$

4 Prediction of VI feasibility

Figure 3 shows the flow of VI feasibility prediction. This paper combines the multiple factors affecting the realization of course goals of DAD teaching, and establishes a prediction model for the realization degree of these goals. The teacher-student VI behaviors VI1-8 were imported to the model, in order to predict the realization degree of course goals of DAD teaching.

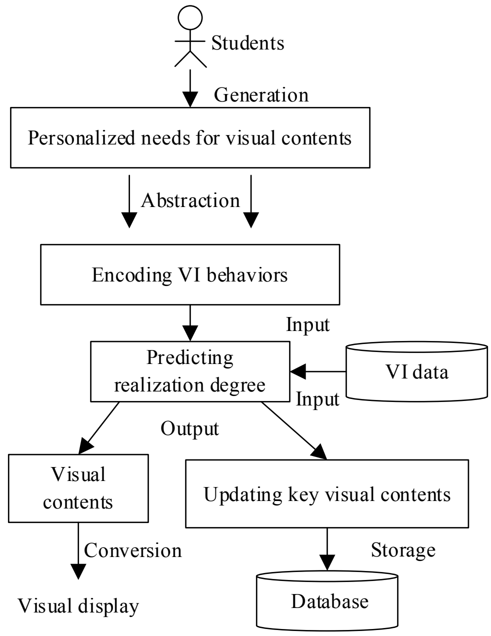

Fig. 3. Flow of feasibility analysis

VI has many common features with traditional teacher-student interaction, and differs with the latter in many respects. This paper explores the relationship between 18 factors and the realization degree of course goals of DAD teaching. Our neural network consists of an input layer, an output layer, and a hidden layer. The different layers are connected in one direction by nodes. Let g be the nonlinear activation function; w be the threshold of nodes. Then, the hidden layer output can be modeled by:

$$P_j = g\left(\sum Q_{ij} \times A_i - w_j\right) \tag{14}$$

The output layer output can be modeled by:

$$B_l = g\left(\sum E_{jl} \times P_j - w_l\right) \tag{15}$$

Sigmoid function was selected as the activation function:

$$g(a) = 1/\left(1 + e^{-a}\right) \tag{16}$$

Let e_{oi} be the expected output of node i; P_{oi} be the output corresponding to i. The error between expected output and calculated output can be expressed as:

$$T_o = 1/2 \times \sum \left(e_{oi} - P_{oi}\right)^2 \tag{17}$$

Let ω_{ij} be the weight matrix between the nodes on the lower layer and the nodes on the upper layer. The learning process of the neural network can be viewed as a setting and error correction of ω_{ij}. Let f be the learning factor; Ψ_i be the calculation error of output node i; P_j be the calculated output of output node j; β be the momentum factor. Then, the self-learning model of the neural network can be expressed as:

$$\Delta\omega_{ij}\left(m+1\right) = f \times \Psi_i \times P_j + \beta \times \Delta\omega_{ij}\left(m\right) \tag{18}$$

5 Experiments and results analysis

To effectively enhance the teaching effect, the key links of DAD teaching include stimulating the learning interest, and attracting the students to the visual contents. Figure 4 summarizes the visual modes preferred by students. It can be seen that the students prefer visual contents like tables, images, videos, and 3D models. The pure text form of traditional teaching mode can no longer meet the needs of DAD learners. On the display of DAD results, 3D models are more likely to attract the attention of students than two-dimensional (2D) images, which are not so realistic and stereo. Using 3D models, the students can understand the DAD process clearly, and comprehend DAD knowledge more profoundly, rapidly, and efficiently. This further demonstrates the necessity of applying VI technology in DAD teaching.

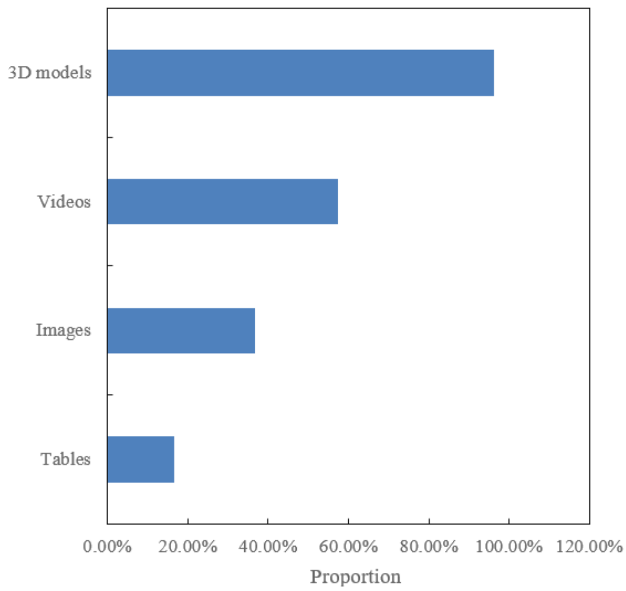

Fig. 4. Summary of visualization modes preferred by students

The overall teacher-student VI behaviors involved in DAD teaching were statistically analyzed as shown in Table 1.

Table 1. Descriptive statistics on VI behaviors

Variables	Symbols	*N*	Minimum	Maximum	Mean	Standard deviation	Variance
Teacher interaction	*VI*1	98	0	8	3.25	1.147	1.025
	*VI*2	93	2	4	3.04	1.326	1.686
	*VI*3	92	4	6	3.62	1.528	1.928
	*VI*4	92	2	4	3.29	0.741	1.360
	*VI*5	96	6	8	3.17	1.306	1.092
	*VI*6	93	4	6	3.07	1.852	1.825
	*VI*7	97	2	4	3.64	1.936	1.637
	*VI*8	95	3	5	3.92	0.792	1.924
Student interaction	*VI*9	97	0	3	3.85	1.629	1.147
	*VI*10	91	3	5	3.67	1.043	1.624
	*VI*11	98	5	7	3.81	1.205	1.052
	*VI*12	99	5	7	3.37	1.362	1.811
	*VI*13	94	1	4	2.62	1.084	1.637
Non-interactive class states	*VI*14	98	2	5	3.84	1.629	1.059
	*VI*15	95	5	7	3.22	1.311	1.102
	*VI*16	93	3	6	3.06	1.742	1.772
VI technology	*VI*17	93	3	5	3.37	1.148	1.258
	*VI*18	96	4	8	3.94	1.354	1.179

The mean represents the frequency of teacher-student interaction. The greater the mean, the more frequent the interaction. The standard deviation shows the difference between teachers and students concerning different interaction behaviors. The greater the standard deviation, the greater the difference between different interaction behaviors. The inverse is also true. As shown in Table 1, only a few teacher-student interactions had a mean smaller than 3. The standard deviation and variance of every teacher-student interaction were greater than 1. Therefore, different subjects have certain differences in selecting VI behaviors during DAD teaching.

This paper not only observes the VI state of a single student, but also collects the VI data of all students. Thus, the VI states of all students were plotted as shown in Figure 5.

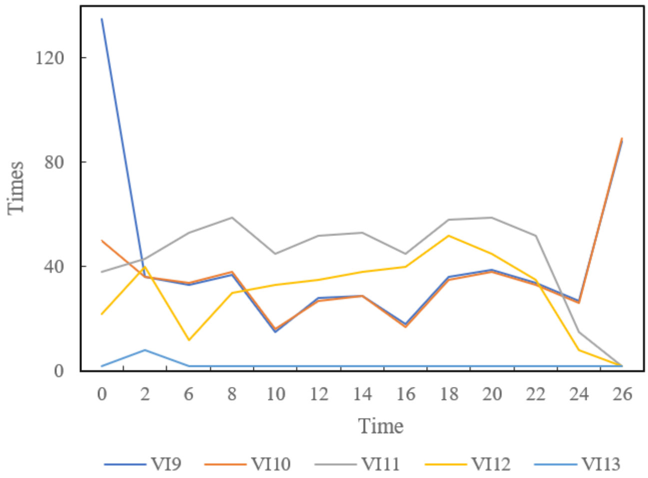

Fig. 5. VI states of students

In addition, the teacher-student VI behaviors of the subjects were subjected to descriptive statistical analysis. The teacher-student VI behaviors were classified into specific types to illustrate the students' behaviors like collective response to teacher interaction, active individual response to teacher interaction, passive individual response to teacher interaction, raising questions about visual contents, and participating the themed discussion of visual contents. Table 2 shows the results of the descriptive statistical analysis.

Table 3 shows the statistics on sample prediction results. It can be learned that the predicted realization degree of course goals of DAD teaching were close to the actual values. Hence, the application of VI technology to DAD teaching can ensure a high realization degree of course goals. The technology is feasible in that scenario.

Table 2. Descriptive statistics of students' VI behaviors

	N	Minimum	Maximum	Mean		Standard deviation	Variance
	Statistic	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Statistic*
*VI*9	95	1	15	2.15	3.25	3.152	13.629
*VI*10	93	4	12	2.63	3.14	3.485	15.268
*VI*11	98	2	17	2.95	3.28	3.629	11.230
*VI*12	91	1	13	2.48	3.62	3.182	17.269
*VI*13	99	3	11	3.62	5.49	5.629	25.027
State list	96	1	15	0.01	0.03	0.07	0.03

Table 3. Statistics on sample prediction results

Group number	15	20	22
Actual value/%	25.1	13.8	7.4
Prediction value/%	21.9	15.2	4.2
Error	4.6	1.3	2.9

Figure 6 shows the ratio of teachers' interaction behaviors to students' interaction behaviors in a unit period. Figure 7 shows the ratio of male students' behaviors to female students' behaviors in a unit period. It can be seen that, during DAD teaching, the teachers' interaction behaviors were much more than the students' interaction behaviors. The students only had more VI behaviors in the latter half of the course, during the themed discussion period. As shown in Figure 7, male students had generally more VI behaviors than female students, and were more active in VI during DAD teaching.

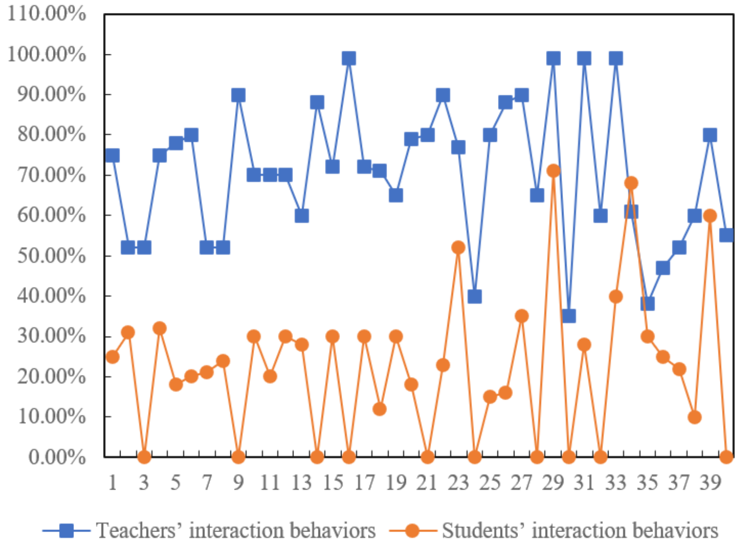

Fig. 6. Ratio of teachers' interaction behaviors to students' interaction behaviors

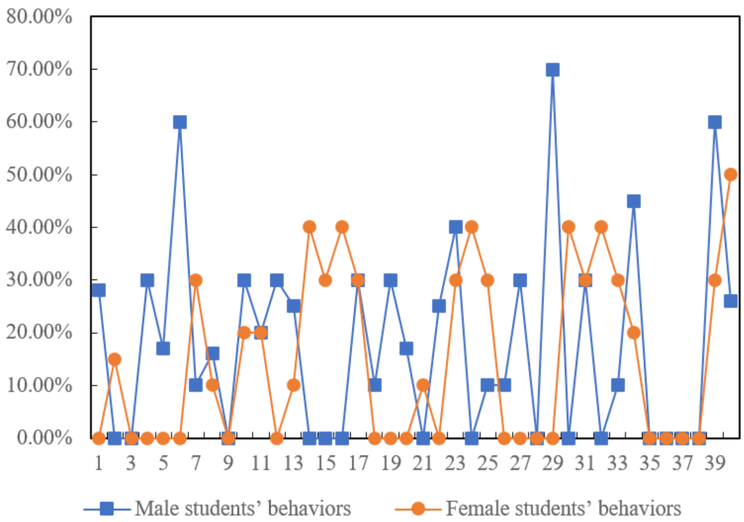

Fig. 7. Ratio of male students' behaviors to female students' behaviors

6 Conclusions

This paper explores the feasibility of VI mode in DAD teaching. After detailing the realization of teacher-student VI on DAD teaching process control platform, the authors set up the topology of VI system in DAD teaching. Then, the VI flow data were analyzed, and the teacher-student VI behaviors in DAD teaching were encoded. Afterwards, a prediction model was established for the realization degree of DAD teaching course goals based on the improved neural network. Through experiments, the visualization modes preferred by students were counted, and the necessity of VI technology application to DAD teaching was verified. Further, different descriptive statistics of VI behaviors were obtained, revealing that different subjects differ in the selection of VI behaviors in DAD teaching. In addition, the sample prediction results were summarized, indicating that the application of VI technology in DAD teaching ensures the high realization of course goals. Finally, the ratio of teachers' VI behaviors to students' VI behaviors, and that of male students' VI behaviors to female students' VI behaviors were plotted, and the relevant conclusions were drawn.

7 References

[1] Hsiao, J.C., Chen, S.K., Chen, W., Lin, S.S. (2022). Developing a plugged-in class observation protocol in high-school blended STEM classes: Student engagement, teacher behaviors and student-teacher interaction patterns. Computers & Education, 178: 104403. https://doi.org/10.1016/j.compedu.2021.104403

[2] Wang, J.G., Qi, Y.M. (2020). Influence of Teacher-Student Matching on Knowledge Innovation of Graduate Students, International Journal of Emerging Technologies in Learning, 15(20): 87-101. https://doi.org/10.3991/ijet.v15i20.17421

[3] Rasmitadila, R., Widyasari, W., Humaira, M.A., Tambunan, A.R.S., Rachmadtullah, R., Samsudin, A. (2020). Using Blended Learning Approach (BLA) in Inclusive Education Course: A Study Investigating Teacher Students' Perception, International Journal of Emerging Technologies in Learning, 15(20): 72-85. https://doi.org/10.3991/ijet.v15i02.9285

[4] Meri-Yilana, S. (2020). Writing online dialogue journals and penzu for student-teacher interaction and autonomous learning: a research plan. Harnessing the Potentials of Technology to Support Self-Directed Language Learning in Online Learning Settings, October 15–16, 2020, Stockholm, Sweden and Chiba, Japan.

[5] Li, S.L., Chai, H.Q. (2021). Recognition of teaching features and behaviors in online open courses based on image processing. Traitement du Signal, 38(1): 155-164. https://doi.org/10.18280/ts.380116

[6] Wen, J., Wei, X.C., He, T., Zhang, S.S. (2020). Regression analysis on the influencing factors of the acceptance of online education platform among college students. Ingénierie des Systèmes d'Information, 25(5): 595-600. https://doi.org/10.18280/isi.250506

[7] Liu, L.M. (2020). Analysis on class participation based on artificial intelligence. Revue d'Intelligence Artificielle, 34(3): 369-375. https://doi.org/10.18280/ria.340316

[8] Izang, A.A., Ajaegbu, C., Ajayi, W., Omotunde, A.A., Enike, V.O., Ifidon, B.O. (2022). Radio frequency identification based student attendance system. Ingénierie des Systèmes d'Information, 27(1): 111-117. https://doi.org/10.18280/isi.270113

[9] Kalamaras, I., Glykos, K., Megalooikonomou, V., Votis, K., Tzovaras, D. (2022). Graph-based visualization of sensitive medical data. Multimedia Tools and Applications, 81(1): 209-236. https://doi.org/10.1007/s11042-021-10990-1
[10] Bai, X., Zhou, J., Ning, X., Wang, C. (2022). 3D data computation and visualization. Displays, 73: 102169. https://doi.org/10.1016/j.displa.2022.102169
[11] de Oliveira, W., Braga, R., David, J.M.N., Stroele, V., Campos, F., Castro, G. (2022). Visionary: a framework for analysis and visualization of provenance data. Knowledge and Information Systems, 64: 381-413. https://doi.org/10.1007/s10115-021-01645-6
[12] Chen, X., Zhang, J., Fu, C.W., Fekete, J.D., Wang, Y. (2021). Pyramid-based Scatterplots sampling for progressive and streaming data visualization. IEEE Transactions on Visualization and Computer Graphics, 28(1): 593-603. https://doi.org/10.1109/TVCG.2021.3114880
[13] Guo, Q. (2020). Detection of head raising rate of students in classroom based on head posture recognition. Traitement du Signal, 37(5): 823-830. https://doi.org/10.18280/ts.370515
[14] Zheng, Y.B., Ma, Y. Cheng, J.C., Feng, Z.X. (2022). Automated identification and visualization of conflict events in bike lanes using trajectory data. China Journal of Highway and Transport, 35(1): 71-84. https://doi.org/10.19721/j.cnki.1001-7372.2022.01.007
[15] Yadav, P., Chaudhary, A., Keshari, A., Chaudhary, N.K., Sharma, P., Saurabh, K. Yadav, B.S. (2022). Data visualization of influent and effluent parameters of UASB-based wastewater treatment plant in Uttar Pradesh. International Journal of Advanced Computer Science and Applications, 13(2): 598-606. https://doi.org/10.14569/IJACSA.2022.0130271
[16] Wu, J. (2018). A space design teaching model using virtual simulation technology. International Journal of Emerging Technologies in Learning, 13(6): 163-175. https://doi.org/10.3991/ijet.v13i06.8585
[17] Alves, F.C., Diniz, M.M., Rodrigues, A., Monteiro, D.C. (2018). Teaching platonic polyhedrons through augmented reality and virtual reality. In Proceedings of the 17th Brazilian Symposium on Human Factors in Computing Systems, 1-4. https://doi.org/10.1145/3274192.3274243
[18] Liu, Q., Ba, S., Wu, L., Huang, J., Li, H. (2018). Virtual dulcimer auxiliary teaching system based on musical instrument digital interface. In 2018 International Symposium on Educational Technology (ISET), 82-86. https://doi.org/10.1109/ISET.2018.00027
[19] Do, T., Krishnaswamy, N., Pustejovsky, J. (2018). Teaching virtual agents to perform complex spatial-temporal activities. In AAAI Spring Symposia.
[20] Wang, N. (2018). A teaching mode for art anatomy based on digital virtual technology. International Journal of Emerging Technologies in Learning, 13(8): 225-238. https://doi.org/10.3991/ijet.v13i08.9053
[21] Zhang, Y., Chen, J., Miao, D., Zhang, C. (2018). Design and analysis of an interactive MOOC teaching system based on virtual reality. International Journal of Emerging Technologies in Learning, 13(7): 111-123. https://doi.org/10.3991/ijet.v13i07.8790
[22] Qi, W. (2017). Evaluating a virtual collaborative environment for interactive distance teaching and learning: A case study. In Advances in Intelligent Information Hiding and Multimedia Signal Processing, 11-18. https://doi.org/10.1007/978-3-319-50212-0_2
[23] Cacho, C.E., Souza, P.S., Bruschi, S.M., Barbosa, E.F., Tiosso, F. (2016). An interactive approach for the teaching of virtual memory using open educational resources. In Proceedings of the 31st Annual ACM Symposium on Applied Computing, 225-231. https://doi.org/10.1145/2851613.2851700
[24] Tourou, P., Einwächter, F., Sourkounis, C. (2013). Web-based interactive animated virtual experiments for teaching wind energy utilization. In 2013 15th European Conference on

Power Electronics and Applications (EPE), 1-10. https://doi.org/10.1109/EPE.2013.6634686
[25] Ding, D., Li, L. (2011). The application study of MCU in visual classroom interactive teaching based on virtual experiment platform. In International Conference on Electronic Commerce, Web Application, and Communication, 199-204. https://doi.org/10.1007/978-3-642-20367-1_31

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The Camera-on or Camera-off, Is it a Dilemma? Sparking Engagement, Motivation, and Autonomy Through Microsoft Teams Videoconferencing

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Abstract—A videoconferencing system to communicate synchronously is an indispensable tool for educators, teachers, students, parents, and administrators in online courses. One of the effective online learning platforms that can increase student engagement and motivation in online courses is Microsoft Teams. This research aimed to explore English as a Foreign Language (EFL) students' views of enacting Microsoft Teams videoconferencing. This study employed a mixed-method design complemented by observation, open-ended questionnaires as well as in-depth interviews for qualitative analysis in capturing and exploring their experience of synchronous learning using the Microsoft Teams in post-pandemic. Furthermore, close-ended questionnaires were also distributed as quantitative data. The results revealed that Microsoft Teams helped the learners to be more involved in debates with both faculty and students as a result of their participation in discussion forums. They also gained a better comprehension and knowledge of language learning. It was clear that they were highly motivated and enjoyed the online course due to its ease of use and fun features, and appreciated direct feedback in the synchronous online meeting. Thus, the learners with strong motivation can develop their learning autonomy. They can monitor and evaluate their self-progress in learning. Further research is highly recommended for exploiting Microsoft Teams to create innovations in a virtual classroom.

Keywords—Microsoft Teams, videoconferencing, students' engagement, students' motivation, learner autonomy

1 Introduction

A videoconferencing system is an indispensable synchronous communication tool for educators, teachers, students, parents, and administrators due to the pandemic. The shift from conventional learning to online emergency distance learning is required. However, this unexpected shift creates teachers' stress and anxiety. Besides, teachers do not have experience in designing, developing and implementing effective online learning. Therefore, emergency distance teaching is an option. This transition creates difficulty for students to get equal online learning opportunities, access digital resources, and doubt data of student security and privacy [1]–[3].

Video conferencing is a synchronous communication model that allows teachers and students to communicate in real-time from different locations. Besides, video conferencing has a better level of interaction and engagement than asynchronous communication which frequently causes a delay in feedback [4], [5]. Video conferencing provides real interaction, effective communication, direct feedback, and closer involvement of teachers and students in expressing themselves by utilizing audio, visual, and verbal communication combined with others. Thus, the ambiguity that usually occurs in asynchronous text communication can be reduced [4], [6].

However, during the pandemic, the education system is still vulnerable to external dangers, and digital transformation of instructional delivery during the pandemic still experiences challenges [7], [8]. One of the challenges is related to the students' academic achievement which is influenced by several considerations: (1) Anxiety about the pandemic affects students' academic achievement, (2) Students' academic achievement can be affected by different races, economies, and resources, (3)Teachers are still unable to deliver instruction effectively [9]. Therefore, a more in-depth investigation of videoconferencing in language learning needs to be carried out to explore how students are engaged and motivated during the synchronous learning process. Besides, the learners' verbal and non-verbal behaviors can be captured, and reasons, why some students are reluctant to turn on their cameras, can also be explored. Moreover, their experience in using synchronous tools that facilitate live interaction and direct feedback can be recorded.

2 Literature review

It is undeniable that the world is now facing digital learning. Digital influence in education needs to be considered more deeply [10]. Teachers need to adapt to the transition of offline to online delivery instructions during the pandemic as they play an important role in the continuation of education quality [11]. Teachers keep going continue their responsibilities such as facilitating and motivating students during the pandemic. There is a relationship between quality of life, happiness, loneliness, and high addiction to internet needs for teachers and school administrators [12].

Online learning highly depends on technological devices and internet access; thus, teachers and students with poor internet connections often experience obstacles to access online learning. The dependence on online learning with technological devices and equipment supplies and the need for stable internet access are still major challenges for institutions, faculties, and students [13].

Three interactions are pivotal components of online learning and are compulsorily considered. They comprise the instructor-student, the student-student, and the student-content. Student content interactions include various pedagogical tools, such as streaming media, presentation slides, and hyperlinks. Besides, online learning can bring several benefits of work and flexibility. A previous study by [14] found three points: (1) Instructor-student interactions were twice as important as student-student interactions,

(2) Student-content interactions were significantly related to perceived learning, it deals with the students' experiences in understanding the content of a course, and (3) The benefits of flexible distance learning are significant but had the least importance among other interactions.

The proper use of technology can help students and teachers engage and collaborate [15], [16]. Student engagement here is defined as the learners' efforts to devote time and energy to participate in educational activities. The learners have active involvement, commitment, and a sense of belonging to take their time and effort to engage in activities aimed at educating [17]. The intention and level of user acceptance in using technology will influence the effectiveness and success of online learning [18], [19]. In brief, teachers necessarily understand students' characteristics and interest in technology. Consequently, the teachers can provide some effective online learning platforms, provide interesting materials, and online learning can run optimally.

One of the effective online learning platforms that can increase student classroom engagement, student interaction, and online learning environments is Microsoft Teams [20]. Microsoft Teams can include 250 participants in synchronous online learning in one virtual meeting. However, the duration of the meeting depends on the types of authentications. However, Microsoft Teams requires a stable Wi-Fi connection to reduce lag. Turning off video and muting audio is an alternative for students to increase connection speed and minimize lag in virtual communication [21].

The importance of synchronous learning is implemented in helping students engage and interact directly with friends and teachers. They are not embarrassed or afraid to turn on their cameras during virtual classes. They can ask questions, give opinions, or deliver arguments confidently. However, students frequently reported some problems when learning synchronously with online learning platforms, such as Teams, Zoom, or Google meet. When the students turn on their cameras, they are afraid that their photos will be screenshotted and uploaded as a status on social media by other students [22]. Furthermore, some reported that they joined virtual classes without listening to the teachers' explanations or left the classrooms but still in the join mode. Therefore, synchronous learning about academic rules, student participation in virtual classes, and camera on mode must be explained at the beginning of the lecture. In addition, the synchronous learning concerning the involvement and good verbal and non-verbal communication between students-students and students-teachers is still necessarily improved.

Quantitative research was conducted by [23]. This study aimed to determine the effects of online grammar instruction on the grammar achievement of English as a Foreign Language (EFL) students. It was also intended to reveal EFL students' attitudes towards the use of online grammar teaching to enhance their grammar ability. A quantitative study was chosen using convenience sampling and 43 students participated in this study. Pre-test, post-tests as well as a questionnaire were collected as data collection. The findings demonstrated that online grammar instruction successfully satisfied the learners and enhanced students' grammar ability.

Another research in descriptive qualitative was also explored to investigate the students' interaction and learning environment on synchronous online learning via Microsoft Teams [20]. A five-point Likert scale questionnaire was distributed to twenty-eight students to capture their perceptions. His findings revealed that the learners gave positive perceptions regarding students' interaction as well as the learning environment in online learning through Microsoft Teams. Furthermore, the study on the effectiveness of Microsoft Teams for MBA and graduate learners was conducted [24]. The class met 210 minutes over weekends. An observation was gathered to capture the learners' activities in the classroom session. The results revealed that Microsoft Teams facilitated the learners with an interesting learning environment, provided recorded audio-video as well as PowerPoint. The most important thing is they can easily review the materials as they were professional workers who divided their time either to study or to work. Moreover, the context of the research was conducted at a university in Kuwait, investigating the perception of pre-service teachers on the usefulness of Microsoft Teams during virtual learning. Data were taken from questionnaires, the results showed that Microsoft Teams is a videoconferencing learning platform that is capable of facilitating interactive learning activities and providing immediate feedback [25].

Studies have also elaborated on student and teachers' acceptance of Microsoft Teams as a synchronous online learning platform. The context of the study that took place at a university in India was exploring Microsoft Teams as an online learning platform where its usability is perceived evaluated. For evaluation aims, a dual strategy was continued by using the System Usability Scale (SUS), which is a Human-Computer Interaction (HCI) based approach, and modified Technology Acceptance Model (TAM), which is an Information Systems (IS) based approach. From the questionnaires, the results demonstrated similarities and equivalence between the two methodologies, with the Perceived Ease of Use (PEOU) construct of TAM having a greater similarity with SUS (System Usability Scale)[26]. The context of the research was also carried out at a university in Indonesia aimed at investigating teacher acceptance of cloud-based learning technologies, especially Microsoft 365 (i.e., Microsoft Teams) which is currently being used massively in online learning. Within the theoretical framework, the Technology Acceptance Model is used by incorporating two original constructs, namely, perceived usefulness (PU), perceived ease of use (PEU), and two extensive variables, namely perceived risk (PR) and social influence. (SI) which will predict the intention of teachers to use cloud-based learning technology during the Covid-19 pandemic. Data from the online survey showed a significant relationship between factors that influence technology use, except PU (path coefficient)[27].

Many publications have already explored the students' engagement in online learning or videoconferencing system, however, to my best of knowledge, few studies that explored students' motivation as well as learner autonomy on Microsoft Teams videoconferencing. Thus, the researchers attempted to answer the following research questions:

1. How does Microsoft Teams improve student engagement?
2. How does Microsoft Teams improve student motivation?
3. How does Microsoft Teams improve learner autonomy?
4. What challenges do students face during using Microsoft Teams video conferencing?

3 Method

3.1 Research design

This study employed a mixed-method design complemented by observation, open-ended questionnaires as well as in-depth interviews for qualitative analysis in capturing and exploring their activities, experiences, and opinions of synchronous learning using the Microsoft Teams in post-pandemic. Furthermore, close-ended questionnaires were also distributed as quantitative data. Besides, the transition from the face-to-face learning method to the online learning method certainly provides a new experience for each student and their respective perspectives. Google Forms and written WhatsApp were used to collect demographic data in preparation for interviews related to gender, backgrounds of research participants, and academic experience.

3.2 Context and participant

This study involved 63 students of semester six of the Early Childhood Education Study Program, who took the language development method course at one of the Public Universities in Jember, Indonesia. 60 students or 95% are females and 3 students or 5% are males. Furthermore, the majority of students are between 16-25 years (n=30), 26-35 years (n=25), and the rest are between 36-45 years (n=8). This research collected participants' information via Microsoft Teams and asked for their consent to fill in the Google Form. The researchers explained the research objectives, research methods, and possibly emerging to the participants. The open-ended interviews, as well as close-ended questionnaires, were distributed to the learners (n=63) to retrieve information about student experiences during the online learning with Microsoft Teams. To maintain the privacy of participants, the researchers did not provide their full names. Furthermore, semi-structured interviews were also conducted via WhatsApp to provide misinformation from the Google Form. The students who participated in written interviews via WhatsApp were one female and one male. The students aged are between 16-25 years (n=1), and 26-35 years (n=1).

In this synchronous meeting, the teacher as the researcher constructed learning objectives aiming at enhancing learners' engagement, motivation as well as autonomy. Under obligation, we carefully expanded the instructions and materials delivered in Microsoft Teams videoconferencing. We posted academic rules, instructions for each task in the first meeting including group presentation so that they could plan and prepare for the topics as well as the materials for group presentation for the next meeting (meeting 2-8). We also encouraged them to have active participation, discussion, and group presentation. In addition, we gave comments as well as feedback to observe their progress in the synchronous meeting.

3.3 Procedures for data collection

In understanding how the participants exploit videoconferencing through Microsoft Teams, the data were gathered through participatory analysis. The researchers were involved in videoconferencing through Microsoft Teams with the learners over one semester in the class of language development method. The course was delivered synchronously within eight meetings via Microsoft Teams videoconferencing. Each meeting had two hours session on Teams for the lecture, discussion as well as group presentations. Besides, the student's participation in the videoconferencing course was captured whether they had a positive engagement or negative engagement during the virtual classroom session. First, after prospective participants completed videoconferencing language learning course and had willingly become research participants, the researchers distributed open-ended questionnaires to the participants (n=63) about their backgrounds, questions regarding engagement, motivation, autonomy, and obstacles using Microsoft Teams during videoconferencing language learning. Second, the virtual interviews via WhatsApp were distributed to the participants (n=2) to confirm unclear data and information via WhatsApp. The written interview agreed with the predetermined time and place and lasted for 10-20 minutes. The interview was recorded by smartphone applications, such as Google Form and WhatsApp, viewed repeatedly, transcribed, and copied into a format table to help the researchers easily identify and classify data. The interview transcript was conducted in Indonesian after being validated for content validity by two experts from one of the public universities in Jember, Indonesia. It aimed to minimize miscommunication so that the students could answer questions correctly. Moreover, adapted close-ended questionnaires on a five-point Likert scale across five domains; access to information and learning resources, support and motivation, participation in course activities, feedback, and critical reflection were also distributed to the participants. [28]. Of 63 participants, only 31 students completed the online survey. These items were separated into five domains that shape students' experience: access to information and learning resources (four items), support and motivation (four items), participation in course activities (four items), feedback (four items), and critical reflection (four items).

4 Results

4.1 Student engagement

During an observation in the synchronous class, the researcher found that the students were enthusiastic about participating in the videoconferencing class and their active engagement was increased. They became more involved in debates with both faculty and students as a result of their participation in discussion forums. They also gained a better comprehension and knowledge of language learning. Moreover, videoconferencing could encourage students to prepare content for the following meeting's discussion or presentation. Interaction with colleagues and instructors was much more enjoyable since they could interact and communicate in real time.

As seen in Table 1, data showed their responses in terms of behavioral engagement. The responses were from two students who participated in a written interview via WhatsApp.

Table 1. The students' responses in terms of behavioral engagement

No	Questions	Responses
1	Do you review the materials before the online course through Microsoft Teams?	*"I always review the materials before online classes and I always do it after class as long as I have free time."* (S1 via WhatsApp) *"Yes, I review the materials before the online class, because I need to do that to help me learn the materials easily."* (S2 via WhatsApp)
2	Do you actively ask questions in online courses through Microsoft Teams?	*"I think yes, I have actively asked questions in online classes related to materials or other activities related to the materials."* (S1 via WhatsApp) *"Yes, asking what I don't understand will help me to understand the learning materials."* (S2 via WhatsApp)
3	What do you think about the level of discussion (student and lecturer discussions) in online courses through Microsoft Teams?	*"The level of discussion is very interesting, by having a discussion forum we can solve problems related to learning materials that we find difficult to understand*." (S1 via WhatsApp) *"In my opinion, the level of discussion in an online class through Microsoft Teams is 'real level", and it depends on the learning atmosphere of the discussion and how students and lecturers interact with each other. For example, in a student-teacher discussion, if there is feedback, then the discussion will be live and fun, but on the contrary, if there is no feedback, then the discussion becomes boring and refers to "dead level."* (S2 via WhatsApp)

Several students confirmed that Teams is attractive and provides practical features so that they are curious about exploiting the application. Therefore, participating in synchronous online learning helps them to focus on the material or presentation delivered virtually better. This condition was conveyed by students in the following interview excerpts

"The application is not complicated to use so I can focus on learning materials online." (S 36 via Google form)

"I love using Microsoft Teams during online learning as it is more effective, easy, and practical rather than other platforms." (S 38 via Google form)

The data that emerged from an interview also showed that the students gained several benefits in terms of live interaction, by doing so they are more likely engaged to participate and interact directly with fellow students and lecturers virtually. This condition is reported by students in the following interview excerpts.

"Thank God, we are still allowed to receive knowledge and receive face-to-face lectures virtually during a pandemic, even though online." (S 8 via Google form)

"There are so many benefits. I can receive the same material as during face-to-face lectures, even though I did not meet face-to-face, but I can still learn about the course well." (S 13 via Google form)

"We can discuss the course material with friends who are guided directly by the tutor even though online, receive material explanations from the tutor according to the course." (S 23 via Google form)

"Learning using Microsoft Teams is easier because we can interact directly with the lecturers." (S 37 via Google form)

"Yes, because we can discuss or ask about course material if we encounter difficulties and we can convey our arguments directly." (S 23 via Google form)

"Yes, there are many benefits for me personally, apart from being able to keep in touch with lecturers and friends, I can interact more closely with friends during online learning, I am more confident, increase my concentration in the study." (S 40 via Google form)

4.2 Student motivation

Based on the observation in synchronous learning by capturing the students' attitude during the course session, the students enjoyed participating in the course via Microsoft Teams, and they were motivated to learn and discuss together both with the tutor and the classmates as well. In the end, they were quite motivated, even when some of them were still hesitant to turn on the camera or were afraid to speak up. Hence, giving a quiz and pointing out the students who did not turn on their cameras was an effective solution. The most visible reaction occurred when the teacher provided direct feedback and awarded points to those who actively participated in the discussion or expressed their views on a given topic. It was clear that they were highly motivated and enjoyed the online course, and appreciated direct feedback that they did not get in asynchronous online learning.

Data from the interview showed the learners' voices regarding motivation. They confirmed that self-motivation is also an essential factor during online learning because it enables learners to be actively involved, increase their ability to learn something, and achieve targets or success in their learning experience. This condition is reported by students in the following interview excerpts. As seen in Table 2, data showed their responses in terms of autonomous motivation.

Table 2. The students' responses in terms of autonomous motivation

No	Questions	Responses
1	In your opinion, what makes videoconferencing language learning through Microsoft Teams important?	*"During a pandemic like this, for me, online classes are very important because by conducting online classes we don't need to delay our learning activities so that we can finish our education on time."* (S1 via WhatsApp) *"I think online classes through the Microsoft team are very important. "By applying Microsoft teams, we can discuss directly with lecturers and friends how to solve problems that we don't understand in the material, but if we only go online by applying Online Tutorial (LMS) classes, we cannot have live interaction and direct feedback."* (S2 via WhatsApp)
2	In your opinion, what makes videoconferencing language learning through Microsoft Teams interesting?	*"I think it's interesting because we can get a new learning experience, a new learning atmosphere, and in particular we get knowledge about the Microsoft Teams application which is very useful for educational development."* (S1 via WhatsApp) *"It depends on the atmosphere of the class and how the lecturer conveys the learning materials. For example, if the lecturer conveys materials in a non-monotonous method, I will feel interested and enthusiastic, especially if there is a class discussion that inspires me to be curious about solving certain problems. On the other hand, if the lecturer conveys the material monotonous, my friends and I will feel bored and become an unattractive online class."* (S2 via WhatsApp)

3	How can participating in videoconferencing language learning through Microsoft Teams provide a pleasant experience?	*"I think it's certainly fun like when I lose the signal, I have to move to try to find a signal, sometimes during online activities, it depresses me as we are afraid of missing important information conveyed by lecturers or friends."* (S1 via WhatsApp) *"In my opinion, this online class is very fun because lecturers and students can directly communicate and quickly share files. My great experience is when I can share my experiences and get solutions regarding problems in online teaching."* (S2 via WhatsApp)

4.3 Learner autonomy

During an observation in the virtual class session, it revealed that students carried out their plans by browsing the content they desired for presentations or discussions about language learning. Students employed strategies and tools to help them achieve their learning goals. For instance, accessing YouTube videos for pronunciation practice, as well as Google Translate and digital dictionaries to assist them in interpreting the reading text and difficult vocabulary as well. Students also consulted with tutors about their final project, shared their presentation topics directly. By doing so, teachers could provide direct and live feedback and could monitor their progress on the final project.

Data that emerged from the interview displayed that learners with strong motivation can develop their learning autonomy. Moreover, they can monitor and evaluate their self-progress in learning as presented in Table 3.

Table 3. The students' responses to autonomous learning in terms of the ability to monitor the usage of learning strategy and establishment of learning goals

No	Questions	Responses
The ability to monitor the usage of learning strategy		
1	How can you monitor your English progress during videoconferencing language learning?	*"I can monitor my progress and improve my digital literacy and technology experiences because I often ask friends who are technology experts."* (S 49 via Google form) *"Microsoft Teams can motivate me during online learning and develop my autonomous technology skills so that I can become more familiar with the technology."* (S 38 via Google form)
2	How do you identify and resolve difficulties in your study during videoconferencing language learning?	*"I suddenly became an independent learner; I could access modules and learn videos of language learning on YouTube independently."* (S 48 via Google form) *"We can directly share ideas and solve the problems related to the topic in live-online interaction."* (S 21 via Google form)
Establishment of learning goals		
1	How do you set your study objectives based on the class's requirements?	*"I should have high responsibility; we need to more concentrate on the activities during an online course for a better learning result."* (S 11 via Google form) *"I believe that discipline increased when we have a good responsibility or autonomy in learning*." (S 19 via Google form)

4.4 Results from the close-ended questionnaires

We surveyed EFL students' perceptions toward the use of Microsoft Teams videoconferencing by analyzing their responses to 30 items across five domains; access to information and learning resources, support and motivation, participation in course activities, feedback, and critical reflection. To discuss this particular, descriptive statistics (means and standard deviations) were computed for the students' responses toward the questionnaire domains.

Table 4 displays that the feedback domain (4.00 ± .78) was ranked first based on the mean value and the access to information and learning resources (3.98 ± .86) was ranked as the second. However, the mean score of participation in course activities (3.88 ± .86) was ranked as the least. These results indicate that the overall mean score of the students' responses was 3.94 ± .82. The students' responses toward the use of Microsoft Teams in terms of access to information and learning resources, support and motivation, participation in course activities, feedback, and critical reflection were positive.

Table 4. Means and standard deviation of students' responses

No	Dependent variables	M	SD	Degree	Rank
1	Access to information and learning resources	3.98	.86	High	2
2	Support and motivation	3.94	.83	High	3
3	Participation in course activities	3.88	.86	High	5
4	Feedback	4.00	.78	High	1
5	Critical reflection	3.90	.79	High	4
	Total	3.94	.82	High	

4.5 The challenges of Microsoft Teams as a videoconferencing

While observing videoconferencing classrooms, it showed that unmotivated students were faced with poor interaction with classmates in online classes. They were taking online courses through Teams interact with friends only when they were asked to collaborate/ make a group for presentations and discussion between groups. In addition, the fear and insecurity of speaking live via videoconferencing was also the biggest challenge. Based on the verbal expression of students, they seemed worried if their classmates would interrupt and judge when they said something wrong during the online session. Some chose to turn off their cameras so their friends cannot screenshot their pictures unless they were asked to turn on the camera by the tutor. Another reason was that most of the students were unable to take advantage of collaborative learning and they just appreciated learning from the tutor rather than from their classmates.

Students reported several challenges that frequently occurred during online learning. This is conveyed by students in the following interview excerpt. Several students reported they experienced poor signals, and sometimes the signal immediately disappears. Therefore, they need to re-login to access the video conferencing.

"Maybe there is a poor internet connection, sometimes the connection immediately disappears/leaves the conversation or application, and we have to re-login from the beginning." (S 12 via Google form)

"In my opinion, during online learning using Microsoft Teams, the obstacles are related to signal constraints and we often enter and exit the application by itself." (S 50 via Google form)

"The obstacles I experienced were bad signals as I live in the countryside." (S 52 via Google form)

"Barriers to online learning are due to signals. A weak signal causes learning to be interrupted." (S 39 via Google form)

Some students also complained about the incompatibility between the audio and visuals. Therefore, when the lecturers explained their materials or when students or small groups presented their papers, miscommunication frequently occurred.

"Obstacles due to the slow internet network, sometimes the visual and audio are not aligned so I have difficulty understanding the explanation." (S 48 via Google form)

5 Discussion

The purpose of this study was to explore Microsoft Teams videoconferencing to improve student engagement, student motivation, and learner autonomy. In addition, it also scrutinizes the challenges that students encounter during the synchronous online meeting.

Regarding the engagement in the videoconferencing courses, this present study showed that the students could be engaged in the meeting of Microsoft Teams videoconferencing, directly asked their questions or arguments in the class. This is consistent with Pal & Vanijja's findings, they claimed that Microsoft Teams provides interesting features, such as a good study room with conference facilities for direct interaction that enables the learners to become engaged in the meeting. Besides, teachers enable to record videos and upload them to the application easily. Moreover, this application provides file sharing for all file types, such as power-point, word, or PDF and this app can be combined with all features in a single application[26]. Furthermore, Microsoft Teams helped students chat and interact easily with teachers and their peers during or after learning [29]. However, this result contradicts [30], reporting that online learning using Microsoft Teams provides insufficient social interaction. The students only interacted when asked to work in pairs or groups. Moreover, they were less able to interact because they concern with expressing inappropriate opinions/arguments and taking advantage of cooperative learning. On the other hand, some students just respected the virtual learning scheduled by the teachers, not their desire to interact with their friends.

This present study also highlighted that motivation is a factor that determines the success or failure of learners. Students who motivate themselves to achieve their learning targets will always manage their time to study intensively[31], [32]. Online learning platforms are necessarily equipped with interesting and usable features adjusting with the needs and characters of students because this adjustment becomes a factor that motivates students in the teaching and learning process. Several previous studies reported that the success or failure of learners is influenced by motivation. Motivated students will tend to do challenging activities, be actively involved, enjoy the teaching and learning process, and continuously enhance their performance. [33]–[35].

This present study showed the challenges that students encountered while joining synchronous online learning via Microsoft Teams. The students reported that they frequently encountered poor internet access. For example, the signal immediately disappeared. Consequently, they left the meeting or application and had to re-login from the beginning. The other obstacles were poor internet network and not-aligned visual and audio; thus, the learners got difficulty understanding the explanation during the virtual class. Such conditions were in line with the report of [4], asserting that students often experienced technical problems, such as network interruptions, image quality, and low sound, the time lag between sound and picture; these problems interfered with students' learning.

During an observation, it showed that some students had the anxiety to speak so they chose not to turn on the camera. this finding was supported by several studies [36], [37], confirming that if technology can create barriers and anxiety, it affects effective communication, and language learning can create fear. Language anxiety includes feelings of worry, being overwhelmed and fear stemming from learning or using a foreign language. Anxiety that arises can result in a low willingness to communicate in a foreign language [38], and a desire to quit following language courses [39]. The problem that often arises in language learning interactions through video conferencing is the monopoly of conversation by the most vocal, intelligent, and confident learners. As a consequence, there is no equal opportunity to participate and explore opinions [40]. To avoid this, teachers must be aware that equal participation becomes one of the important factors for the success of video conferencing in language learning.

6 Conclusion

This present study aimed to explore students' voices of using the Microsoft Teams videoconferencing in post-pandemic. The results revealed that the students could still enjoy the synchronous learning process, take advantage of interesting features provided, and interact directly with fellow students and lecturers. Despite the problems during synchronous learning, the students still actively participated in a videoconferencing meeting, asked questions, and discussed some issues. This research theoretically contributes to independent learning students which can be built through interaction and learning collaboration with friends. Thus, they can ask each other, discuss topics, and share assignments. Moreover, self-reflection and support from surrounding people, such as lecturers, parents, and friends, are supporting factors to develop and motivate them to learn. However, this current research has a limitation; first, it only focused on one of the public universities in Jember, Indonesia, especially in language development courses. Hence, it is suggested that these results could be examined in other institutions in different countries, different levels of users, for instance in primary or secondary students. Second, this study is limited in capturing the learner's views on questionnaires and interview protocols only, thus, it can be considered for further studies to provide varied data collection, for instance by adding focus group responses as qualitative data. Furthermore, future research should investigate the importance of student interaction, engagement, and satisfaction to identify the impact of their success on engaging videoconferencing language learning.

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8 References

[1] C. Hodges, S. Moore, B. Lockee, T. Trust, and A. Bond, "The difference between emergency remote teaching and online learning," *Educause Review*, 2020. https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning (accessed Nov. 27, 2021).

[2] N. B. Milman, "This is emergency remote teaching, not just online teaching," *Education Week*, 2020. https://www.edweek.org/leadership/opinion-this-is-emergency-remote-teaching-not-just-online-teaching/2020/03 (accessed Nov. 27, 2021).

[3] T. Trust, "The 3 biggest remote teaching concerns we need to solve now," *EdSurge*, 2020. https://www.edsurge.com/news/2020-04-02-the-3-biggest-remote-teaching-concerns-we-need-to-solve-now (accessed Nov. 27, 2021).

[4] Y. E. Karal, H., Çebi, A., & Turgut, "Perceptions of students who take synchronous courses through video conferencing about distance education," *Turkish Online J. Educ. Technol.*, vol. 10, no. 4, pp. 276–293, 2011, [Online]. Available: https://www.learntechlib.org/p/53321/

[5] F. Martin, M. A. Parker, and D. F. Deale, "Examining interactivity in synchronous virtual classrooms.," *Int. Rev. Res. Open Distrib. Learn.*, vol. 13, no. 3, pp. 227–261, 2012. https://doi.org/10.19173/irrodl.v13i3.1174

[6] N. Kock, "Media richness or media naturalness? The evolution of our biological communication apparatus and its influence on our behavior toward e-communication tools," *tools. IEEE Trans. Prof. Commun.*, vol. 48, no. 2, pp. 117–130, 2005. https://doi.org/10.1109/TPC.2005.849649

[7] A. Bozkurt and R. C. Sharma, "Emergency remote teaching in a time of global crisis due to Corona Virus pandemic," *Asian J. Distance Educ.*, vol. 15, no. 1, pp. i–iv, 2020. https://doi.org/10.1080/10494820.2020.1813180

[8] R. Ribeiro, "How university faculty embraced the remote learning shift," *EdTech Magazine*, 2020. https://edtechmagazine.com/higher/article/2020/04/how-university-faculty-embraced-remote-learning-shift (accessed Nov. 27, 2021).

[9] J. Feldman, "To grade or not to grade?," *ASCD*, Jul. 2020. https://filecabinetdublin.eschoolview.com/6D88CF03-93EE-4E59-B267-B73AA2456ED7/ToGradeorNottoGradearticle.pdf (accessed Nov. 27, 2021).

[10] S. Poultsakis, S. Papadakis, M. Kalogiannakis, and S. Psycharis, "The management of digital learning objects of natural sciences and digital experiment simulation tools by teachers," *Adv. Mob. Learn. Educ. Res.*, vol. 1, no. 2, pp. 58–71, 2021. https://doi.org/10.25082/AMLER.2021.02.002
[11] T. Karakose, R. Yirci, and S. Papadakis, "Exploring the interrelationship between covid-19 phobia, work–family conflict, family–work conflict, and life satisfaction among school administrators for advancing sustainable management," *Sustain.*, vol. 13, no. 15, 2021. https://doi.org/10.3390/su13158654
[12] T. Karakose, T. Y. Ozdemir, S. Papadakis, R. Yirci, S. E. Ozkayran, and H. Polat, "Investigating the relationships between COVID-19 quality of life, loneliness, happiness, and internet addiction among K-12 teachers and school administrators—A structural equation modeling approach," *Int. J. Environ. Res. Public Health*, vol. 19, no. 3, pp. 1–20, 2022,. https://doi.org/10.3390/ijerph19031052
[13] A. Olasile Babatunde and S. Emrah, "COVID-19 pandemic and online learning: the challenges and opportunities," *Interact. Learn. Environ.*, vol. 9, pp. 1–13, 2020. https://doi.org/10.1080/10494820.2020.1813180
[14] R. B. Marks, S. D. Sibley, and J. B. Arbaugh, "A structural equation model of predictors for effective online learning," *J. Manag. Educ.*, vol. 29, no. 4, pp. 531–563, 2005. https://doi.org/10.1177/1052562904271199
[15] T. Gonzalez *et al.*, "Influence of COVID-19 confinement in students' performance in higher education.," *PLoS One*, vol. 15, no. 10, 2020. https://doi.org/10.1371/journal.pone.0239490
[16] M. Bower, "Technology-mediated learning theory," *Br. J. Educ. Technol.*, vol. 50, pp. 1035–1048, 2019. https://doi.org/10.1111/bjet.12771
[17] P. Chad, "The use of Team-Based Learning as an approach to increase engagement and learning for marketing students: A case study," *J. Mark. Educ.*, vol. 34, no. 2, pp. 128–139, 2012. https://doi.org/10.1177/0273475312450388
[18] A. Kemp, E. J. Palmer, and P. Strelan, "A taxonomy of factors affecting attitudes towards educational technologies for use with technology acceptance models," *Br. J. Educ. Technol.*, vol. 50, pp. 2394–2413, 2019. https://doi.org/10.1111/bjet.12833
[19] A. Tarhini, K. Hone, X. Liu, and T. Tarhini, "Examining the moderating effect of individual-level cultural values on users' acceptance of E-learning in developing countries: A structural equation modeling of an extended technology acceptance model," *Interact. Learn. Environ.*, vol. 3, no. 25, pp. 306–328, 2016. https://doi.org/10.1080/10494820.2015.1122635
[20] A. R. Rojabi, "Exploring EFL students' perception of online learning via Microsoft Teams: University level in Indonesia," *English Lang. Teach. Educ. J.*, vol. 3, no. 2, pp. 163–173, 2020. https://doi.org/10.12928/eltej.v3i2.2349
[21] T. Trowbridge, T. McDaniel, B. Shafi, and C. Copeland, "Use of Microsoft Teams private channels for in-person small group hands-on instruction during COVID-19 social distancing requirements," *J. Dent. Educ.*, vol. 85, no. December 2020, pp. 2030–2031, 2021. https://doi.org/10.1002/jdd.12539
[22] X. Chen, S. Chen, X. Wang, and Y. Huang, "'I was afraid, but now I enjoy being a streamer!,'" *Proc. ACM Human-Computer Interact.*, vol. 4, no. CSCW3, pp. 1–32, 2021. https://doi.org/10.1145/3432936
[23] M. Ekinci and E. Ekinci, "Online based grammar instruction via Microsoft Teams: A quantitative study," *Pearson J. Soc. Sci. Humanit.*, vol. 6, no. 14, pp. 32–39, 2021. https://doi.org/10.46872/pj.276
[24] J. Poston, S. Apostel, and K. Richardson, "Using Microsoft Teams to enhance engagement and learning with any class : It's fun and easy," *Pedagog. Conf. Proc.*, vol. 6, pp. 1–7, 2020, [Online]. Available: https://encompass.eku.edu/pedagogicon

[25] A. A. Almodaires, F. M. Almutairi, and T. E. A. Almsaud, "Pre-Service Teachers' Perceptions of the Effectiveness of Microsoft Teams for Remote Learning," *Int. Educ. Stud.*, vol. 14, no. 9, p. 108, 2021. https://doi.org/10.5539/ies.v14n9p108
[26] D. Pal and V. Vanijja, "Perceived usability evaluation of Microsoft Teams as an online learning platform during COVID-19 using system usability scale and technology acceptance model in India," *Child. Youth Serv. Rev.*, vol. 119, no. 9, pp. 1–13, 2020. https://doi.org/10.1016/j.childyouth.2020.105535
[27] I. Q. Utami, I. Fahmiyah, R. A. Ningrum, M. N. Fakhruzzaman, A. I. Pratama, and Y. M. Triangga, "Teacher's acceptance toward cloud-based learning technology in COVID-19 pandemic era," *J. Comput. Educ.*, no. 0123456789, 2022. https://doi.org/10.1007/s40692-021-00214-8
[28] A. E. E. Sobaih, A. E. Salem, A. M. Hasanein, and A. E. Abu Elnasr, "Responses to COVID-19 in higher education: Students' learning experience using Microsoft Teams versus social network sites," *Sustain.*, vol. 13, no. 18, 2021. https://doi.org/10.3390/su131810036
[29] T. V. M. Yen and N. T. U. Nhi, "The practice of online English teaching and learning with Microsoft Teams: From students' view," *AsiaCALL Online J.*, vol. 12, no. 2, pp. 51–57, 2021, [Online]. Available: https://asiacall.info/acoj/index.php/journal/article/view/41
[30] T. P. Ngoc and L. T. K. Phung, "Online language learning via Moodle and Microsoft Teams: Students' challenges and suggestions for improvement," 2021. https://doi.org/10.2991/assehr.k.210226.013
[31] O. A. Sogunro, "Motivating Factors for Adult Learners in Higher Education," *Int. J. High. Educ.*, vol. 4, no. 1, pp. 22–37, 2014. https://doi.org/10.5430/ijhe.v4n1p22
[32] E. A. Linnenbrink and P. R. Pintrich, "Motivation as an enabler for academic success," *School Psych. Rev.*, vol. 31, no. 3, pp. 313–327, 2002. https://doi.org/10.1080/02796015.2002.12086158
[33] A. Chalak and Z. Kassaian, "Motivation and attitudes of Iranian undergraduate EFL students towards learning English," *GEMA Online J. Lang. Stud.*, vol. 10, no. 2, pp. 37–56, 2010, [Online]. Available: https://ejournal.ukm.my/gema/article/view/108
[34] D. H. Schunk, P. R. Pintrich, and J. L. Meece, *Motivation in education*, (3rd ed.). Upper Saddle River, NJ: Pearson Merrill Prentice Hall., 2008.
[35] A. St. George, M. Hartnett, and J. Dron, "Examining motivation in online distance learning environments: Complex, multifaceted, and situation-dependent," 2011. https://doi.org/10.19173/irrodl.v12i6.1030
[36] P. D. MacIntyre and T. Gregersen, *Affect: The role of language anxiety and other emotions in language learning*. London: Palgrave, 2012. https://doi.org/10.1057/9781137032829_8
[37] E. Yüce, "Possible Problems in Online Foreign Language Teaching at a University Context," *Int. J. Curric. Instr.*, vol. 11, no. 2, pp. 75–86, 2019, [Online]. Available: https://acces.bibl.ulaval.ca/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1232749&amp%0Alang=fr&site=ehost-live
[38] T. Yashima, *Willingness to communicate: Momentary volition that results in L2 behaviour*. London: Palgrave MacMillan, 2012. https://doi.org/10.1057/9781137032829_9
[39] J. M. Dewaele, "Why do some young learners drop foreign languages? A focus on learner-internal variables," *Int. J. Biling. Educ. Biling.*, vol. 16, no. 6, pp. 635–649, 2009. https://doi.org/10.1080/13670050802549656
[40] H. Zubiri-Esnaola, A. Vidu, O. Rios-Gonzalez, and T. Morla-Folch, "Inclusivity, participation and collaboration: Learning in interactive groups," *Educ. Res.*, vol. 62, no. 2, pp. 162–180, 2020. https://doi.org/10.1080/00131881.2020.1755605

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A Semantic Representation of Online Teaching Business Process Architecture

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Abstract—A Business process architecture (BPA) is one of the significant assets in educational systems as it helps to understand and optimize educational processes by focusing on the key processes rather than the organizational specific details. The semantic, Riva-based business process architecture (srBPA) ontology is an abstract ontology that semantically conceptualizes the business process architecture's components and the relationships between them. This ontology can be instantiated for a specific domain to provide a general semantic-based BPA for organizations working in that domain. This paper instantiates the srBPA ontology for online teaching to provide a general semantic architecture for online teaching process that can be used as a reference by educational systems. This ontology was evaluated for completeness by referring to the national quality standards for online teaching and online courses. The evaluation has revealed that all quality standards were covered in the instantiated ontology through the classes, individuals, attributes and semantic rules that were defined.

Keywords—business process architecture, online teaching, semantic modeling, srBPA ontology, Riva method

1 Introduction

The rapid development of information technology and reliance on internet use in our daily lives has become an urgent necessity in many applications. The covid-19 pandemic has affected many sectors in the world, one the most critical sectors is education. Schools, colleges and universities have been deeply impacted and have directed their efforts to implement online learning and teaching strategies in order to ensure the persistence of the educational process.

The importance of online teaching is growing in all kinds of teaching scenarios. ELearning is an effective learning process that allows for online interaction between learners and their instructors without any face –to –face instruction. It is usually synchronous i.e. real-time, asynchronous i.e. through different ways such as online discussion groups with the instructor and students or learners depending totally on their selves through online materials and videos [1]. Having different online teaching and learning strategies, it is important to have a unified process architecture to represent the main online teaching processes. In addition, providing a semantic representation of the process architecture adds more value where it provides a machine interpretable source of information of online teaching process architecture. This paper provides a semantic online teaching business process architecture that is the result of instantiating Riva-based business process architecture (srBPA) ontology [18].

Section 2 provides background information about the Riva method and the srBPA ontology, and then describe literature related to our research work. Section 3 describes the instantiation of the srBPA ontology for online teaching to generate a Riva-based business process architecture ontology for online teaching. Section 4 evaluates the completeness of the resulting ontology by referring to the national quality standards for online teaching and online courses [19, 20]. Finally, section 5 concludes the paper.

2 Background and literature review

2.1 The Riva method

The Riva method was defined by Ould [15, 16] to derive business process architectures from the essential entities of a business. The main steps of this method are shown in Figure 1.

In order to identify an organization's process architecture in Riva, the boundary of the organization is agreed, then the essential business entities (EBE)s are identified through a brainstorming activity of the organizations' subject matter. The EBEs that have a lifetime which is handled by, or are the responsibility of, members of the organization are classified as Units of Work (UOWs). The next step is to produce a UOW diagram that depicts the dynamic relationships between UOWs. For each UOW, there is: a case process that handles single instances of the UOW; and a case management process for dealing with the flow of instances. The next step is to transform the UOW diagram into a first-cut process architecture; then, to use a number of provided heuristics to generate a second-cut process architecture. The Riva method was shown to be simple and easy to understand and apply [17].

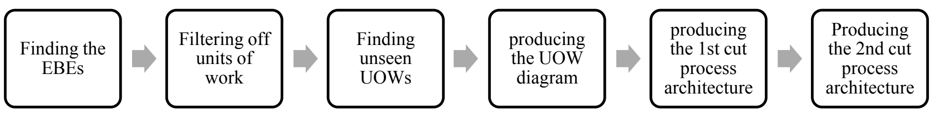

Fig. 1. Riva method steps to derive a BPA from EBEs

2.2 The srBPA ontology [18]

The srBPA ontology is an OWL-DL ontology that was developed to formally represent the Riva BPA elements and relationships between them. This ontology includes the classes that conceptualize the Riva elements as well as the attributes, axioms and rules that set the relationships between classes in order to formally represent the Riva rules. Figure 2 shows a graphical representation of part of the srBPA ontology, and Table 1 describes some of the defined classes and their related attributes.

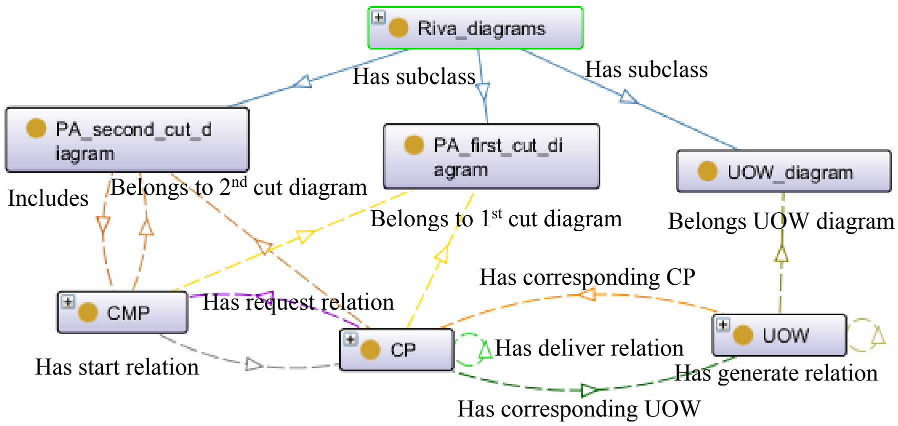

Fig. 2. Part of the srBPA ontology classes and relationships

Table 1. A description for part of the srBPA ontology classes and related attributes

Concept	Description	Attributes
EBE	The Essential Business Entities of an enterprise.	1) isConsideredUOW: Boolean.
UOW_diagram	The units of work diagram according to the Riva method.	1) hasUOW of type UOW, and 2) hasOutsideWorld of type Outside_world.
PA_first_cut_diagram	The 1st cut process architecture diagram according to the Riva method.	1) hasCP of type CP, 2) hasCMP of type CMP, and 3) hasOutsideWorld of type Outside_world.
PA_second_cut_diagram	The 2nd cut process architecture diagram according to the Riva method.	1) hasCP of type CP, 2) hasCMP of type CMP, and 3) hasOutsideWorld of type Outside_world.
UOW	The units of work in the UOW diagram, according to the Riva method.	1) BelongsToUOWDiagram of type UOW_Diagram, 2) hasCorrespondingCP of type CP, and 3) hasGenerateRelation of type Generate.

2.3 Online teaching

Universities have used different learning techniques to deliver knowledge and to satisfy the needs of their students. Along with the traditional teaching (face –to- face lectures in a class room), online teaching was designed to serve students who cannot attend traditional classes but have access to the internet. The potential of e-learning to improve learning and teaching, has been seen recently when many educational institutions were forced to shift to online mode of teaching.

"Online learning is defined as "learning experiences in synchronous or asynchronous environments using different devices (e.g., mobile phones, laptops, etc.) with internet access". [14]

E-Learning is a computer–assisted teaching, the learning can take place anywhere and anytime and when it is needed. Hence, e-learning can reduce the costs of education and the learning time since it spares the students from travelling long distances to attend the classes. On the other hand, there are some issues and challenges of implementing e-learning facing instructors as well as students. The most important challenge for instructors is to move from offline mode to online mode and to be able to use online tools and infrastructure. Instructors had to focus on well-developed courses where it is necessary to engage students and make the learning process student-centered. Instructors must be effective in responding to student's emails and messages as well as changing their teaching methodologies.

Students lack strong self-motivation and time management skills which may influence the failure or success in online learning. Instructors and students must embrace and bare the shift away from traditional standard classroom teaching to an e-learning approach to education. Understanding the advantages and disadvantages of online learning will help educational institutes in creating strategies to increase the efficiency of distance learning and creating new methods to deliver knowledge to the people who are eager to get.

E-learning technologies have evolved from basic content delivery to rich media based content delivery through the use of learning management systems such as moodle and blackboard. Knowledge construction through the active participation of students become a factor in e-learning. To facilitate the process of knowledge construction, facilities for a collaborative learning environment are provided [10].

Matthew N. O. Sadiku, Philip O. Adebo, and Sarhan M. Musa [5], provided a brief introduction to online teaching and learning. In their research article, they discussed the importance of online learning and teaching in offering opportunities to expand the learning environment for diverse student populations. Online teaching and face- to - face teaching have much in common, except in pace and delivery. On-line learning is suitable for students who have work or other commitments and wish to pursue an internationally recognized degree. Generally, students should have access to a computer system with high internet connections to acquire knowledge. The success or failure of implementing on-line teaching and learning depends on student's self-directed learning and instructors' effectiveness in delivering courses and getting used to online tools and infrastructure.

Fatimah A Albrahim [8], sheds light on the skills and competencies required for teaching online courses in higher education. She did a comprehensive review analyzing the literature concerning the competencies, skills, responsibilities and roles the instructors need to cope with the current standards of learning in higher education. These skills and competencies are classified into six categories: (a) pedagogical skills, (b) content skills, (c) design skills, (d) technological skills, (e) management and institutional skills, and (f) social and communication skills. In her research, she noted that instructors and learners must be educated about different aspects of online learning. Online learning organizations and educational institutions should support online instructors by providing a general framework and guidelines to improve their teaching skills and competencies and to help in designing and creating professional development programs. According to her research, it is difficult for online instructors to execute equally all the skills and roles, so the instructor should determine the priorities of the skills to execute according to his role. The competencies can help online instructors to self-evaluate their teaching skills, qualifications and abilities to teach online.

Ida Panev[6], analyzed the advantages and disadvantages of online teaching in higher education. The author found that online teaching is appropriate for well-organized, mature and motivated students who can manage their time, while it is inappropriate environment for other students who lack the ability of time management and self-discipline. Ida divided online teaching into two types: Asynchronous teaching which can include for example: teaching materials and pre-recorded lectures. Synchronous interactive teaching can include for example: live streaming. Ida discussed the advantages in terms of convenience, less expensive, technology as well as the additional benefits. While there are many advantages to online teaching, the disadvantages of digital learning can't be ignored. The most important issue is that there is no face –to- face interaction between teachers and students. This can cause sociological and psychological problems. Moreover, teachers and students have to make additional efforts. Teachers has to prepare attractive and interactive materials to grab their students' attention. On the other hand, students have to make effort not to be only passive observers of the educational process. The researcher's final goal is to have well educated students regardless whether they got their education in classrooms or online.

2.4 Related work

Semantic web and ontologies technologies influence ELearning systems and applications. A number of papers have been devoted to the study of the importance of semantic web and ontologies in ELearning.

Many e-Learning applications are lacking in knowledge representation technology. To satisfy e-learning requirements to be fast, just-in-time and relevant learning, sematic web with its properties of common-shared-meaning and machine-processable metadata is used. SW enables machines to understand the semantics, or meaning, of information on the World Wide Web. Semantic web is an intuitive web application with the ability to access information which is needed precisely [2].

Semantic web gives learners the ability to search the web and to retrieve information easily by making it possible for learners to find relationships between tagged information using ontologies [13].

The Semantic Web provides a new technology for the web-based information and services that would be understandable and reusable by both humans and machines across different applications. In order to achieve this, it is necessary at the conceptual level to form a consensus in the domain using ontology. Ontology is considered the main component of Semantic web and is defined as the backbone for the Semantic web architecture. It provides a link between the learning material and its conceptualization results in individualized learning paths. Ontology facilitates communication between people and different applications and helps machines to process the meaning and facilitates sharing of information [1, 3, 12, 13].

T.Sheeba S.Hameetha Begum M. Justin Bernard [1], discussed the significance of semantic web in ELearning content and the use of ontology in developing E-Learning content. Tools, languages, steps and approaches for ontology development are also discussed. By focusing on ontology of content infrastructure, e-learning community is realized to have much more effective services than what is currently provided by any of the available computer aided tutoring or learning management systems. ELearning is the use of technology to enable people to learn anytime and anywhere. The semantic web is the emerging technology aiming at web based information and services that would be understandable and reusable by both humans and machines. The semantic web has opened new horizons for internet applications in general and for eLearning in particular.

A similar study is done by Samir A. El-Seoud, Hosam F. El-Sofany and Omar H. Karam [4]. They discussed how the semantic web helps in developing an E-learning platform with a common interface for accessing learning materials. They also discussed how to integrate the semantic web technologies with e-learning systems, taking into consideration the standards and reusable learning objects. In their paper, they proposed an updated e-learning model based on the latest semantic web architecture where the main model for their research is the layered architecture. In their proposed model, the metadata, rules and annotations are stored externally in the ontology and knowledge base. Their model has the advantages of being able to reduce storage space, to retrieve meta-description stored in a database easily and to have different descriptions of the learning material according to the different contexts.

Pankajdeep Kaur, Pallavi Sharma and Nikhil Vohra [3], proposed a platform architecture for e-learning. The proposed a flexible educational system based on ontology technology and semantic web designed to be easy to modify and update. It is an e-learning management system with metadata, where the metadata main components includes system login, learning evaluation, course syllabus, the teaching approach etc. The system architecture of the e-learning system they explained in their paper consists of four components, Learning environment, repository, semantic web and administrator. The interface they designed makes the system easy to access irrespective of user's computer knowledge. The user can search for information using keywords as well as their synonyms. The user interface uses an ontology search engine to search ontology files from database for the keywords. The proposed system is capable of handling 1000 requests simultaneously.

Since the main purpose of education is knowledge sharing, an e-learning system has to be developed based on specific ontologies named educational ontologies. Mihaela Oprea[7] , developed an educational ontology , Univ_Edu_Onto, for teaching university courses. It was implemented in Protégé, a java-based ontology editor. The structure of the ontology has general terms for any university course and specific terms for an undergraduate students Artificial Intelligence course. The general terms may include a curriculum, objectives, pedagogical resource, learning resource, content, exams, problem, application, exercise, solution, lab, project and software. The specific terms are particular to each course and include concepts from the domain of knowledge. For the

Artificial Intelligence course, the researcher include specific terms such as knowledge, inference, heuristic, knowledge base, inference engine, knowledge based system and expert system. Relationships between the terms of the ontology are developed such as has, part of and is-a. The developed ontology can be used in the e-learning platform used for teaching in the universities.

The paper written by Neepa K. Shah focused on e- learning [9], benefits and requirements of e-learning and the uses of semantic web technology in e-learning. According to a study conducted by WR Hambrecht, online learning increased the retention rates of the learning material by 25-60%. It gives the student immediate access to the most current data since instructors are able to update contents instantly. The information delivered can be consistent to all users. In online learning the content is customizable taking into consideration each students strengths and weakness. It is self-paced and learner control. In the paper, the author differentiated between traditional learning and e-learning. The traditional learning has the following characteristics centralized authority, push delivery, lack of personalization and static learning process. On the other hand, e-learning is a distributed, student-oriented, personalized and dynamic learning process. Thus the author concluded that e-learning is replacing traditional learning but there are certain requirements to be achieved such as it needs to be fast and just in time. This needs a suitable content and organized material.

Shabina Dhuria and Sonal Chawls focused on the following points [2]: the use of semantic web and ontologies for realizing e-learning requirements, ontologies applications and the analysis of various ontology tools that are helpful in knowledge retrieval, storage, and sharing. The researchers explained that the purpose of semantic web is to find and access web sites and resources by keywords and definitions of their contents. Ontology, as an important component of semantic web, allows sharing and reusing of information in an organized manner. Both semantic web and ontology provide intelligent access to and management of web content that result in more intelligent e-learning. In the research paper the focus was on ontologies in educational systems. The paper discussed two projects about the usage of ontologies in e-learning. LT4eL project is a multilingual project, where there are nine languages to display the ontology concept. LT4eL enhances search process in LMS. It uses semantic web technology to improve the retrieval of learning material. It also facilitates personalized access to the learning content and defines domain ontology for semantic search. The second project is O4E project [11]. As in many other ontology-based applications, it works on two types of knowledge subject i.e. domain and structure, which leads to two types of ontologies, domain ontology and structure ontology. As a result of their analysis, there exists many ontology tools to apprehend the learning benefits. When compared to other tools, Protégé tool is being used with 68.20%. The percentage of ontology usage in education domain is 31% while it is 69% in other domains.

As can be seen from reviewing the literature, most research work has focused on using semantic web to provide better methodologies and tools for online teaching, however, our work focuses on providing a business process architecture that helps identify the main processes of online teaching without having to worry about organizational-dependent details.

3 Instantiation of srBPA ontology for online teaching

In this section, we first show how the Riva method is used to generate a BPA for online teaching then we show how it is semantically represented using srBPA ontology.

3.1 Online teaching BPA

In this section we show how to generate a Riva based business process architecture for online teaching

Finding the EBEs. The first step in to identify the essential business entities (EBE) for the online teaching process, this is a brainstorming activity that should be conducted by people working in the domain, since the authors of this paper are well experienced in the online teaching process, they had two sessions to brainstorm the list of EBEs, the questions suggested by Ould [16] were used to help identify them.

Three simple filters should be applied to the list of EBEs to ensure that each entity is truly essential to the business; the first one is to discard any entity that doesn't make sense to add the word 'a' or 'an' in front of it, the second one is to discard any designed entity, which is there because of the way the business runs, rather than because they fundamentally characterize the business. The third filter is to discard entities that are roles and are not of the essence of the business.

Table 2 shows the questions that were used to prompt suggestions and the essential entities that were identified as answers to those questions.

Table 2. Questions used to identify the list of EBEs

Questions to prompt suggestion of candidate EBEs	**Candidate EBEs**
What do we make?	**Online courses, Online courses syllabus**, **courses material,** online lectures, handouts – videos – booklets – course files – **Assignments** – **Exams** – **projects** – conferencing – Lecture notes - Books
What services do we offer?	Teaching –**multiple class coordination - grading – students' evaluation** counseling – **online office hours** – guiding – giving references- **projects online supervision** – **students' performance monitoring**
What things can we simply not get away from?	exams reviews - accreditation requirements – **exit surveys**, **stakeholder involvement** – **continuous improvement** – **course evaluation** – instructor evaluation – **course regulations**
Who are our external customers?	External examiners – External researchers – external teachers – external students – accreditation employees – maintenance employees – service providers
Who are our internal customers?	Students– Instructors – teaching assistants – administrative staff – lab supervisors – e-learning staff members – committee members
Are there things that our customers have, or want, or do that are EBEs for us?	**Disabled students management** - complaints – asking questions – submitting answers – uploading files and videos – downloading files and videos –requesting grades review – requesting to update grades – **exit surveys** – **absent students management**
What things do we think differentiate our organization from others in the same business?	**Online courses – continuous improvement**

What sorts of things do we deal with day in, day out?	**Teaching platform**, **exams platform**, **grading platform**, Complaints – students questions – system failure —time management
What events in the 'outside world', the world outside our organization, do we need to respond to?	**Stakeholder involvement**, **university regulations- quality standards**
What business entities are listed in our corporate data model?	Grades – students' information – instructors' information
What things do our information systems keep information on?	Labs – computers - library – rooms (Lectures or offices – staff members – instructors and students – Research information Lectures, **students absence**, students grades

Filtering off units of work. The resulting list of EBEs in the previous step describes the subject matter of the online teaching process. The next step is to find the units of work (UOW) from the list of EBEs, these units of work are entities that have lifetime during which we must look after them. So each UOW starts, proceeds and stops during the process, and some actions must be taken to handle it.

Accordingly, the list of EBEs will be examined to filter out any entity that is not a unit of work, a role that only plays part in the process, and any entity that is part of EBE and doesn't have a separate lifetime. The units of work appear in bold face in Table 2.

Finding unseen UOWs. This step tries to find UOWs that could've been missed through examining the names of the departments, putting the words "change to" and "collection of" in front of each UOW to see if it creates another UOW. After examining this step, no unseen units of work were found.

Producing the UOW diagram: Finding the dynamic relationships between UOW. There are possible relationships between UOWs, especially when one UOW requires information from another, a neutral word 'generates' could be used to describe the dynamic relationship between units of work. Accordingly, if two UOWs A and B have the relationship 'A generates B', then this means that "during the lifetime of a case of UOW A, cases of UOW B are required/needed/activated/called for".

Figure 3 shows the UOW diagram which represents all units of work identified for online teaching and the dynamic relationships between them.

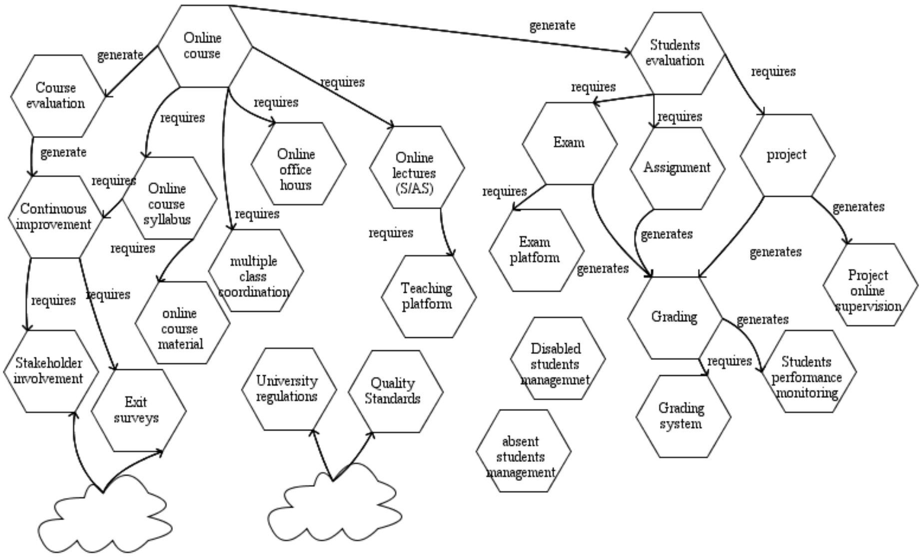

Fig. 3. Unit of work diagram for online teaching

Producing the first cut process architecture. This is a mechanical step where it is hypothesized that for each UOW in the UOW diagram, there are three processes; a case process, a case management process and a case strategy process. The "generate" relationship between units of work are represented as different relationships between the corresponding processes as shown in Figure 4.

The first cut process architecture diagram was generated automatically using the RPage tool [21], Figure 5 shows part of this architecture, the full diagram was not included because of the large number of relationships between case processes and case management processes that makes the diagram difficult to read.

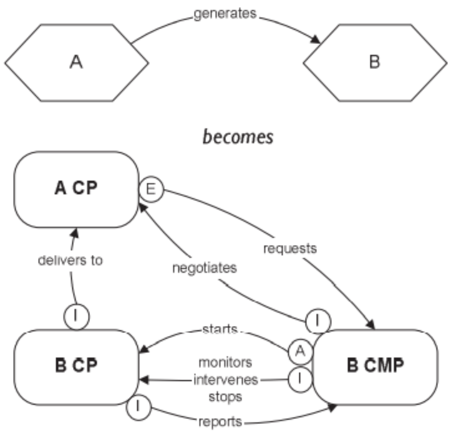

Fig. 4. Rule to generate case processes and case management processes

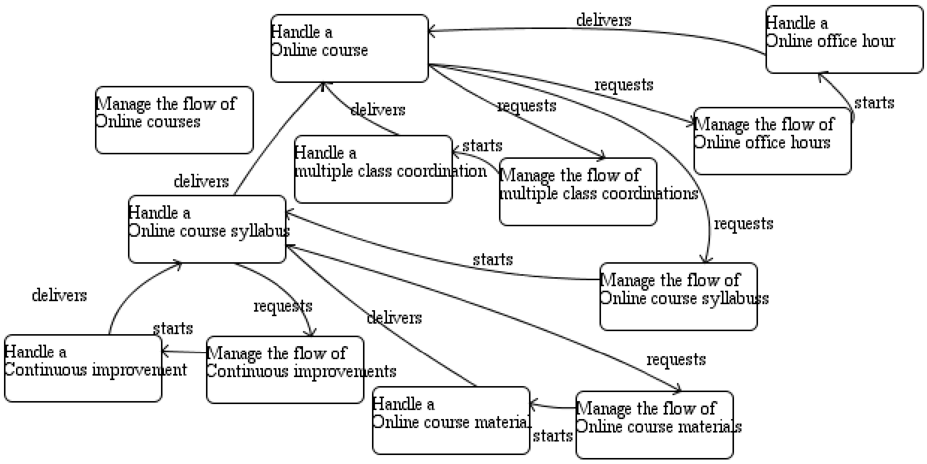

Fig. 5. Part of the 1st cut business process architecture for online teaching

Producing the second cut process architecture. The first cut process architecture involves more information that is actually present in a process architecture. In this step a domain expert is required to validate the first cut process architecture to decide on which processes and relationships should remain and which should be removed. For example, some case management processes can be encapsulated in the requesting case processes, so these should be folded into the requesting case processes. Another validation is to check each "deliver" relationship if it really happens, because some "request" relationship doesn't hold in reality. The domain expert should also check if the case management process is not empty, because sometimes there is no process to handle the flow of certain cases, if this applies then the case management process should be removed. One final validation is to check chains of requests, for example if A request B and B request C then instead of making C delivers to B and B delivers to A, the "deliver" relationship can be short-circuited where C delivers immediately to A.

Having validated the first cut process architecture by a domain expert and removed unrealistic processes and relationships, the second cut process architecture provides the target process architecture. This architecture is more realistic and represent the main processes of the system and the relationships between them, to provide an abstract view of the system. Figure 6 shows the second cut process architecture.

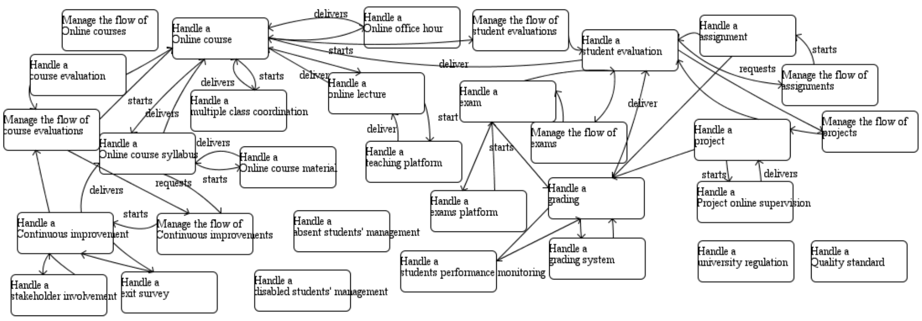

Fig. 6. 2nd cut process architecture for online teaching

3.2 Semantic representation

In this step, we semantically represent the BPA and all its elements using the srBPA ontology [18]. The following algorithm describes the steps used to instantiate the srBPA ontology for online teaching process. Figures 7, 8 and 9 shows snapshots from the protégé tool which was used to instantiate the srBPA ontology for online teaching.

```
  Algorithm I: instatiating srBPA ontology for online
teaching
  Input: SrBPA ontology, the set of essential business
entities for the online teaching process OT_EBEs = {ebe1,
ebe2, …, eben} where n is the number of EBEs.
  Output: OT_srBPA ontolog: the instantiated srBPA onol-
ogy for the online teaching process
  Begin
  1. Create the individual OT_UOW_Diagram as an instance
     of the class UOW_Diagram
  2. Create the individual OT_PA1_Diagram as an instance
     of the class PA1_Diagram
  3. Create the individual OT_PA2_Diagram as an instance
     of the class PA2_Diagram
  4. For each eben ϵ OT_EBEs:
      Create an individual for the class "EBE"
      If eben is considered a UoW, then Set the relation
"isConsideredUoW" as true
      End for
  5. Run the following SWRL rule to create corresponding
     UoWs individual
      EBE(?x) ^ isConsideredUOW(?x, True) -> UOW(?x)
  6. Run the following SWRL rule to set all UOWs to be-
     long to OT_UOW_Diagram:
      UOW(?u) -> belongsToUOWDiagram(?u, OT_UOW_Diagram)
```

7. Run the following Jess rule to create the corresponding CP of each UOW and set hasCorrespondingUOW:

```
(defrule create_CP ?f <- (object (is-a UOW) ) =>
 (make-instance (str-cat (instance-name ?f) "__Handling") of CP (hasCorrespondingUOW ?f)))
```

8. Run the following Jess rule to create the corresponding CMP of each UOW and set hasManaging CP:

```
(defrule create_CMP ?f <- (object (is-a UOW)
(hasCorrespondingCP ?cp) ) =>
 (make-instance (str-cat (instance-name ?f) "__flow-Managing") of CMP (hasManagingCP ?cp) ))
```

9. Run the following SWRL rules to assert that each CP belongs to both the 1^{st} and 2^{nd} cut diagrams

```
CP(?cp) -> belongsTo1stCutDiagram(?cp, OT_PA1_Diagram) ^ belongsTo2ndCutDiagram(?cp, OT_PA2_Diagram)
CMP(?cmp) -> belongsTo1stCutDiagram(?cmp, OT_PA1_Diagram)
```

10. Run the following jess rule to perform the translation of the relationships present in the UOW diagram into relationships between the corresponding CPs and CMPs in the 1^{st} cut PA diagram:

```
(defrule translate_relations
(object (is-a Generate) (OBJECT ?f) (hasUOWSource ?a) (hasUOWDestination ?b))
(object (is-a CP)(OBJECT ?acp) (hasCorrespondingUOW ?a)) (object (is-a CP) (OBJECT ?bcp) (hasCorrespondingUOW ?b))
(object (is-a CMP ) (OBJECT ?bcmp) (hasManagingCP ?bcp))
=>
(make-instance (str-cat (instance-name ?f) "_d" ) of Deliver (hasCPSource ?bcp) (hasCPDestination ?acp))
(make-instance (str-cat (instance-name ?f) "_r") of Request (hasCPSource ?acp) (hasCMPDestination ?bcmp))
(make-instance (str-cat (instance-name ?f) "_s") of Start (hasCMPSource ?bcmp) (hasCPDestination ?bcp)))
```

11. Delete irrelevant CMPs by setting the Boolean property isActive as false
12. Run the following SWRL rule to delete all relevant "Request" relations to it (if exists)

```
CMP (?cmp) ^ isActive (?cmp, false) ^ Request (?r) ^ hasCMPDestination (?r, ?cmp) -> isActive(?r, false)
```

13. Modify The "Start" relations to the managed CP by changing the source from the CMP to the CP that should have requested it.

14. Run the following SWRL rule to identify those CMPs that belong to the 2nd cut diagram

```
CMP(?cmp) ^ isActive(?cmp, True) ^ be-
longsTo1stCutDiagram (?cmp, OT_PA1_Diagram) -> be-
longsTo2ndCutDiagram (?cmp, OT_PA2_Diagram)
```

End

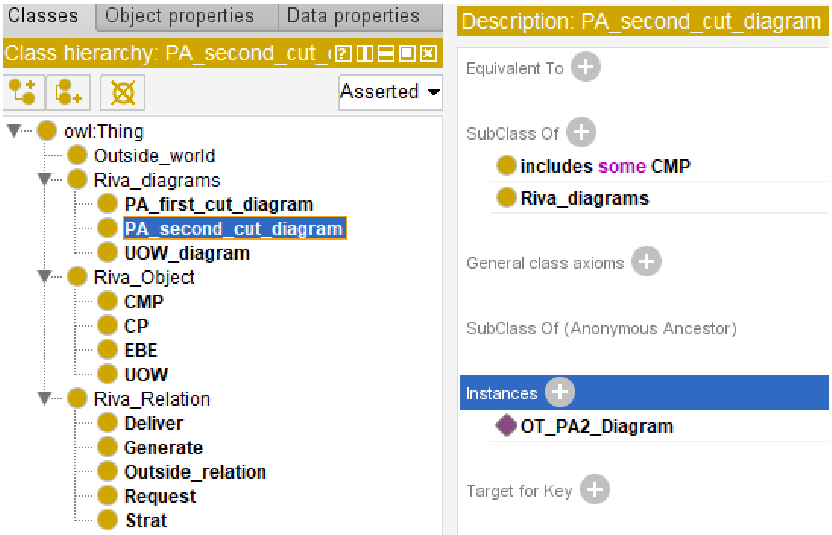

Fig. 7. A screenshot from the protégé tool that shows the main classes of the srBPA ontology

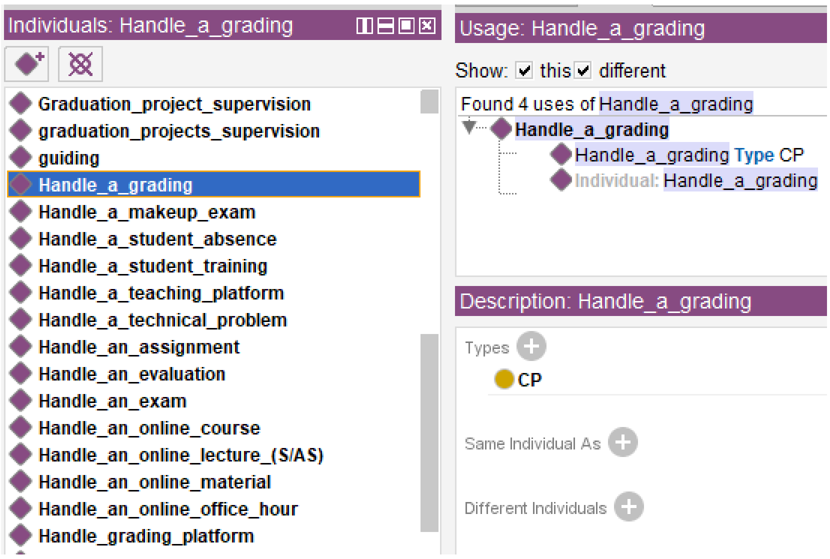

Fig. 8. A screenshot from the protégé tool that shows part of the instances created for the CP class

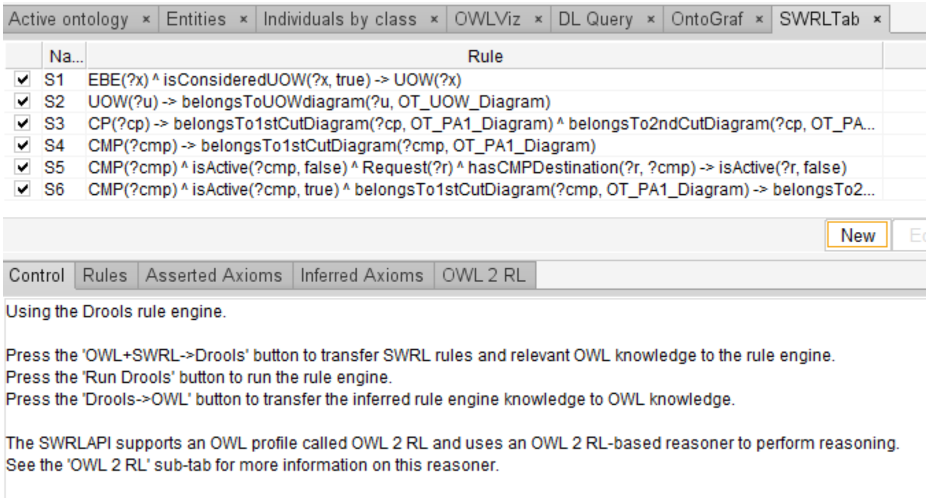

Fig. 9. A screenshot from the protégé tool that shows part of the SWRL rules

4 Discussion

Online teaching methods and best practices are constantly evolving and in order to keep teachers up to date, experts from Quality Matters (QM) and the Virtual Learning Leadership Alliance (VLLA) released a revised version of the National Standards for Quality Online learning, which previously had been updated in 2011 by iNACOL.

This aligns to our main goal of providing a semantic representation of the online teaching process architecture which is to provide a standard source of information of the high-level activities present in any online teaching process. Our added value here is the semantic representation of information to make it machine interpretable.

In this section we explain the value of instantiating srBPA ontology and providing a semantic representation of the online teaching process architecture through the comparison with the National Standards for Quality Online Teaching [19] and the National Standards for Quality Online course [20]. Tables 3 and 4.

Table 3. Mapping between the standards for quality online teaching and the semantic representation in SrBPA ontology

Standard	Description	Semantic implementation in SrBPA ontology
Standard A: professional responsibilities	The online teacher demonstrates professional responsibilities in keeping with the best practices of online instruction.	The following case process instance was defined: *Handle continuous improvement*. The following case management process was defined: *Manage the flow of continuous improvements*
Standard B: Digital pedagogy	The online teacher supports learning and facilitates presence (teacher, social, and learner) with digital pedagogy.	The following case process instances were defined: *Handle teaching platform, handle grading platform, handle online lecture, handle online material and handle online office hours*

Standard C: Community building	The online teacher facilitates interactions and collaboration to build a supportive online community that fosters active learning.	The following case process instances were defined: *Handle online lecture, handle online assignment, handle project online supervision*
Standard D: Learner engagement	The online teacher promotes learner success through interactions with learners and other stakeholders and by facilitating meaningful learner engagement in learning activities.	The following case process instances were defined: *Handle an exit survey, handle stakeholder involvement* The following case management process instance was defined: *Manage the flow of exit surveys*
Standard E: Digital citizenship	The online teacher models, guides, and encourages legal, ethical, and safe behavior related to technology use	The following case process instances were defined: *Handle course regulations, handle university regulations*
Standard F: Diverse instruction	The online teacher personalizes instruction based on the learner's diverse academic, social, and emotional needs.	The following case process instances were defined: *Handle disabled students, Handle student performance monitoring, handle continuous improvement*
Standard G: Assessment and measurement	The online teacher creates and/or implements assessments in online learning environments in ways that ensure the validity and reliability of the instruments and procedures. The teacher measures learner progress through assessments, projects, and assignments that meet standards-based learning goals, and evaluates learner understanding of how these assessments measure achievement of the learning objectives.	The following case process instances were defined: *Handle course evaluation, handle students evaluation, handle an assignment, handle an exam, handle project online supervision, handle continuous improvement* The following case management processes were defined: *manage the flow of students evaluations, manage the flow of assignments, manage the flow of exams, manage the flow of continuous improvements.*
Standard H: Instructional Design	The online teacher curates and creates instructional materials, tools, strategies, and resources to engage all learners and ensure achievement of academic goals.	The following case process instances were defined: *Handle a teaching platform, handle grading platform*

Table 4. Mapping between the standards for quality online courses and the semantic representation in SrBPA ontology

Standard	Description	Semantic implementation in srBPA ontology
Standard A: Course Overview and Support	The overall design of the course is made clear to the learner at the beginning of the course.	The following case process instance was defined: *Handle online course syllabus*
Standard B: Content	The online course provides learners with various content options that promote their mastery of content and are aligned with state or national content standards	The following case process instance was defined: *Handle online material*
Standard C: Instructional design	The online course incorporates instructional materials, activities, resources, and assessments that are aligned to standards, engage all learners, and support the achievement of academic goals.	The following case process instance was defined: *Handle an online course*

Standard D: Learner Assessment	A variety of assessment strategies are used throughout the course geared toward learning and engagement and learners are provided with feedback on their progress	The following case process instances were defined: *Handle course evaluation, handle students evaluation, handle an assignment, handle an exam, handle project online supervision* The following case management processes were defined: *manage the flow of students evaluations, manage the flow of assignments, manage the flow of exams,*
Standard E: Accessibility and usability	The course design reflects a commitment to accessibility so that all learners can access all content and activities and to usability so that all learners can easily navigate and interact with all course components	The following case process instances were defined: *Handle a teaching platform, handle grading platform, handle an exam platform*
Standard F: Technology	The technologies enabling the various course components facilitate active learning and do not impede the learning process.	The following case process instances were defined: *Handle a teaching platform, handle grading platform, handle an exam platform*
Standard G: Course evaluation	The online course is evaluated regularly for effectiveness, using a variety of assessment strategies, and the findings are used as a basis for improvement	The following case process instances were defined: *Handle a course evaluation, handle continuous improvement.* The following case management processes were defined: *manage the flow of course improvements*

As can be seen from the mapping tables, the srBPA ontology has included all quality standards for online teaching and online courses. For example, the case processes: "Handle teaching platform" and "Handle grading platform" satisfy standard B of quality standards for online teaching as well as standard F for quality standards of online courses where the activities include how teachers use digital pedagogical tools for teaching, interaction and communication.

The ontology presents abstract and general case process instances whose activities can be different from one organization to another, and this is the essence of presenting business process architectures rather than business process models. Accordingly, having a semantic representation for online teaching process architecture helps understand the main processes that should be present to have successful outcomes, without having to concern about process details as it could be variant according to organizations and strategies.

5 Conclusion

In this paper, the srBPA ontology was instantiated for online teaching, with the aim to provide a semantic representation of the online teaching business process architecture. The BPA method used is based on the Riva method, where the essential business entities were identified and the units of work were extracted and used to generate a unit of work diagram that shows the relationships between UOWs. The first cut BPA can be generated automatically, and then the second cut BPA is generated after applying a number of heuristics. All components of the Riva-based BPA are represented semantically in srBPA ontology as well as the relationships between them, in addition to the rules that makes the Riva method. In order to instantiate the ontology, individuals are created for each class, so instances were either defined or generated automatically through the rules to conceptualize EBEs, UoWs, CPs, CMPs, diagrams and relationships.

The instantiated srBPA ontology was evaluated for completeness by referring to the national quality standards for online teaching and online courses [19, 20]. Each standard was examined to check its availability in the instantiated ontology, mapping resulted in all quality standards covered through multiple case process and case management process instances.

Adapting this semantic representation in educational systems will be beneficial as it provides a single source of information that is machine interpretable and can be used as a core component in systems that aim to monitor and optimize the online teaching process.

6 References

[1] Sheeba, T., Begum, S. & Bernard, M. (2012). Semantic Web to E-Learning Content. International Journal of Advanced Research in Computer Science and Software Engineering, 2 (10), 58-66.

[2] Shabina Dhuria, S. C. (2014). Ontologies for Personalized E-Learning in the Semantic Web. International Journal of Advanced Engineering and Nano Technology, 1(4) ISSN: 2347-6389.

[3] Pankajdeep K., Pallavi S., and Nikhil. V. (2015). An Ontology Based E-Learning System. International Journal of Grid Distribution Computing, 8(5), pp. 273-278. https://doi.org/10.14257/ijgdc.2015.8.5.27

[4] Samir A. El-Seoud, Hosam F. El-Sofany and Omar H. Karam (2015). The Semantic Web Architecture and its Impact on E-learning Systems Development. International Journal of Emerging Technologies in Learning (IJET) – 10(5), pp. 29-44. https://doi.org/10.3991/ijet.v10i5.4754

[5] Matthew N. O. Sadiku, Philip O. Adebo, and Sarhan M. Musa (2018). Online Teaching And Learning. International Journals of Advanced Research in Computer Science and Software Engineering, 8(2), pp. 73-75. https://doi.org/10.23956/ijarcsse.v8i2.549

[6] Panev, I. (2021). Online Teaching in Higher Education during COVID-19 Pandemic. World Journal of Educational Research, 8(2). ISSN 2375-9771 (Print) ISSN 2333-5998 (Online). https://doi.org/10.22158/wjer.v8n2p96

[7] Oprea, M (2011). An Educational Ontology for Teaching University Courses. In 6th International Conference on Virtual Learning–ICVL, no. 39, pp. 117–122.

[8] Fatimah. A. (2020). Online Teaching Skills and Competencies. TOJET Turkish Online J. Educ. Technol., 19(1), pp. 9–20.

[9] Neepa K. Shah (2012). E-learning and semantic web. International Journal of e-Education, e-Business, e-Management and e-Learning, 2(2), pp.113. https://doi.org/10.7763/IJEEEE.2012.V2.91

[10] Amin Daneshmand Malayeri, Nikos E. Mastorakis (2012). Ontology-Based Learning Environment in Distance Education Systems, Recent Researches In Communications And Computers, pp. 283 – 290 ISBN: 978-1-61804-109-8.

[11] Dicheva D., Sosnovsky S., Gavrilova T., and Brusilovsky P (2004). Ontological web portal for educational ontologies // Int. J. Inf. Theor. Appl. 13(4). P. 303–308.

[12] Alsultanny Y, (2006). e-Learning System Overview based on Semantic Web. The Electronic Journal of e-Learning. 4(2), pp 111 – 118.
[13] Betül Ö. C. (2014). THE SEMANTIC WEB IN TEACHER EDUCATION. TOJET: The Turkish Online Journal of Educational Technology, 13(4).
[14] Dhawan, S. (2020). Online Learning: A Panacea in the time of COVID-19 crisis. Journal of Educational Technology Systems, 49(1), pp. 5–22. https://doi.org/10.1177/0047239520934018
[15] Ould, M. (2005) Business Process Management: A rigorous Approach, BCS, UK.
[16] Ould, M.A., 2019. Business process management. Meghan-Kiffer Press.
[17] Green, S. and Ould, M (2004). The Primacy of Process Architecture. 5th Workshop on Business Process Modelling, Development, and Support, in conjunction with the 16th Conference on Advanced Information Systems Engineering (CAiSE04), Riga, pp.154-159.
[18] Yousef, R. and Odeh, M. (2011), December. The srBPA ontology: A formal representation of the Riva-based business process architecture. In 2011 IEEE Jordan Conference on Applied Electrical Engineering and Computing Technologies (AEECT) (pp. 1-8). IEEE. https://doi.org/10.1109/AEECT.2011.6132537
[19] Quality Matters. (2019). National standards for quality online teaching. Access November, 2021 at https://www.nsqol.org/the-standards/quality-online-teaching/
[20] Quality Matters. (2019). National standards for quality online courses. Access November, 2021 at https://www.nsqol.org/the-standards/quality-online-courses/
[21] Luu. D. (2009). RPage tool, Riva Process Architecture Graphical Editor, MSc Dissertation Report, The University of the West of England.

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Development of the Improved Exercise Generation Metaheuristic Algorithm EGAL+ for End Users

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Abstract—Exercise generation is a subject worthy of investigation. In our previous papers, a new multi-objective harmony search metaheuristic algorithm called EGAL was presented, designed to address a widely recognised problem: generating diverse exercises to measure students' knowledge on various topics. An improved metaheuristic algorithm (EGAL+) has since been created, and it is presented in this study. The aim of this research was to further develop EGAL and to investigate the differences between the original and the new algorithm. This newly acquired algorithm preserved the advances of EGAL – the generated exercises cover as many areas of the course as possible, the difficulty of the exercises are equal, and they are diverse. Moreover, the improved algorithm is also usable for non-expert users, since the introduced input fields are restricted to the ones which are freely editable. It is sufficient for the user to be proficient in their own field and to operate the program with subject-specific questions. These statements were confirmed by running EGAL+ on a large number of samples.

Keywords—exercise generation problem, multi-objective optimisation, harmony search metaheuristic algorithm, web-based applications, end-user development

1 Introduction

Creating and correcting tests are slow and difficult tasks in education. This is one of the practical reasons why exercise generation has been at the forefront of research for a long time. Generating exercises represents a challenging problem that has been identified by many researchers. Manually creating exercises is time-consuming, so several powerful exercise-generating systems have been proposed over the last few years, and many online learning platforms, which are robust and complex systems, generate exercises automatically. Later in this chapter, some examples of such systems are provided. These exercise-generating systems are useful for teachers because they save time and effort, and teacher workload is reduced as these tools are suitable not only for generating exercises, but also for correcting, evaluating and grading the answers. These tools are also useful for students because most of these systems are personalised and give effective feedback.

Some of these tools apply different levels of difficulty to handle students with different knowledge levels. Many were developed specifically for a particular field, such as language learning (grammar vocabulary trainers), engineering studies, mathematics or geometry exercises, SQL tasks etc. However, some of these tools are developed for general purposes. Some examples for these different types of exercise generators will now be enumerated.

It should be noted that the use of metaheuristic algorithms to solve educational problems is a common practice. Two recent examples are a genetic algorithm solution for a multi-objective optimisation problem, to create exam schedules [1], or a harmony search metaheuristic solution for automatic composition of instructional units [2]; however, there are many other similar examples [3], [4], [5], [6], [7], [8], [9], [10].

The generation of exercises has been extensively studied for a long time by many researchers e.g. [11], [12], [13], [14], [15], [16], [17], [18], [19]. Many automated exercise generation systems can be included in the Data Science domain. Data science emerged as a new field over the last few years, and new data science algorithms were developed to generate exercises [20]. Whereas the generation of exercises is a constantly evolving field of science, research published in the last decade has been examined in this chapter.

However, not only have topic-specific approaches been developed, but such tools have also been developed based on the way of reaching students. A template-based MOOC (Massive Open Online Course) approach is proposed by [12] to automate the teaching life cycle addressing creation of problems. The authors present suitable solutions and grading.

The key characteristics of MOOCs were identified by [21] which affect the affinity of students to online educational systems over a longer period. The most important measurements are the user's affinity towards teaching content, difficulty, workload, and the duration of a lesson.

As emphasised in [11], most of the former solutions could not handle general problems, but only specified questions. The authors proposed a general solution for representing user inputs in the automated exercise generation process.

Some other applications prioritise personalisation. The ODALA+ (Ontology Driven Auto-evaluation Learning Approach) is presented by [22] for developing suitable exercises, which is a learning system on user personalisation. The authors have shown that developing adapted learning materials is an activity of fundamental importance. Knowledge, skills, and behaviour information was collected from the evaluation module and was integrated into ODALA+.

Next, some specific problem-solving applications will be presented. A solution is proposed by [23], which was developed to produce SQL questions automatically. This system uses difficulty levels and gives feedback for the users to help them improve their knowledge. The teachers do not need to create SQL questions, only database schemes.

A solution is offered by [24] for teaching differential equations in the field of Mathematics. It is personalised, because the student is identified using his or her answer history record of past answers, and the difficulty of the problems are optimised according to his or her knowledge.

Numerous task generation systems have been developed to support language learning. An approach is developed by [25] to generate FITB (Fill In The Bank English) learning exercises.

Some other applications prioritise ease of use, in that way similar of our EGAL+ algorithm. Passarola, a simple, powerful, exercise generation system was developed in such a way that anyone without a computer science background can use it to generate exercises. The researchers offer a specific language for creating more complex types of exercise than usual, such as multiple choice, data type or file comparisons [26]. The target is not a specific subject, as the system can solve general problems. The publication offers a set of examples of exercises created for courses that range from Mathematics to Music and Geography.

Moodle, one of the most popular LMSs (a learning management system is a form of software that users apply in the web-based learning process) is also capable of generating exercises for students and teachers. During such generation, different conditions may be specified. Various plug-ins have also been developed for Moodle. However, no solution can be found neither in Moodle nor among the plug-ins nor in any other LMS to the specific problem which is described in the next paragraph.

An overview of EGAL+, together with a description of the ways in which it differs from and is similar to the above, now follows. The purpose of this algorithm is to generate multiple different subsets of predetermined tasks (i.e. exercises) to test students' knowledge on various topics, in such a way that firstly, the quality of these subsets should be good enough according to a predefined quality matrix (i.e. they should cover the most important parts of the topics as much as possible), and secondly, the exercises are of equal difficulty. It is up to the teacher to decide which parts of the topics are the most important. These tasks are selected by the teacher based on which discipline – statistics, mathematics, informatics, language, and so on – he or she wants to assess students' knowledge of. For example, the topic can be the cascading style sheet subject in web development, and the parts can be some concrete CSS formatting, or another example can be the English grammar knowledge of verb tenses, and the parts can be the past tense of some concrete verbs. The previous examples [27], [28],[29] are university level exercises, but EGAL and EGAL+ can be used with students of different age and different knowledge depending on the teachers' choice.

Exercises should be diverse (according to a matrix and a diversity scale, which are both inserted into the multi-objective fitness function). Although the difficulties of these tasks can be different from each other, the difficulty of the subsets of the tasks should be the same. This is a problem without any satisfactory solution, as is shown in the above examples. Our previous studies have addressed this deficit. Unfortunately, the optimisation algorithm presented in our former publications has been usable only by researchers skilled in the field. Only they have been able to properly reconstruct and use it, based on the detailed information in our previous publications. The EGAL algorithm has now been transformed to an "easy-to-use" program, in a way that end users with no computer science and optimisation background could also use it, with certain restrictions and improvements. The improved metaheuristic algorithm (EGAL+) is presented in this paper. The goal of this research is to improve EGAL and to show the differences between EGAL and the newly acquired EGAL+.

Satisfying the needs mentioned previously – the quality of the subsets and the difficulty of the exercises – represents a much smaller-scale problem than that addressed by the other solutions in this chapter. One relevant difference is that EGAL+ is not a complex system, for example, this solution is not personalised and does not give feedback for the users.

On the other hand, this solution resembles other solutions previously described in this paper in the sense that is general, i.e. the problem can come from any field of science, e.g. statistics, mathematics, informatics, language, and so on, since EGAL+ will solve the problem regardless.

To summarise, in reviewing the literature it is found that - although many complex, adaptive, personalised, easy-to-use and effective exercise generating systems have been developed - such a tool capable of solving exactly the specified problem - to generate multiple different subsets of predetermined tasks, in such a way that the quality of these subsets should be good enough according to a predefined quality matrix, and the exercises are of equal difficulty – does not yet exist. No similar solution has previously been found, since the predefined quality matrix gives the solution a unique character, and no problem statement has previously been found where multiple different subsets of predetermined tasks are generated. Moreover, achieving all these things with an interface designed for non-expert users is also unprecedented, indicating that the added value of the EGAL+ algorithm is unquestionable.

2 End user problem

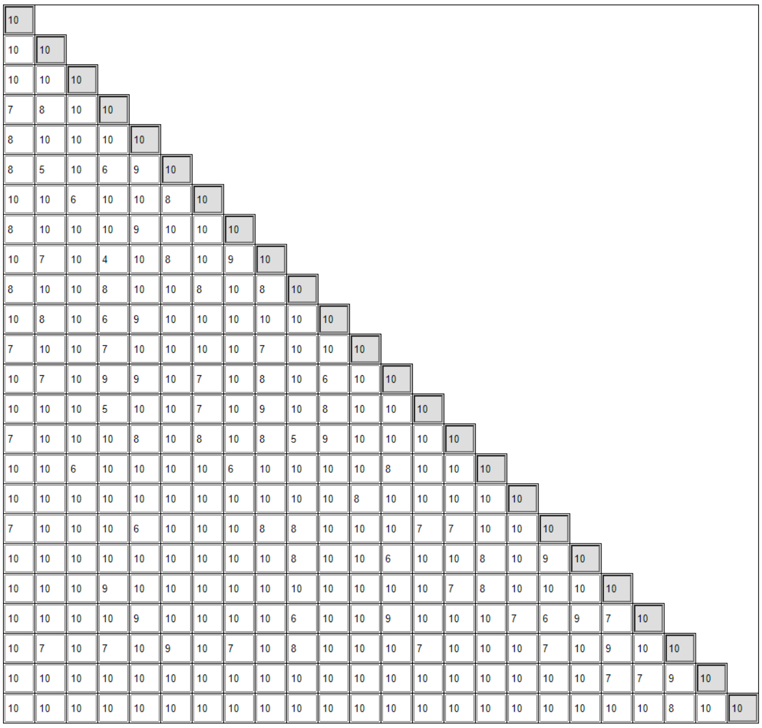
EGAL+ is an improvement of the EGAL algorithm, which was published in our former papers [27], [28], [29]. It will be shown that the original EGAL algorithm can be transformed for use by end users without a computer science and optimisation background, with some restrictions and improvements. In this paper the new algorithm EGAL+ will be presented, which differs in many respects from the original EGAL algorithm. The most important modifications are (i) choosing appropriate initial parameters; (ii) limiting the number of zeros in the quality matrix (iii); inserting a new function, which handles the difficulty problem and (iv) improving the fitness function.

EGAL+ is a web-based app that can be used via any current browser. Before going into the details of the system, it should be described how the EGAL+ algorithm is displayed to a user. A demonstration is available at https://egalplus.azurewebsites.net/. Here the user can run general cases – where the tasks are Task1, Task2, etc. –, and a specific CSS example can be run here as well – when the tasks are CSS formats. This example is one of those that were investigated in our former publications [27].

It should be noted that hosting the new algorithm imposes certain restrictions as regards running time. The probability of these restrictions occurring is small, but if the reader would like to check the algorithm without restrictions, it is recommended to use the GitHub code. The algorithm's code can be found at: https://github.com/balazs-domsodi-h53osf/EGALplus. In the *readme.txt* file, the reader can find a detailed user guide.

A brief explanation of how to run EGAL+ with the help of a short example now follows. When the teacher wants to generate some exercises using EGAL+, he/she first sets the following parameters: (i) PopSize: the number of the students in the class, for whom he or she wants to generate PopSize pieces of exercises, which are different and have acceptable quality according to a predefined quality matrix, (ii) NoT: the number of the optional tasks, (iii) the name of the tasks according to the specific problem, which in this example are: Task1, Task2, etc., (iv) TSize: the number of questions in one exercise, (v) difficulty: the difficulty of the tasks.

As mentioned previously, the purpose of the end user - for example, a teacher - is to generate multiple different subsets of predetermined tasks (i.e. exercises) to test students' knowledge. The first requirement of the teacher is that the quality of the subsets should be good enough according to a predefined quality matrix (i.e. they should cover the most important fields as much as possible). Consequently, the teacher sets the quality values in the quality E matrix (see Figure 1), which is a symmetric matrix. The matrix contains elements between 0 and 10, and has NoT rows and columns. The values of the elements indicate how much the user wishes to use the corresponding tasks in the same exercise. A value of zero means the two tasks cannot be run simultaneously, and a value of ten means they should appear together. In-between values indicate that the teacher prefers to include these tasks at the same time. A value closer to zero indicates that the tasks appear together less often.



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10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	7	7	9	10	
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	8	10	10

Fig. 1. Quality matrix

The second – and also important – expectation of the teacher that exercises should be diverse and although the difficulty of the tasks (“difficulty”) can be different, the difficulty of the subsets, i.e. the sum of the difficulty of the selected tasks (“Difficulty”) has to be of the same value, because it is assumed that one would like to use fair exercises. As the teacher sets the difficulty values of the tasks (see Figure 2), he or she can select these values from the set: {1,2,3,4,5}.

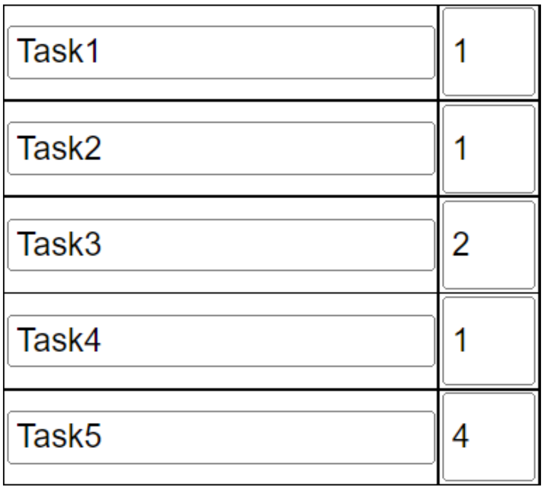

Fig. 2. Task difficulty values

The program – or more precisely, a function of the program – will offer three possibilities for the teacher – low, medium, and high – as the *Difficulty value* of the exercise. The user can choose one of these three values as can be seen in Figure 3.

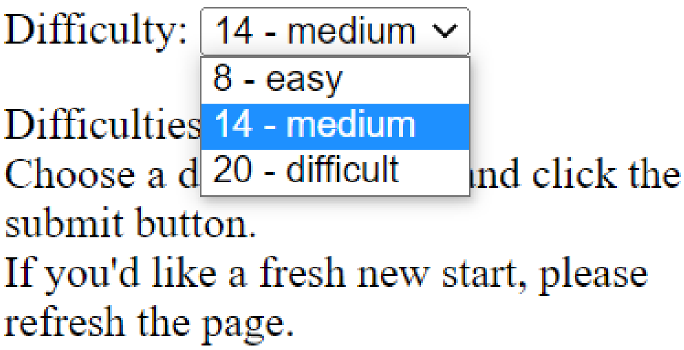

Fig. 3. Difficulty value of an exercise

After these steps, by clicking the run button, the user receives the result: PopSize pieces exercises which are different and have acceptable quality according to a predefined quality matrix. A part of an output example is shown in Figure 4. In this case the chosen Difficulty value was 28.

1. Task4 / difficulty: 1	1. Task1 / difficulty: 1
2. Task5 / difficulty: 4	2. Task2 / difficulty: 1
3. Task7 / difficulty: 1	3. Task3 / difficulty: 2
4. Task8 / difficulty: 2	4. Task5 / difficulty: 4
5. Task9 / difficulty: 1	5. Task8 / difficulty: 2
6. Task11 / difficulty: 5	6. Task13 / difficulty: 1
7. Task13 / difficulty: 1	7. Task15 / difficulty: 5
8. Task16 / difficulty: 1	8. Task16 / difficulty: 1
9. Task17 / difficulty: 3	9. Task18 / difficulty: 1
10. Task19 / difficulty: 3	10. Task19 / difficulty: 3
11. Task20 / difficulty: 2	11. Task21 / difficulty: 2
12. Task22 / difficulty: 4	12. Task24 / difficulty: 5

Fig. 4. A part of an EGAL+ output

In the EGAL program, the user can choose the above parameters, and the cumulated Difficulty value as well, independently of each other. In that process the user must be proficient at optimisation to select the right difficulty values, because occasionally the parameter settings could be contradictory. Some extreme examples are examined below. If every difficulty value is even but the exercise Difficulty value is not even, the parameter values are contradictory. Another contradictory case would be if a too big or too small a cumulated Difficulty value is selected: in this case, the freedom of the algorithm would be reduced. Another possible error would be if the user sets a NoT value which is less than the TSize value; in this case the values are contradictory, or the freedom of the heuristic algorithm has lost. Several other problematic examples could be shown.

It can be concluded that the user who selects the parameters must be familiar with metaheuristics, or the user and the optimisation expert must work together closely to choose the right input values. The EGAL program required the user to be a person with a solid knowledge of metaheuristics and optimisation. In the case of the EGAL+ program, the user can not choose contradictory parameter values. While developing EGAL+, the goal was to provide a modified, more user-friendly algorithm that anyone without an optimisation background can use to create powerful exercises.

3 An improved harmony search algorithm

In this chapter the improved exercise generation process, EGAL+, is introduced, with a special emphasis on improvements. Detailed description of the original EGAL can be found in our previous publications. Here the unchanged code parts are only briefly summarised, and details are given of those parts that are new or different in EGAL+.

It was not possible to use an exact algorithm to solve the exercise-generating problem mentioned above because the number of possible cases was unmanageable, so a harmony search (HS) metaheuristic algorithm [30] was applied. Since HS is a population-based heuristic algorithm, it converges to a global maximum or minimum. In the harmony memory – namely *population* – there are binary vectors for this algorithm. The fitness function value represents the quality of a vector. The quality of the individual value is maximised by maximising the fitness function value. In searching for the global optimum, the fitness function value should be maximised through further improvisations [30].

At the beginning of the HS, the corresponding parameters are set. These are (i) the harmony memory size (HM), (ii) the maximum generation number (iii), the HMCR (harmony consideration rate), and (iv) the PAR (pitch adjustment rate). After that the population of random vectors is initialised. The following is the improvisation step. According to Lee and Geem [30] a new harmony is improvised using HMCR and PAR probabilities. The quality of the population improves by each iteration until the algorithm is terminated.

The detailed description of EGAL+ is shown in the following. The first step sets the parameters. In this case, the harmony memory is the size of the population (PopSize), and the low and upper bounds are 10 and 100. HMCR and PAR were set as recommended by Lee and Geem to HMCR=0.5 and PAR=0.2. The Epsilon value was set low enough for the program to run long enough so that metaheuristics could give results which meet the specified requirements detailed in Chapter 2 with Epsilon=0.0000000001. This statement will be confirmed with the run results being shown later. The user can select only the PopSize value, as the other values are fixed.

At this point, the improvisation process had to be changed a little. If the user freely selects the difficulty values, the extreme situation occurs very rarely where the modification of the vector selected from the memory will not be successful at all. To solve this problem, if the modification does not occur after a specified period, a totally new vector is generated instead of the modified one. The probability of this case occurring is negligibly small.

It should be noted that depending on the other parameter settings, it is possible that they have a different value than the one specified, which would make the algorithm more efficient, run faster, or possibly give slightly better fitness values. For now, this increase in efficiency is not studied, because the primary goal of the research is to develop an easy-to-use program for the end user. The parameter calibration problem is worthy of further investigation in the future.

For the following parameters, upper and lower limits are specified, and the users are free to choose the values between the limits, which are presented in Table 1.

Table 1. Parameter settings

Parameters	Minimum value	Maximum value	Note
HM=PopSize	10	100	The number of students for whom exercises should be generated
Number of Tasks (NoT)	20	50	The optional tasks count
TSize	NoT/4	NoT/2	The number of the questions in one exercise
E quality matrix values	0	10	The maximum number of zeros: (((NoT-1+TSize*2)/2)*(NoT-TSize*2))/10 maximum number of zeros in a row: (NoT-TSize)/4
difficulty values	1 (easy)	5 (difficult)	The user is completely free to choose from the values of {1,2,3,4,5}

In the next step, the user sets the quality values in the quality matrix E. The procedure was described in detail in the previous chapter. One of the most important differences between EGAL and EGAL+ is the how the E matrix values are handled. In the case of EGAL, the user had to understand the optimisation and had to select the matrix values in such a way to run the algorithm without freezing. In EGAL+ a user can select relatively freely the values of the matrix, but this problem of freedom must be managed. It is necessary to limit the number of zeros in the matrix and the number of zeros in a row/column, to prevent the user from entering too many zeros. The result of too many zero values can be a problem. For example, the program loses its freedom and cannot run. You can find the suitable limits in Table 1. These limits are calculated in the following way: first those cases are specified for which the number of the zeros will prevent the algorithm from running. Then these limits are relaxed until the required freedom is reached and the algorithm will run. This statement is to be confirmed later.

Since EGAL+ is HS, the following is the initialisation. The initial population consists of random vectors. Every vector contains TSize pieces of 1-bits, and NoT-Tsize zeros. If the *ith* bit of a vector is zero, the *ith* task is not chosen, otherwise it is chosen.

In the next step, the fitness function values are calculated. In the case of EGAL the goal was to maximise the quality of exercises, and the distance between individuals in the population simultaneously. These features were inserted into the fitness function. In the case of EGAL+, the purpose is the same, but the fitness function had to be modified, because the user can select most of the parameters freely without optimisation knowledge. The two operands are the same, the modifications are the deleted normalisation of the operands, and inserting new ratio multipliers in the function.

The first operand of the fitness function was calculated as described, where p is an individual and E is the quality matrix:

$$F_{first}(p) = \sum_{i=0}^{NoT-1} \sum_{j=0}^{NoT-1} p[i] * p[j] * E[i,j] \tag{1}$$

The second operand in the fitness function is the diversity measure. The distance of two vectors in the same population equals the number of different digits. Then the diversity measure (D) of the p vector is determined. It is equal to the sum of the diversity for all vectors in the population.

The selection function combines these two operands with an addition operation. In the case of the diversity and fitness values the ranges may differ. In the case of EGAL+, the fitness function was modified due to the free parameter settings. Initially, the normalisation was deleted, then afterwards the values in the second operand were divided by PoPSize/20. The purpose in doing this was that in the case of every parameter value, the quality operand was more, or at least as, important as the difference operand. It was aimed to keep the ratio of the two operands between 0.1 and 1. In the next chapter it is shown that this value is within the required limits in all parameter settings. After these steps, the fitness function will be equal to the sum of the first operand and to the second operand*20/PopSize.

The last important difference between the original and the new algorithms is how the user selects the Difficulty value for the exercises. First the user selects the difficulty values for the tasks between 1 (easy) and 5 (difficult). In the previous chapter the freedom problem that can occur when a non-expert user selects a cumulative Difficulty value is demonstrated. The EGAL+ program will offer three possibilities for the teacher - low, medium, and high - as the Difficulty value of the exercise according to the selected difficulty values. These values were calculated in such a way as to give enough freedom to the program. It is shown in detail below how the three values were calculated.

Since examining all possible combinations is to be avoided for performance reasons, a heuristic solution is used instead of an exact algorithm. A function in the program randomly lists the possible difficulty combinations and puts the task sequences which already have been examined into a "taboo list", which stores them in a vector, so they will not be double-checked unnecessarily. A form of taboo list is used [31], with the difference that it is not FIFO; nothing is deleted from it. In addition, the possible total difficulties and their occurrences are collected in a two-dimensional vector. If the occurrence number of a total difficulty value exceeds a predetermined value (2 * PopSize), the user is allowed to select it. This function is stopped when it is considered that it has given a sufficient and well-distributed total number of difficulties. The number of pieces is three, because easy, medium, and difficult exercises are to be generated.

The distribution problem was solved according to the following heuristic: the minimum and maximum cumulative Difficulty values are considered and half of their distance (difference_goal) is taken as the starting value. The program is run for a predetermined time interval and the outputs are examined: whether the three values are returned whose distance is "*difference goal*" or not. If they have not been returned yet, the difference goal value is decreased by one again and again, always examining whether the three values are returned or not. This step is repeated until three values are returned: x1, x2, x3 as "easy", "medium", "difficult" values for the distance-goal distance from each other. The viability of this part of the program will be confirmed with random run results.

After this, more improvisation phases follow until the algorithm is terminated, which occurs if the average fitness value of the last 10 populations did not improve more than Epsilon.

The most important difference between the original and the new algorithms were (i) how the parameters were handled: some of them were fixed and some of them could be chosen by the user between some limits, (ii) how the number of zeros in the E matrix was limited, (iii) how the D difference was handled: a function was calculated and the user could choose only from the generated results and (iv) how the ratio was inserted into the fitness function. With these and some other minor modifications, the algorithm could be transformed for end users without computer science and optimisation background. By the end of the algorithm, the population will consist of exercises which are different and have acceptable quality according to a predefined quality matrix - these are guaranteed by the fitness function - and the Difficulty of the exercises will be equal. This statement will be confirmed in the next chapter, in which the program is run on a large number of samples.

4 Computational results

Reviewing the relevant literature indicates that there is no formerly existing algorithm which solves exactly the specific problem described in the Introduction, so the result of this algorithm cannot be compared with the results of other formerly existing algorithms. To illustrate the essence and viability of this algorithm, detailed computational results are given in this chapter. Random values were selected for each possible parameter between the upper and lower limits given in Table 1, and computational results were given for each case. All procedures were coded in the PHP 7.0 language. All computational results were acquired on a Laptop with Intel Core i7-9750H 2.6 GHz CPU and 16.0 GB RAM.

250 such random parameter sets were created, and the algorithm was performed for 20 runs for each instance, so the number of the total run is 5000. Aggregated results are shown in Table 2. (More detailed results can be found here: https://github.com/balazs-domsodi-h53osf/EGALplus/raw/main/result.xlsx.) Fitness function values, fitness function value improvements, difference values, the ratio of the two fitness function operands and solution times can be found in the tables. For these values, you can find minimum and maximum, average, and standard deviation values rounded to three decimal places.

Table 2. Computational results

	Minimum	Maximum	Average	Standard deviation
Fitness value improvement (%)	1.12%	14.95%	3.54%	0.55%
Difference (%)	2.182	25.235	13.445	0.162
Operands ratio	0.122	0.993	0.323	0.005
Solution time (sec)	4.000	1243.000	45.026	3.822

The results of the tables show that the algorithm ran for each random parameter set, and the improvement of the fitness function values can be seen. In addition, the ratio of the two fitness function operands is between 0.1 and 1 as mentioned before, the minimum value was 0.122 and the maximum value was 0.993. Although the solution times are in most cases within acceptable limits (0-360 sec), a few higher values can be found

– higher than 360 seconds (1.64% of all cases). In the next chapter, a planned improvement will be mentioned to reduce these high results. The results show that the difficulty problem is solved, and the exercises are different in one population. When the algorithm is run using the same parameter sets twenty times, the detailed standard deviation values confirm the robustness of the algorithm.

A detailed discussion of how the set goals were met now follows. As stated at the beginning of this article, the goal of this research was to improve EGAL and to show the differences between EGAL and the newly acquired EGAL+. Firstly, this new algorithm has managed to preserve the advances of EGAL – the generated exercises cover as many areas of the course as possible according to the predefined quality matrix and the multi-objective fitness function, the exercises are diverse according to the diversity measure, and their difficulty are equal. Furthermore, the improved algorithm has become usable for end users without a computer science and optimisation background since the newly introduced input fields are restricted to the ones which can be changed freely without breaking the program. It is sufficient for the user to be an expert in their field and to upload the program with questions adequate to the subject. One of the most significant changes in the algorithm is that the background calculation of the difficulty options was introduced so that the user can only select from the available goals calculated by the program. The statement – the program gives correct results within predetermined acceptable time using values within the allowed limits – was confirmed by running the algorithm on a large number of samples.

As previously mentioned, the results obtained here could not be compared to earlier research findings, so the detailed run results were investigated on their own to corroborate our statements. These values showed that the set goals have been achieved, and that EGAL+ is viable, efficient, robust and solves the specific problem described in the Introduction.

5 Conclusions and future improvements

When the algorithm was created, the goal was to generate more subsets of predefined tasks (i.e. exercises) to test students' knowledge in such a way that the quality of these subsets should be good enough according to a predefined quality matrix (i.e. should cover the main topics of a course as much as possible) and exercises should be diverse (according to a matrix and a diversity measure, which are inserted into the multi-objective fitness function). Moreover, although the difficulty of these tasks might be different from each other, the difficulty values of the subsets needed to be equal.

In this paper it has been shown that, according to the initial hypothesis, this algorithm could be made available for use by end users without a computer science and optimisation background subject to certain restrictions and improvements. The improved metaheuristic algorithm (EGAL+) was created and presented in this study. The hypothesis for this improved algorithm was confirmed by running it on a large number of samples.

Many improvements for this algorithm are planned in the future. A self-learning EGAL+ algorithm is planned to be developed in the future, where the difficulty values are updated using the results gained from users. It is also planned to modify the representations of the individuals in a certain way, with an expected decrease in run times. Furthermore, it is to be examined how this algorithm could be integrated into a learning content management system, for example into Moodle. The parameter calibration problem, as mentioned earlier, is also worthy of future investigation. Finally, it is also worth examining how the "group problem" and the "precedence relation problem" mentioned in [28] and [29] could be integrated into the algorithm.

6 References

[1] Son Ngo Tung, Jaafar, J. B., Aziz, I. A., Hoang Giang Nguyen, & Anh Ngoc Bui. (2021). Genetic Algorithm for Solving Multi-Objective Optimization in Examination Timetabling Problem. International Journal of Emerging Technologies in Learning, 16(11): 4–24. https://doi.org/10.3991/ijet.v16i11.21017

[2] Hnida, M., Idrissi, M. K., & Bennani, S. (2018). Automatic Composition of Instructional Units in Virtual Learning Environments. International Journal of Emerging Technologies in Learning (IJET), 13(06): 86–100. https://doi.org/10.3991/ijet.v13i06.8107

[3] Tu, C., Liu, Y., & Zheng, L. (2021). Hybrid Element Heuristic Algorithm Optimizing Neural Network-Based Educational Courses. Wireless Communications & Mobile Computing, 1–12. https://doi.org/10.1155/2021/9581793

[4] Lewis, R. (2012). A time-dependent metaheuristic algorithm for post enrolment-based course timetabling. Annals of Operations Research, 194(1): 273–289. https://doi.org/10.1007/s10479-010-0696-z

[5] Vaziri, S., Zaretalab, A., & Sharifi, M. (2020). Development of multi-objective simulated annealing based decision support system for course timetabling with consideration preferences of teachers and students. Muṭāliāt-i Mudīriyyat-i Ṣaṅatī, 17(55): 35–64. https://doi.org/10.22054/JIMS.2019.29331.1982

[6] Al-Betar, M. A., Khader, A. T. , & Zaman, M. (2012). University course timetabling using a hybrid harmony search metaheuristic algorithm. IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews, 42(5): 664–681. https://doi.org/10.1109/TSMCC.2011.2174356

[7] Xiangliu Chen, Xiao-Guang Yue, Rita Yi Man Li, Ainur Zhumadillayeva, & Ruru Liu. (2021). Design and Application of an Improved Genetic Algorithm to a Class Scheduling System. International Journal of Emerging Technologies in Learning (IJET), 16(01): 44–59. https://doi.org/10.3991/ijet.v16i01.18225

[8] Sukstrienwong, A. (2017). A Genetic-algorithm Approach for Balancing Learning Styles and Academic Attributes in Heterogeneous Grouping of Students. International Journal of Emerging Technologies in Learning, 12(3): 4–25. https://doi.org/10.3991/ijet.v12i03.5803

[9] Liping Wu. (2015). The application of Coarse-Grained Parallel Genetic Algorithm with Hadoop in University Intelligent Course-Timetabling System. International Journal of Emerging Technologies in Learning, 10(8): 11–15. https://doi.org/10.3991/ijet.v10i8.5206

[10] Alam, T., Qamar, S., Dixit, A., & Benaida, M. (2020). Genetic Algorithm: Reviews, Implementations, and Applications. International Journal of Engineering Pedagogy (IJEP), 10(6), 57–77. https://doi.org/10.3991/ijep.v10i6.14567

[11] Nentwich, V., Fischer, N., Sonnenbichler, A. C., & Geyer-Schulz, A. (2016). Computer aided exercise generation: A framework for human interaction in the automated exercise generation process. ICETE 2016 - Proceedings of the 13th International Joint Conference on e-Business and Telecommunications, 2: 57–63. https://doi.org/10.5220/0005947700570063

[12] Sadigh, D., Seshia, S. A., and Gupta, M. (2012). Automating exercise generation: A step

towards meeting the MOOC challenge for embedded systems. In Proceedings of the Workshop on Embedded and Cyber-Physical Systems Education, pp 1–8, Tampere. ACM. https://doi.org/10.1145/2530544.2530546
[13] Arianna Zanetti, Elena Volodina, & Johannes Graën. (2021). Automatic Generation of Exercises for Second Language Learning from Parallel Corpus Data. International Journal of TESOL Studies, 3(2): 55–70. https://doi.org/10.46451/ijts.2021.06.05
[14] Eryiğit, G., Bektaş, F., Ali, U., & Dereli, B. (2021). Gamification of complex morphology learning: the case of Turkish. Computer Assisted Language Learning, 1–29. https://doi.org/10.1080/09588221.2021.1996396
[15] Malafeev, A. (2014). Language Exercise Generation: Emulating Cambridge Open Cloze. International Journal of Conceptual Structures and Smart Applications (IJCSSA), 2(2): 20–35. https://doi.org/10.4018/IJCSSA.2014070102
[16] Almeida, J. J., Araujo, I., Brito, I., Carvalho, N., Machado, G. J., Pereira, R. M. S., & Smirnov, G. (2013). Math exercise generation and smart assessment. 2013 8th Iberian Conference on Information Systems & Technologies (CISTI). pp 1–6.
[17] Gómez-Abajo, P., Guerra, E., De Lara, J., & Merayo, M. G. (2018). A tool for domain-independent model mutation. Science of Computer Programming, 163: 85–92. https://doi.org/10.1016/j.scico.2018.01.008
[18] Pilán, I., Volodina, E., & Borin, L. (2016). Candidate sentence selection for language learning exercises: from a comprehensive framework to an empirical evaluation. Traitement Automatique Des Langues, 57(3): 67–91.
[19] García, I., Benavides, C., Alaiz, H., & Alonso, A. (2013). A Study of the Use of Ontologies for Building Computer-Aided Control Engineering Self-Learning Educational Software. Journal of Science Education & Technology, 22(4): 589–601. https://doi.org/10.1007/s10956-012-9416-6
[20] Chrysafiadi, K., & Virvou, M. (2013). Student modeling approaches: A literature review for the last decade. Expert Systems with Applications, 40(11): 4715–4729. https://doi.org/10.1016/j.eswa.2013.02.007
[21] Adamopoulos, P. (2013). What makes a great MOOC? An interdisciplinary analysis of student retention in online courses. In Thirty Fourth International Conference on Information Systems, pp 1–21.
[22] Bouarab-Dahmani, F., Si-Mohammed, M., Comparot, C., Charrel, P.-J. (2011). Adaptive Exercises Generation Using an Automated Evaluation and a Domain Ontology: The ODALA+ Approach. International Journal of Emerging Technologies in Learning (IJET), 6(2): 4–10. https://doi.org/10.3991/ijet.v6i2.1562
[23] Basse, A., Diatta, B., Ouya, S. (2021). Ontology-Based System for Automatic SQL Exercises Generation Advances in Intelligent Systems and Computing, 1192 AISC, pp. 738-749.
[24] Ono, K., & Konaka, E. (2017). Automatic exercise generation and their equating on a coursework of differential equations. 2017 56th Annual Conference of the Society of Instrument and Control Engineers of Japan, SICE 2017, 2017–November. pp151–156. https://doi.org/10.23919/SICE.2017.8105450
[25] Mehta, S., & Smetannikov, I. (2020). Finding the Blank with Sequence Labeling for English Learning. 2020 International Conference on Control, Robotics and Intelligent System. https://doi.org/10.1145/3437802.3437834
[26] Almeida, J. J., Araujo, I., Brito, I., Carvalho, N., Machado, G. J., Pereira, R. M. S., & Smirnov, G. (2013). PASSAROLA: High-order exercise generation system. 2013 8th Iberian Conference on Information Systems & Technologies (CISTI). pp 1–5.
[27] Láng, B.; Kardkovács, T. Zs. (2016). Solving exercise generation problems by diversity oriented meta-heuristics, In: Shuang, Cang; Yan, Wang (eds.) SKIMA: 2016 10th International Conference on Software, Knowledge, Information Management & Applications: University of Information Technology, December 15- 17 2016, Chengdu,

China, pp. 49-54, https://doi.org/10.1109/SKIMA.2016.7916196
[28] LÁNG, B. (2019). Solving Exercise Generation Problems Using the Improved EGAL Metaheuristic Algorithm. SEFBIS Journal, 13: 23–31.
[29] Láng, B. (2020). Solving Exercise Generation Problems Using the Improved EGAL Metaheuristic Algorithm with Precedence Constraints (Vol. 1135). Springer International Publishing. 569-579 https://doi.org/10.1007/978-3-030-40271-6
[30] Lee, K. S., & Geem, Z. W. (2005). A new meta-heuristic algorithm for continuous engineering optimization: harmony search theory and practice. Computer Methods in Applied Mechanics and Engineering, 194(36): 3902–3933. https://doi.org/10.1016/j.cma.2004.09.007
[31] Glover, F. (1986). Future paths for integer programming and links to artificial intelligence. Computers and Operations Research, 13(5): 533–549. https://doi.org/10.1016/0305-0548(86)90048-1

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Practice and Principle of Blended Learning in ESL/EFL Pedagogy: Strategies, Techniques and Challenges

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Abstract—The present study aims to investigate the efficacy of the Blended learning or Hybrid learning. It also explores the practical challenges and suggests strategies to implement in the actual classroom. Additionally, the study throws light on the advantages and disadvantages of online pedagogy following qualitative method based on interview method of individuals using or utilized Blended learning in the classroom. The interview was conducted through sending emails and the response was recorded and received. The responses of participants were thoroughly evaluated, analyzed and discussed in detail. The article significantly helps in implementation of Blended learning in classroom pedagogy and allows offering a broad view of how the amalgamation of online teaching is possible in an effective way. It also explores pedagogical concerns of actual classroom situations using Blended learning or relying on online teaching. Learning outcomes depends on how well the approach, method, and technique is used or implemented followed by formative and summative assessments. The study highlights the use of blended learning and difference of relying on online teaching. It is important for the stake holders to realize that here is no escape but to find effective way which can ultimately deliver the expected learning outcomes.

Keywords—blended learning, flipped classroom, self-directed learning, pedagogy, strategies

1 Introduction

The acceptance of English language as lingua franca demands the teachers and students to become a proficient facilitator and active learner. It is the language that creates a kind of bridge between the speaker and listener through which they can exchange their thoughts, feelings, emotions, and information. However, students often face problems to uttering the appropriate language structures despite of having the necessary competency. This happens because students are adapted to what they have been taught over the years in the classroom. The traditional methods of teaching English barely develop or enhance the language skills and its usage in real-life situations. Then, the questions arise what is the solution? How can it be solved? And what are the measures that need to be taken care of?

Moreover, the introduction of Information and Communication Technology (ICT) in classroom pedagogy has positively influenced language teaching across the world. It has simplified the process of learning through its flexibility of accessing anywhere in the world. Simplifying the ICT concept in education is receiving the information through the web, creating educational material on the internet, transmitting among others, communicating with the peers, and collaborating with others to understand it in a better way. Computer Assisted Language Learning (CALL) and Mobile Assisted Language Learning (MALL) also exist in the segment of ICT pedagogy.

Additionally, there are two models of teaching and learning which have emerged or evolved in recent time, the first has been used and the second has still been evolving. One is learning through typical classroom teaching and other is teaching-learning through the internet. The argument is that if there is any existing praxis with the mixture of both the platforms where the learning process of students can be intensified by the effective implementation of strategies in the classroom. Here comes the idea of Blended Learning in the classroom pedagogy because it blends or creates a mixture of both the models like traditional model of teaching in the classroom and modern idea of learning through the online materials and courses.

1.2 Blended learning: Concept and background

Blended Learning integrates the traditional classroom experiences with new innovative learning methods and ideas that have the potential to democratize language learning. It is supported by an intelligent adaptive technology that enables learners to achieve the competence with ease. Adaptive learning technologies are the way through which the learners learn as they want to learn not as the teachers want to teach. Alamri and Watson [1] define adaptive learning technology as "software and online platforms that adjust to individual students' needs as they learn. Through interacting with the technology, behavioral and cognitive patterns are recorded and personalized learning experiences are shaped accordingly" (p. 7). It also offers student friendly materials accordingly. Through Blended learning, one can support, scaffold learners irrespective of the different background of knowledge and level of understanding.

The concept of Blended Learning can be defined as using online materials and sources as a tool for learning and not necessarily learning about computers or online materials. Garrison and Kanuka [2] defined Blended Learning "the thoughtful integration of classroom face-to-face learning experiences with online experiences" (p. 96). Bliuc et al. [3] describe blended learning as "activities that involve a systematic combination of co present (face to face) interactions and technologically mediated interactions between students, teachers and learning resources" (p. 234). Blended learning can simply be defined as the mixed approach of teaching which incorporates the traditional classroom teaching and online learning in the classroom. It can be explained as an amalgamation of 'face to face learning' and 'web-based learning.'

Blended learning helps to unlock the learning potential of the students and help them to learn with the mixture of real and virtual pedagogy. Amalgamation of online and web-based materials in the real classroom provides authenticity of the materials which are adapted and graded by the teacher and it also provides an opportunity to have a range of activities, lessons, and topics which can be improvised and used as teaching materials. The students can make use of the content and develop their creativity and appropriateness of language usage in real authentic and spontaneous situations that they encounter in day to day life.

This model of learning empowers students and boosts their confidence. Furthermore, by practicing the complex linguistic structure and their usage inside or outside classroom scenario minimizes the hesitation of the students. "Blended learning will be the new traditional model for course delivery in higher education" [3] [4]. "Courses that integrate online with traditional face-to-face class activities in a planned, pedagogically valuable manner; and where a portion (institutionally defined) of face-to-face time is replaced by online activity" [5] (p. 8).

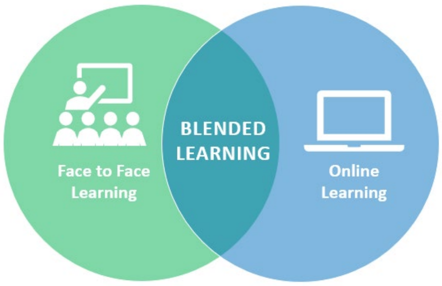

Fig. 1. Blended learning as a model of pedagogy

Furthermore, the idea of using blended learning as a model of pedagogy in the classroom has become an essential requirement in this era of globalization where English is not considered as only a language but a vehicle through which one can access the entire world. It has also become the reason of employability nowadays and is considered a status symbol too. In a situation like this where traditional teaching approaches failed to develop the mutual intelligibility and confidence among students to use language in a spontaneous situation, there is a need to rethink the teaching pedagogy and implement the new trends and techniques which can offer unique ways to express and learn the language in real-life situations. Blended learning as a teaching methodology has the capability and potential to develop the confidence and creativity of the students and also to promote self-directed learning (SDL). It is a purely learner-centred approach which engages students in the classroom and outside to develop language skills.

2 Literature review

Blended learning approach is a latest trend because of the unprecedented situation created by Covid-19 and an unprecedented situation requires an unprecedented measures. Contactless teaching learning can only be possible if one switches regular classroom into a virtual one.

The application of blended learning module in the actual classroom demands a number of aspects which can collectively and collaboratively contribute in achieving the learning outcomes. Osguthorpe and Graham's [7] suggested six reasons: pedagogical richness; access to knowledge; social interaction; personal agency (i.e. learner control and choice); cost effectiveness; and ease of revision. Interestingly the term 'pedagogical richness' is used rather than 'pedagogical effectiveness' [8] (p. 13). As discussed above the module does not have a clear strategy and techniques rather it is a mixture of different aspects which constitute a space or learning environment and the outcomes can be achieved through the effective implementation of necessary strategies. There is a significant gap in the BL approach and its implementation because it is a new phenomenon that is evolving in the academics and still needs a significant effort which can help the academia to learn how to utilize in the classroom pedagogy. The above statement can be supported by the scholars like Graham, [9]; Graham and Allen [10]; Graham, Allen, & Ure, [11], and Osguthorpe and Graham, [12] as they say blended learning module has begun to appear in academic circle recently.

However, a significant amount of research articles and books has been published in the area, but there is no simple and straight forward formula how to implement it in the actual classroom. This is because this approach is amalgamation of a number of factors like classroom infrastructure, students' competence, teachers' technological competence and so on. Individual instructors or facilitators make use of whatever the limited resources available. The present study however discusses and elaborates on use of the blended learning and its advantages and disadvantages. After exploring pertinent literature available on the subject, the researcher has found that the challenges and strategies are not discussed in detail until now. The studies that discuss the challenges of implementing blended method of teaching are limited and insufficient.

BL requires a collective collaboration of a number of aspects which functions as a catalyst. It is a systemic synchronization of factors like the platform which the individual teacher is using, adaptability and accuracy of the teacher and students, internet connectivity so on and so forth. Hofmann [13] accentuates "institutions also need a solid grasp of the advantages and disadvantages of the various delivery methodologies from an instructional perspective, understanding that a single delivery method will probably not be the optimal solution" (p. 7). It is evident by the description given by Hoffmann that the module is a mixture of components which collectively work to ensure the maximum learning outcomes but the need of the hour is to channelize and design process of blending the individual course. The concept is well elaborated by Stein, and Graham, [14], "blending a course is very different from just simply online teaching because it requires a careful evaluation of online and offline environments and requires learning outcomes over technology alongside keeping students engaged" (p. i).

Additionally, the idea of how to blend a course is elaborated by number of scholars but firmly discussed by Graham, et al [15], Porter et al., [16], Porter, et al. [17], Porter and Graham, [18], Halverson, et al., [19]. Additionally, Boelens, et al., [20] asserted that there are four key areas that should be channelize and focused while blending a course. They are fostering an effective learning environment, facilitating interaction, incorporating flexibility, and taking care of students' learning process. The problems faced by students during online teaching-learning and blended learning module have been addressed by Brown, [21], Broadbent, [22], Prasad, et al., [23], Medina, [24], and Ocak, [25]. They provide a detailed discussion on challenges and problems involved in online teaching-learning and the blended learning. However, they are limited in nature and each one has some limitations. The study of Akçayır & Akçayır, [26] sheds light on the technological challenges of the approach and limitation of flipping the classroom.

"Blended learning offers flexibility, pedagogical richness and increase in cost effectiveness" [27] (p. 3–21); blended learning ensures value interaction and learning engagement [28] (p. 88–89); and it is considered valuable for different sorts of learners [29]. Bernard [30] says that the technical advancement and the role played by artificial intelligence in online platforms changed the scenario. For example it provides a lot of flexibility in the teaching learning process. As Low [31] articulates that the teaching learning process highlights the role of teachers which in post-method era has taken a shift. Like the teachers' role is to be a guide and facilitator rather than being simply a content provider. From the above discussed literature, it is clear that in post-method era blended learning module is effective in achieving the learning outcome and changing the dynamics of classroom. The holistic approach is capable enough to integrate the language skills and collaborate with the factors which are involved like technological competence of teachers and students, blending course contents, support from the institutions and so on. In this context Allan [32] says "blended learning will make learning more accessible, engaging and relevant. It will provide flexible learning opportunities and reduce time constraint by dropping activities which help students to learn. It will exploit ICT and can be used for big classrooms (p. 2).

The idea of using blended learning in the classroom provides the opportunity to manufacture the learning experiences through the help of online contents and classroom discussions which offer the appropriacy and correctness in learning the language at the suitable time with necessary accuracy for every individual. The term 'blended learning' is commonly explained or understood as an amalgamation of traditional teaching plus the use of internet-based teaching.

Blended learning as a strategy and technique of teaching can become effective only if it is used consciously in the classroom pedagogy. It is capable of promoting and developing the group cohesion and collaborative learning. However, in ELT, it can be effective through the integration of the two components i.e. online-learning and face-to-face learning. The idea is to complement each other with the proper use of technology not to replace the efforts of a teacher.

Furthermore, the idea of blending refers to the use of ICT in the teaching methodology because it uses the online web-based learning model. Use of technological advancement and platforms which offer online distance mode learning will have an impact on learning outcomes. Nowadays, at university level ICT and language labs are effectively and rigorously used for English Language Teaching and Training. It is a strong medium which offers authentic materials and native exposure to the non-native students and teachers. O'Toole and Douglas [33] advocate that "Student response to ICT in the classroom is mixed and it is not difficult to find e-learning enthusiasts but hints of concern about the technology are beginning to emerge" (180).

As discussed above, there are no clear instructions of the approach which can be applied. While using it rather as a trial and error method is going accordingly around the globe. Another problem with BL is that there are number of studies which have been done and published in the area which are a repetition of the same idea again and no clear techniques and strategies are established to implement in the classroom pedagogy. It happened because technology is changing at a rapid speed and different platforms are being introduced through which one can teach, conduct, and blend online and offline classes. Take India for example, from 2000 to 2016, there was no such online platform which was used for online teaching but after 2016 the access to the internet and reach to online content increased offering plentiful of options for online pedagogy. And Covid-19 just elevated the game. Platforms like Zoom, Google meet, YouTube, WhatsApp and many more boomed. People started searching for alternatives where they can simply conduct their online classes and share materials. Now the problem is that in ESL settings adequate training is not provided to the teachers and they don’t know how to handle the technology in pedagogy. Even in EFL settings teachers are lacking in how to conduct online classes flawlessly. Other related problems faced by teachers are the connectivity problems, unresponsive learners and son on. The respondents for the present study have shared their experiences through an interview questionnaire and the same will be discussed in detail in the present study.

The present study tries to highlight the problems of virtual teaching and importance of blended learning. The study also discusses teaching learning problems and possible solution of how Blended learning can be utilized post pandemic. As discussed above, online options are explored enough to have an idea about what are the ways to use and implement blended learning approach.

The above-discussed ideas clearly hint at the technological competence of the students and teachers who want to use blended learning as a strategy of pedagogy in their classroom. In addition, a country like India which is in the transition phase of technological advancement in education still needs infrastructure, fund, and training courses which allow enriching the teaching learning process. However, very few public universities or some private universities have proper infrastructure and latest technology in their classroom but in semi-urban or rural areas universities do not even have their language labs.

3 Methodology of the study

The hypothesis of the present study is to enquire and investigate the use of Blended learning in a more interesting way along with the holistic process of language teaching/learning in an ESL/EFL classroom and discuss the aspect of using and relying on online based teaching and blending the classroom.

The present study follows the qualitative method of data collection through interviewing the respondents. To collect the responses from the participants, the researcher has developed an interview based questionnaire. Because of the pandemic it was not possible to conduct the physical interview, so digital platforms and email were used to collect the responses. The respondents were given flexibility to record the responses and sent it through emails and so on. To check the reliability and validity, a pilot study was conducted before the main study. Participants were chosen using the purposive method and questionnaire were sent to collect the responses. Accuracy and appropriacy of the questions were checked after the pilot study. Post pilot study some of the questions were deleted, merged, and some were changed. The ordering of the questions was changed and long questions were shortened. Questions were randomized to seek the exact experiences of the respondents.

Since the study comprises of ESL/EFL aspects of blended learning the participants were chosen taking care of the same. Similarly, the participants were selected using purposive sampling technique. The main study includes twenty-eight (28) participants teaching in ESL and EFL classroom using online or blended learning module. They discussed their experiences and ideas about the approach through the questionnaire. Later, the responses were collected, analyzed and discussed in detail. The inferences of the individual responses are elaborated and made to conclude the present study.

4 Collaboration, synthesis and group cohesion data analysis, discussion, and inferences of questionnaire

The questionnaire for the present study is developed by the researchers in the form of interview. The questionnaire comprises of open-ended set of questions seeking detailed answers from the respondents. It has sixteen questions (16) and each question is dynamic in nature asking more than one aspect of online and hybrid teaching. The participants were provided ample time to reflect and record their experiences about online teaching or blending their courses. The participants were chosen using the purposive sampling technique and only those were chosen who teach online or blend their course using different platform available to them. As the study requires ESL/EFL data, so the aspect of mixing both the pedagogues has taken care and participants were chosen accordingly. Each question is discussed in detail with the responses that was collected from the samples.

The first question in the questionnaire asks general information about online teaching to get an idea of what the respondents think about it. The respondents firmly said that online teaching is something which can be done with internet and virtually. Teacher and students are connected through different platforms. As the nature of the question is dynamic it asks about the platform which respondents generally use to conduct their online classes. The data says that Zoom meetings, Google duo, Google meet, Google classroom, YouTube, WhatsApp, Telegram, Skype, Facebook and Messenger are the platforms which are used in ESL classrooms. They further said that they use pdf materials for uploading and sharing materials, assignments and evaluation. Furthermore, the data shows that teachers who responded to the questionnaire are connected to their students through WhatsApp for better monitoring. The participants from EFL classroom responded that they use Blackboard and Zoom to conduct their classes. The purpose of asking the question is to have an idea about the experiences of the respondents and which platform they used to conduct their classes. This question also serves to get a familiarity with the idea of online teaching and blended learning and which platforms are used in ESL/EFL context.

The second question asks about the perspective of virtual classes to seek the information whether the participants find it effective or not. However, participants raised concern over the lack of physical classroom atmosphere and presence of students. Even some of them compared online classes to distance mode of learning. Because of the pandemic there is no choice left but to use these options to continue teaching learning process. The second part of the question seeks to know about the effectiveness of the virtual classes. Almost each participant responded negatively and they said if the students are technically good then it helps the teaching process to a great extent for the classroom community and teacher. The number of such students is fewer who are good in managing online classes and most of the students' do not get any assistance from their parents, not knowing how to use the online platforms, and technical problems such as internet speed issues.

One of the participants said virtual classes may work for a short time but isn't fit for a long-term as physical interaction and rapport building is essential in teaching and learning processes. However, it cannot be considered a cost-effective medium as such platforms cannot be accessed by those from unprivileged sections of society. Also, Virtual classes are prone to conditions such as short attention span of the student, technical barriers and so on which can adversely affect such interactions. Moreover, the participants' responses indicate that there is no check and balance in online teaching and accurate assessment is not possible as compared to physical classroom. It is working as a substitute because of the pandemic only. It will take time to develop infrastructures and most importantly mindsets of both teachers and students to have positive impacts on the teaching-learning process.

The third question enquires about having no choice but to conduct online classes using different mediums to continue the teaching learning process. The participants said that they have no choice because of the pandemic but to go for online teaching although they said that virtual classes are prone to conditions such as short attention span of the students, technical barriers of both teachers and students, unavailability of good internet connection and so on which can adversely affect classroom interactions. The particular conditions are not limited to ESL classrooms only. They are even stipulated in EFL context also.

The fourth question seeks to enquire about the advantages of teaching online or blending the course. The participants emphasized that one can get it done anytime anywhere. Lectures can be uploaded, recorded and revisited again and again for future references and revision. Physical space is not an issue in online class. Hundreds of students can come together and join from different locations. It gives teachers an opportunity to deal with innovative technologies and helps in automating various types of assessments sparing more time for significant interactions. Apart from this, it also allows to having collaborative interactions with students. After summarizing the entire responses one can say that it is a flexible medium that allows the stakeholders to conduct classes as per the convenience but there is a gap of training teachers and students to become comfortable with the virtual medium. Computer literacy and knowledge of the Learning management Systems (LMS) which the individual is using to conduct the class is essential in ESL and EFL contexts.

The fifth question enquires about the problems often faced by the teachers while conducting online classes. The purpose is to collect information about the different problems and challenges faced by teachers while conducting online classes. The participants said that technical barriers could cause communication problems in terms of audio and video, bandwidth and so on which can turn a possibly fruitful interaction into a half-baked idea. Network hindrance is the biggest problem. Prolong use of computer and mobile can have a negative effect on eyes. Another problem is computer literacy which causes a blockage in online teaching or blended learning. Some of the teachers responded that lack of motivation in students is also a problem in teaching. The respondent also said that there is a regular break-down of communication while teaching online because of unstable connection.

The sixth question is intended to know about the preference of the teacher to conduct their online classes post-pandemic because the researcher wants to have a clear idea of the relevance of teaching online. A number of participants said that online classes could not replace the physical classroom. Moreover, each participant said that they will not continue to teach online post pandemic rather will use online mode for assignments and amalgamating syllabi. A few of them responded that they would use online teaching after the pandemic once a week.

The seventh question queries about the problems individual teacher faced while conducting online sessions or classes. This particular question is a replication of question number five to just have an overview of problems on the part of teachers. The participants pointed out the reluctance of students in giving their responses and of course most of them expressed their concern over the technical problems faced during online session. One of the participants opted for audio-lecturing and said it became difficult to know whether or not students are able to absorb all the information provided to them. It was also difficult to know whether they are paying equal attention to all of my lectures or not. The biggest challenge is to keep students engaged and motivated. One could never know if they are actually listening to the teacher or not. Another difficulty is unavailability of the stable internet connection. However, the participants said that online teaching is not a cent percent effective medium but partial use can be effective.

The eighth question introduces the term blended learning or hybrid learning to seek information from the participants if they are familiar with the term or not. The respondents said that they had used it to incorporate different techniques of teaching and to utilize the notion of no one left out. They responded that the hybrid learning module is more interactive and can develop the accuracy and fluency of the students by using PPTs, audio-visual materials, e-resources and so on. It also develops the communication skills of the students. Whereas some of the participants said that they have neither used it nor do they possess the required technical competence and infrastructure.

The ninth question enquires about whether an individual is comfortable in using blended learning approach in the classroom. And the collective responses says that the participants are comfortable but there is a lack of support from the authorities such as providing the necessary infrastructure, language labs with new technology and software, allocation of ample time and so on. Whereas some participants reiterated that they feel they don't possess the required technical competence to improvise the approach in their classroom.

The tenth question seeks information about the effectiveness of blended learning module. The participants said it was an effective module where the heterogeneous classroom nature would be catered through different assignments and activities discussed in the classroom and practiced online to achieve the maximum learning outcome. It also provides motivation to the students because there is human interaction that works as a force and develops mutual intelligibility. The Blended model is an effective way as it involves activity-based teaching learning which does provide a comprehensive range of ideas and inspiration. An amalgamation of both online and face to face teaching would certainly be effective considering the flexibility it would provide pertaining to the needs of the learners. Furthermore, BL increases the efficiency of the teacher in terms of technological competence. It also increases the interest of the learners as it motivates in learning by doing. Complex topics can be taught through simulation mode which makes the topic easy to understand. It allows students to engage with the material at their own pace, helping to balance a classroom of both slow and quick learners.

Question number eleven makes an exploratory investigation about the learning outcomes that can be achieved from the utilization of the technology or incorporation of technology in pedagogy. The participants were positive about using or blending technology in the classroom to achieve the desired learning outcome. By using online contents teacher and student can have an additional advantage in grasping the nuances of language and its supra-segmental features. Introduction of ICT in teaching has challenged the pedagogues around the globe to learn how to do it and embrace it enthusiastically. It provides a better teaching learning outcome and experience to both teachers and students.

Question number twelve asks about facilitating the students in the classroom and finishing the syllabus through online teaching. Some participants responded that it is merely a medium of finishing the syllabus leaving the students aside while some said that it depends upon the infrastructure and the support given by the institution.

Question number thirteen highlights and enquires about facilitating interactive classrooms and how to incorporate the learner centred aspect of online teaching. The participants said that interaction in online teaching is partially possible because fewer students actively participate in virtual classroom. Interactive classroom provides an open platform for interpersonal communication and it also inculcates new ideas in students by mutually sharing their opinions. Although the responses collected clearly indicate that interactions are hardly possible in a virtual classroom. One of the participant said interactive classroom and facilitating students mean interacting with them, assessing them, to know their strengths and weaknesses and improve them accordingly. But it is not possible in online teaching. It is indeed challenging to make virtual classroom interactive but it could be done with innovative ideas to facilitate the learner centred classroom. Using quizzes, close ended questions, small surveys, multiple choice can be used to make virtual classes more interactive.

The next question asked was about the problems of monitoring the virtual classroom. The respondents said that monitoring the virtual classroom is a difficult job. It is mentally exhaustive and unhealthy for both, the teachers and the students. Sometime students are not attentive and serious. Not all students are equally attentive, and they tend to take online classes very casually. While some participants said that often students are passive in online sessions. Further they lack technical competence in managing online tools.

After discussing all the possible aspects of blended learning and online teaching the questionnaire asks about the possible use of think-pair-share in a virtual classroom. The purpose of the question is to collect information about the use of collaborative learning in online teaching. Most of the participants responded that they face a lot of problem while trying to incorporate the collaborative learning strategy in virtual classroom. Students are often not responsive and attentive, network problem, poor connectivity and so forth are some of the problems which were quite visible in the responses provided by the participants.

The final question of the questionnaire asks about the effectiveness of blended learning on students' learning outcomes. The participants said that if the proper measures are taken to conduct the virtual classroom and blending is done by the experts, this module will be a great success in academics especially when it comes to teaching English in ESL and EFL context. To implement the Blended Learning one has to understand that it requires a proper motivation of students and teachers with technical competence to achieve the required teaching learning outcomes.

5 Findings of the study

The key findings of the present study show that there is a gap in the technological competence of the teachers who use the virtual classroom or try to blend their classrooms.

1. Teacher training course (CELTA, TESOL, DELTA), orientation programmes, FDPs, refresher courses which focus on how to blend the course and use the technology in the classroom should be introduced and made compulsory before implementing online teaching or blended learning in the classroom. Proper training will sensitize teachers to use and make the most from BL.
2. Synchronization of technology and platform which are going to be used is essential before changing the medium of teaching. Teacher should know each and every aspect and component of blended learning modules.
3. Clear instruction of course module which allows teachers and students to know when and how the components are switched to online and face to face.
4. Support from the institution to implement the new techniques and strategies of blended learning are essential in order to achieve the maximum learning outcomes in the classroom pedagogy.
5. To achieve all of the above the key components for the teacher and the students is to be motivated throughout the course. Motivation will come gradually when the stake holders will be positive and supportive in ESL and EFL context.

6. It is a cost effective method as it does not require smart classroom setup. Moreover, with minimum infrastructure, blended learning module can be utilized. It can be effective only if it is implemented seriously.
7. Infrastructure should be developed and new software's and updated systems should be provided by the institutions to incorporate BL in the classrooms.

All of the above findings of the present study are very important and play a key role in the use and implementation of blended learning. The success of the module will depend upon how seriously stakeholders want to implement it to develop the mutual intelligibility and competence of the students and teachers. Because the module is the synchronization of many components, there is a need to channelize it in a proper ways ensuring maximum learning outcome and perseverance should be achieved to remain motivated.

6 Issues and challenges in implication of blended learning model

The blended learning model, first of all, needs the specific infrastructure of accessing the online content with a high-speed internet facility which should be available to all the students and teachers. Therefore, it should be the responsibility of the policy makers to provide a good infrastructure as language labs, updated software, lab technician, tutorial classes and so forth. Apart from this, teacher training programmes will enable the pedagogues to utilize the potential of blending. The training programmes should focus on content and instructional methods of how a teacher should use instruction in the classroom while using blended learning model.

The next important aspect is content moderation in blending the course as the teacher has to moderate the content which he/she wants to teach. The concern is what kind of material student should be allowed to access and how much should the teacher guide them.

The issue with this approach is the assessment of the students. It is challenging to evaluate students using this model, but one can mix modern and traditional testing tools to evaluate the class. For example, one can give the students portfolios to check the competence level; formative assessment can be extremely helpful.

7 Strategies and techniques used in the classroom teaching

To use blended learning in the language classroom with the use of Bloom's Taxonomy can be effective and efficient. Apart from this, collaborative learning techniques like group work, pair work and think pair share can be utilized using the process of blending. To incorporate the blending process platforms like EDMODO can be used where one can give assignments and receive feedbacks also. Khan Academy, BYJUS, EDX, COURSERA, NPTEL, GIAN are the online platforms that offer a range of course for teaching and self-regulated learning. The teacher can assign online courses from these platforms and moderate the content for better learning outcomes. Training courses on how to use LMS (Learning Management System) like Zoom meetings, Google duo, Google meet, Google classrooms, YouTube, WhatsApp, Telegram, Skype, Facebook and Messenger should be available for the teachers. Adaptation of materials can be extremely effective if it is done seriously according to level and background information of the students. Teachers and practitioners should make sure that their students can access the content easily.

Students should know how to watch these videos and make notes to discuss in the forthcoming classes. Teacher's job is to enable them to interact with video content in a meaningful way that causes to reflect and enhance the critical thinking on what they are exposed to. One of the problems encountered while using blended learning and in flipping a classroom is how to ensure that students should watch the video and make the notes. To resolve the issue teachers can make use of google forms; easy way to make sure students are attentive to the lessons that are going to be discussed in the next class. Google Forms can have a different sets of questions related to the video content that is supplied to the students. The answers should be the entrance ticket to the classroom. The idea is to use videos as effective content delivery tools in the classroom pedagogy.

Conversely, these techniques and strategies are only helpful in teaching after proper training of teachers in content moderation and instructional methods. The in-service programmes and induction courses should be made compulsory for the teachers to use blended learning model.

8 Conclusion

The present study clearly delineates the positive aspects of blended learning and the challenges of using it in a classroom scenario. Although, there are challenges of using it in the Indian and EFL context, it can be extremely helpful for the students and the teachers if they use it in a cooperative environment. Teaching is about the relationship between teachers and students and if by any means can maximize the relationship by harnessing the technology that will impact the learning outcome. The findings of the present study are in line with the research carried out by NCERT consists a huge sample size of 34000 respondents. The same has been reported by NDTV [34] anchor Ravish Kumar which was aired on 28 August, 2020.

Blended learning as a teaching strategy enables students to have a clear picture of what they are going to be taught in the classroom. It encourages students to become an independent learner and promotes autonomy where teachers and learners actively and voluntarily engage in the teaching-learning process. Moreover, Castillo-Cuesta et al., [35] article and findings "ICT tools are essential and effective in classroom pedagogy" (p. 11). Li, Z. [36] accentuates "online learning platforms have developed the learning situation analysis function to analyze the relationship between students' learning behavior and learning effect (p. 224). It personalizes the learning for each individual.

9 Limitations and future scope of work

The study is conducted on a small scale and for policy making it is necessary to conduct a survey on a large scale. It is not possible for individual scholars to conduct such a large survey. Government agencies can only conduct these large surveys because they can fund and provide the necessary work force. The approach of blended learning is still evolving and there are a number of aspects which remain explored till date. Further scope of study is there and research is needed and required to ensure how to blend the courses accordingly. As Mu, D., & Guo, W. [37] emphasize in their study about impact of online and virtual learning.

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11 References

[1] Alamri, H.A., Watson, S. & Watson, W. (2020). "Learning technology models that support personalization within blended learning environments in higher education". *Tech Trends*. https://doi.org/10.1007/s11528-020-00530

[2] Garrison, D. R., & Kanuka, H. (2004). "Blended learning: Uncovering its transformative potential in higher education". *The Internet and Higher Education*, 7, 95-105. https://doi.org/10.1016/j.iheduc.2004.02.001

[3] Bliuc, A.-M., Goodyear, P., & Ellis, R. A. (2007). "Research focus and methodological choices in studies into students' experiences of blended learning in higher education". *The Internet and Higher Education*, 10, 231 -244.https://doi.org/10.1016/j.iheduc.2007.08.001

[4] Norberg, A., Dziuban, C. D, & Moskal, P. D. (2011). "A time-based blended learning model". *On the Horizon*, 19, 207-216. https://doi.org/10.1108/10748121111163913

[5] Ross, B., & Gage, K. (2006). *Global perspectives on blending learning: Insight from WebCT and our customers in higher education*. In C. J. Bonk & C. R. Graham (Eds.), *Handbook of blended learning: Global perspectives, local designs* (pp. 155- 168). San Francisco, CA: Pfeiffer Publishing.

[6] Picciano, A. G. (2009). "Blending with purpose: The Multimodal Model. *Journal of the Research Center for Educational Technology" (RCET)*, 5(1), 4-14. DOI: http://doi.org/10.24059/olj.v13i1.1673

[7] Osguthorpe, R. T., & Graham, C. R. (2003). "Blended learning environments: Definitions and directions". *The Quarterly Review of Distance Education*, 4 (3), 227-234. Retrieved August 18, 2020 from https://www.learntechlib.org/p/97576/

[8] Tomlinson, B., & Whittaker, C. (2013). Blended learning in English language teaching: Course design and implementation. London: British councilWagner, B. J. Dorothy Heathcote: Drama as a Learning Medium. Portsmouth, N.H: Heinemann, 2007.

[9] Graham, C. R., & Allen, S. (2005). *Blended learning: An emerging trend in education*. In C. Howard, J. V. Boettecher, L. Justice, & K. D. Schenk (Eds.), *Encyclopedia of Distance Learning: Online Learning and Technologies*, 4. Hershey, PA: Idea Group Inc. https://doi.org/10.4018/978-1-59140-555-9.ch024

[10] Graham, C. R., & Allen, S. (2005). *Blended learning environments*. In Howard, C., Boettcher, J. V., Justice, L., Schenk, K. D., Rogers, P. L., & Berg, G. A. s(Ed.), Encyclopedia of Distance Learning (pp. 172-179). IGI Global. http://doi:10.4018/978-1-59140555-9.ch024
[11] Graham, C. R., Allen, S., & Ure, D. (2003). *Benefits and challenges of blended learning environments*. In M. Khosrow-Pour (Ed.), *Encyclopedia of Information Science and Technology* I-V. Hershey, PA: Idea Groups Inc.
[12] Osguthorpe, R. T., & Graham, C. R. (2003). "Blended learning environments: Definitions and directions". *The Quarterly Review of Distance Education*, 4 (3), 227-234. Retrieved August 18, 2020 from https://www.learntechlib.org/p/97576/
[13] Hofmann, J. (2011). *Blended learning*. American Society for Training and Development. Alexandria, vol. 28, Issue, 1108.
[14] Stein, J., & Graham, C. R. (2020). *Essentials for Blended Learning, 2nd Edition: A Standards-Based Guide*. Milton: Taylor & Francis Group. https://doi.org/10.4324/9781351043991
[15] Graham, C. R., Woodfild, W., & Harrison, J. B. (2013). "A framework for institutional adoption and implementation of blended learning in higher education". *The Internet and Higher Education*, 18, 4 14. https://doi.org/10.1016/j.iheduc.2012.09.003
[16] Porter, W. W., Graham, C. R., Spring, K. A., & Welch, K. R. (2014). "Blended learning in higher education: Institutional adoption and implementation". *Computers & Education*, 75, 185–195. https://doi.org/10.1016/j.compedu.2014.02.011
[17] Porter, W. W., & Graham, C. R. (2016). "Institutional drivers and barriers to faculty adoption of blended learning in higher education". *British Journal of Educational Technology*, 47(4), 748–762. https://doi.org/10.1111/bjet.12269
[18] Porter, W. W., Graham, C. R., Bodily, R. G., & Sandberg, D. S. (2016). "A qualitative analysis of institutional drivers and barriers to blended learning adoption in higher education". *The Internet and Higher Education*, 28, 17–27. https://doi.org/10.1016/j.iheduc.2015.08.003
[19] Halverson, L. R., Graham, C. R., Spring, K. J., Drysdale, J. S., & Henrie, C. R. (2014). "A thematic analysis of the most highly cited scholarship in the first decade of blended learning research". *The Internet and Higher Education*, 20, 20–34. https://doi.org/10.1016/j.iheduc.2013.09.004
[20] Boelens, R., De Wever, B., & Voet, M. (2017). "Four key challenges to the design of blended learning: A systematic literature review". *Educational Research Review*, 22, 1–18. https://doi.org/10.1016/j.edurev.2017.06.001
[21] Brown, M. G. (2016). Blended instructional practice: "A review of the empirical literature on instructors' adoption and use of online tools in face-to-face teaching". *The Internet and Higher Education*, 31, 1 10. https://doi.org/10.1016/j.iheduc.2016.05.001
[22] Broadbent, J. (2017). "Comparing online and blended learner's self-regulated learning strategies and academic performance". *The Internet and Higher Education*, 33, 24 32. https://doi.org/10.1016/j.iheduc.2017.01.004
[23] Prasad, P. W. C., Maag, A., Redestowicz, M., & Hoe, L. S. (2018). "Unfamiliar technology: Reaction of international students to blended learning". *Computers & Education*, 122, 92–103. https://doi.org/10.1016/j.compedu.2018.03.016
[24] Cuesta Medina, L. (2018). "Blended learning: Deficits and prospects in higher education". Australasian Journal of Educational Technology, 34(1). https://doi.org/10.14742/ajet.3100
[25] Ocak, M. A. (2011). "Why are faculty members not teaching blended courses? Insights from faculty members". *Computers & Education*, 56(3), 689–699. https://doi.org/10.1016/j.compedu.2010.10.011

[26] Akçayır, G., & Akçayır, M. (2018). "The flipped classroom: A review of its advantages and challenges". *Computers & Education*, 126, 334–345. https://doi.org/10.1016/j.compedu.2018.07.021
[27] Bonk, C. J., & Graham, C. R. (2006). *The handbook of blended learning: Global perspectives, local designs*. San Francisco, Calif: Jossey-Bass.
[28] Dziuban, C., Moskal, P., & Hartman, J. (2005). Higher education, blended learning, and the generations: Knowledge is power: No more. Elements of quality online education: Engaging communities. Needham, MA: Sloan Center for Online Education. https://desar–rollodocente.uc.cl/wpconent/uploads/2020/03/Knowledge_is_power_no_more.pdf.
[29] Heinze, A, & Procter, CT. (2004). *Reflections on the use of blended learning*. 13-14.) University of Salford, Salford.
[30] Bernard, Z. (2017). *Here"s how technology is shaping the future of education*. Retrieved from https://www.businessinsider.com/how-technology-is-shaping-the-future-of-education-2017-12
[31] Low, P. (2017). "E-learning implementation in foundation English class: learners perspectives and learning achievement". *International Journal of Computer Theory and Engineering*, 9(4), 285-289. https://doi.org/10.7763/IJCTE.2017.V9.1153
[32] Allan, B. (2009). Blended learning: Tools for teaching and training. London: Facet Publications.
[33] O'Toole, J M, & Douglas J. Absalom. (2003). "The impact of blended learning on student outcomes: is there room on the horse for two?" *Journal of Educational Media*: (28). 2-3. https://doi.org/10.1080/1358165032000165680
[34] NDTV. Prime Time with Ravish Kumar: Covid "Act of God" we may see economy contract, says finance minister. 28, August, 2020.
[35] Castillo-Cuesta, L., Ochoa-Cueva, C., & Cabrera-Solano, P. (2022). Virtual Workspaces for Enhancing Collaborative Work in EFL Learning: A Case Study in Higher Education. *International Journal of Emerging Technologies in Learning* (iJET), 17(02), pp. 4–18. https://doi.org/10.3991/ijet.v17i02.25937
[36] Li, Z. (2022). Influence of Online Learning Behavior and Video Playing Questions on Students' Learning Effect. *International Journal of Emerging Technologies in Learning* (iJET), 17(02), pp. 223–238. https://doi.org/10.3991/ijet.v17i02.28535
[37] Mu, D., & Guo, W. (2022). Impact of Students' Online Learning Burnout on Learning Performance – the Intermediary Role of Game Evaluation. *International Journal of Emerging Technologies in Learning* (iJET), 17(02), pp. 239–253. https://doi.org/10.3991/ijet.v17i02.28555

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Application of a Gamified Approach to Learning in the Treatment of Problems in Software Process Improvement: Analysis and Discussion of Results

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Abstract—The specialized literature defines Software Process Improvement (SPI) as the fundamental approach to improving software products in software development organizations. In this context, studies report several problems and difficulties that organizations face during the implementation of improvements. Although there are studies that address the problems highlighted in improvement programs, few studies still seek to identify practices in order to mitigate the negative effects of critical factors. Thus, the objective of this work is to discuss and analyze the results obtained in an Experience Report that consisted of a dynamic application with gamification elements in an SPI context related to learning in the treatment of recurring problems or difficulties in the implementation of improvements. It is noteworthy that the dynamics can be developed in organizations (commercial and academic) regardless of the improvement model or standard desired, since it was elaborated in relation to common problems experienced and identified in the SPI implementations scenario. The analysis of the obtained data was performed using an Evaluation Framework for Gamification in Software Engineering, which provided a standard structure for the design of evaluation studies for gamification cases.

Keywords—software process improvement, gamification, teaching and learning, problems and difficulties

1 Introduction

Organizations (commercial and academic) are showing more and more interest in adopting improvement programs in their software processes in order to produce quality software. This interest is driven by the demand level for the quality of services provided by software companies, linked to market competitiveness, as well as the systemic productivity of the software sector [1], [2].

Studies carried out in the software sector in Brazil point to a growth of 28.7% from 2019 to 2020. The growth of the software sector can be attributed to the way companies were forced to change their work structure, due to the confinements caused by the pandemic and the increase in the home-office modality that followed. In order to continue to conduct their business, companies bet on introducing new products, increasing IT (Information Technology) security, increasing productivity and reducing costs [3].

For García et al. [4], the software sector will be in constant change, as innovative technologies are continuously developed, new customers and demands arise, and competitors enter to compete for market space. Thus, the authors point out that an important factor for ensuring the survival of software organizations is the ability to implement improvements in their processes to meet the growing needs of software. For Mendes et al. [5], Software Process Improvement (SPI) aims to know, define and / or improve the processes related to software development to make them more effective and efficient.

There are recommendations in the literature of models, standards and norms that are references to guide a software process improvement initiative in an organization. However, regardless of the models to be adopted, an effective management of the changes to be implemented is necessary for a software process improvement to be successful [6].

Studies carried out in the context of software report problems and difficulties that organizations face to implement SPI based on process models and standards. However, the successful implementation of SPI initiatives fundamentally depends on the strategies and approaches adopted to support the execution of such initiatives. Thus, the absence or lack of adequacy of these approaches is one of the most common reasons for the failure of improvement initiatives [1]. In addition, other factors are also identified as causing failures in the conduct of these initiatives, such as social and cultural factors, lack of communication, motivation and support from top management [7].

Although there are studies that address the problems highlighted in improvement programs, few studies still seek to identify practices to mitigate the negative effects of critical factors [8]. Thus, it is important that every SPI initiative considers methods and techniques in the proposed processes to facilitate the implementation and, thus, minimize the negative effects perceived by those involved in the process [9].

In view of the above, it is noticeable the need to use strategies and approaches in conducting software process improvement initiatives to address or minimize the problems or difficulties identified in SPI implementations. Thus, a strategy that can help in this problem is the use of gamification elements, as a technique that uses elements of technology-enhanced learning, since it encompasses the use of mechanisms and game systems for problem solving and for motivation and engagement of a particular audience [10]. The authors in [11], [12] report many companies have used game strategies to motivate and engage the employee, not only in productivity and fun, but also to encourage and teach innovation and development of their tasks.

Gamification also allows the definition of mechanisms that provide people with motivation and learning to increase productivity and performance, foster innovation, collaboration and participation [13], [14], and offer the opportunity for better user involvement, faster feedback on accomplishments, and more visible progress indicators of continuous software process improvement [15].

Thus, the use of gamification elements can contribute to the definition of teaching and learning mechanisms to stimulate people's motivation and commitment to effectively join and participate in SPI initiatives. This is justified by the fact that gamification uses methods derived from games such as those that use highscore lists, continuous and constant feedback, and the use of rewards with the aim of turning supposedly tiring work into an attractive and stimulating activity [16].

Chou [17] points out how the greatest contribution that gamification can offer to society would be the opposition to the traditional Functionality-Focused Design model for Human Aspect-Focused Design. According to his theory, most of the known production systems are oriented to facilitate that tasks are carried out in the shortest possible time. The simple consideration that the people who perform these jobs have feelings, insecurities and opinions about what is expected of them, or about how they should achieve their professional goals, in itself represents a shortcut for their true motivations to be activated.

For Chou [17], the game elements are factors capable of driving the participant's behavior differently, where some strategies stimulate from inspiration and training, and others from obsession and manipulation. The game elements proposed by the author are structured in the Octalysis Gamification Framework organized into eight Core Drivers and their corresponding correlated game elements (see Table 1). Core Drivers represent basic and fundamental factors in games that provide the motivation to perform a variety of activities and discussions.

Table 1. Core Drivers and their corresponding game elements

Core Drive	Elements
Core Drive 1: Epic Meaning & Calling	Narrative; Humanity Hero; Elitism; Beginners Luck; Free lunch.
Core Drive 2: Development & Accomplishment	Progress bars; The Rockstar Effect; Achievement symbols; Status Points; Classification.
Core Drive 3: Empowerment of Creativity & Feedback	Boosters; Milestones unlock; Choice Perception; Meaningful Choices.
Core Drive 4: Ownership & Possession	Build from scratch; Collection sets; Exchangeable Points; Observer Attachment; Alfred effect.
Core Drive 5: Social Influence & Relatedness	Mentorship; Brag Buttons and Trophy Shelves; Group Quests; Social Treasures; Social Prod; Conformity Anchor; Water Coolers.
Core Drive 6: Scarcity & Impatience	Dangling and anchored juxtaposition; Magnetic Caps; Appointments Dynamics; Torture Breaks; Evolved UI.
Core Drive 7: Unpredictability & Curiosity	Glowing choice; Mystery Boxes / Random Rewards; Easter Eggs / Sudden Rewards; List of Rewards / Lottery.
Core Drive 8: Loss & Avoidance	Legitimate inheritance; Evanescence opportunities; Status Quo Sloth; FOMO Punch; Sunk Cost Prison.

In the organizational context (commercial and academic), employee engagement is essential to achieve the expected goal, so with the application of gamification, intrinsic motivation is aimed at team members. It is noteworthy that gamification is not just giving back to the employee, but motivating him to achieve the reward in a gamified way [18]. For Hamari and Koivisto [19], gamification in a business and academic environment promotes intrinsic changes that provoke the individual to participate in the application of the method. Therefore, above any reward offered in this type of method, gamification seeks to value the personal factor, whether in the relationship with the team, or the appreciation of the individual himself in engaging him to achieve his goals.

In view of the above, this work aims to present the results of the application of a proposal for a solution to SPI problems from the use of gamification elements suitable for the treatment of problems or recurring difficulties in the implementation of improvements, since gamification was identified as a teaching and learning tool that leads to motivation and commitment in several areas [20], [21], including Information Technology and, more specifically, Software Engineering [15]. The results were scaled using the framework for evaluating gamification in Software Engineering by Monteiro et al. [22]. Thus, the research question of this article is: Did the gamified approach help to solve problems or difficulties in the implementation of SPI?

In addition to this introductory section, this article is structured as follows: Section 2 presents the context and issues present in SPI implementations, Section 3 presents the research methodology, detailing its main stages, Section 4 presents related works to the context of this work, Section 5 addresses the gamification evaluation strategy used in the study, Section 6 details the analysis of the results obtained, Section 7 presents discussions regarding the results obtained in the research, Section 8 details the threats to validity that have been identified and, finally, Section 9 presents the conclusions and future work.

2 Software process improvement

According to Moreira [23], several studies carried out in recent years have shown the importance of the systematic and disciplined use of processes for a software company to be successful. This success is related to aspects, such as: increased competitiveness, ability to take greater risks, increased product quality, productivity gains, lower costs and elimination of rework.

The implementation of improvements in software processes is a complex and knowledge-intensive activity [24]. This means that those involved in the initiatives must have knowledge about software engineering and be able to use it to guide the implementation of improvements in the organization's processes, increasing the chances of achieving the expected results [25].

Pressman [26] emphasizes that the lack of adoption of methods, tools and procedures in software development has reached significant numbers of unfinished projects, and completed projects that do not meet customer needs. Other sociocultural issues, such as lack of motivation, are also identified as causing failures in the conduction of improvement initiatives [27].

Mendes et al. [5] report that process improvement deals with issues associated with the analysis, description and improvement of processes related to Information Technology. Several aspects need to be considered in process improvement initiatives, such as: resource allocation, choice of processes to be analyzed and improved, selection of pilot project(s), choice of models to be used and the approach adopted to proceed the initiative.

Researchers such as Habib et al. [28] state that "any significant software process improvement requires a significant investment, time and money". So that these variables are not wasted, it is necessary to carry out a feasibility study and plan the change and improvement. According to Birk and Pfahl [29], this requirement motivated the emergence of standards and reference models, which are used as a basis for the implementation of improvements in software processes.

2.1 Identification of software process improvement problems

Studies carried out in the context of software process improvement (SPI) report problems and difficulties that organizations face to implement process models and standards, mainly related to the inability to overcome some critical factors [30]. Therefore, to identify and analyze the problems and difficulties experienced in SPI initiatives, the authors [31] present in their work the identification and analysis of problems or difficulties, conducted from two perspectives: analyzes carried out in the literature and another from analysis of results obtained from the application of a survey. According to Niazi et al. [25], the accumulated knowledge about critical success factors from the views, experiences and perceptions of people who work in this scenario can help to define more efficient strategies for implementing SPI.

Thus, the literature review allowed the authors [31] to identify 8 (eight) problems and difficulties in the literature that occur during the implementation of SPI. Table 2 presents the problems, the description and the number of times that a given problem was identified in a total of 54 studies.

Subsequently, there was the identification and analysis of the problems and difficulties obtained from the application of a survey by the authors [31]. In total, 12 (twelve) new recurring problems were identified, from the application of the survey, and it was possible to obtain information on the impact (occurrence) that the problems detected in the review caused, in the perception of the participants, according to their experience in MPS, the detailed reports of the participants in relation to the problems detected in the literature, are specified in the work [31]

Table 2. Problems or difficulties identified in the literature

Problem / Difficulty	Description	Citation quantity
1. Culture change in the organization.	It occurs in SPI implementations because there is great resistance on the part of employees in relation to the standardization imposed in the improvement models for the organizational process, since they already adopt their own approach in their routine.	32
2. Lack of knowledge in software engineering	This lack is evidenced in basic procedures necessary in the implementation of the improvement program, where employees are unaware or do not understand technical terms (concepts) or routine activities used in software engineering.	30

3. Lack of understanding of stakeholder responsibilities	Evidenced when roles are not fully established or understood and, in some cases, are vaguely defined, which can make it difficult to understand and progress the process.	17
4. Lack of support tools	Consequence of the lack of standardized tools to support the execution of processes, since without adequate tool support, the development of activities adhering to quality models can be harmed.	15
5. Lack of / little commitment from top management	The non-commitment of top management can affect the progress of the improvement as a whole, since the management is the initial source of investments, resources and decision-making, fundamental to the incentive and support of those involved in the implementation of the improvement.	27
6. Little support from employees	It occurs when employees do not understand the purpose of formalization and discipline in the execution of processes; or in other cases, they even understand, but do not accept, precisely because they do not believe that the improvement will occur with the implementation of SPI. This view contributes to the lack of commitment and motivation to learn about the new practices introduced by the processes.	24
7. Employee turnover	It can negatively affect process improvement activities, as it contributes to the loss of skilled and active individuals in the process, as well as the loss of tacit knowledge. All this can delay and cause a rework in the activities proposed in the application of the model.	8
8. Lack of / little qualified human resources	This problem highlights the difficulties that employees may have during the implementation, due to the unpreparedness to develop the necessary activities, which arise from existing gaps in their qualification.	13

These problems are presented in Table 3, as well as the description and the number of times that a given problem was mentioned by the respondents.

Table 3. Problems or difficulties identified in the survey

Problem / Difficulty	Description	Number of reports
1. Focus on certification instead of focusing on improvement	It occurs in situations where the organization only aims to achieve the final result, directing to a certain certification, without worrying about understanding and dedicating itself to meeting the necessary requirements to reach the pre-established objectives in the SPI.	3
2. Lack of government incentive	The occurrence of this can impact the motivation of those involved in the implementation, since the non-recognition by the government, in the form of financial incentives or not, can negatively influence the work of organizations that seek quality and, consequently, make it difficult to achieve competitive advantages in relation to the market.	3
3. Reduction in consulting hours as a way to reduce costs	It can happen when there is no understanding of the context of application of SPI to those involved, so the lack of understanding will lead them to apply mechanisms to circumvent possible steps and, consequently, reduce costs inappropriately. However, these strategies can negatively impact the results of important steps in the process in question.	1
4. Lack of knowledge of the importance of models by the market	It considers the gaps that exist in understanding in relation to improvement models. Many employees are unaware of the real importance of having a quality seal associated with the organization's image, as they do not understand that the model adds more value to	1

	the context of the organization's performance in relation to the market. A quality seal is very important, as it conveys the message that an organization develops more qualified services, adequate to structural, technical and human resources terms.	
5. Lack of / few projects to validate an improvement program	It is evident when the organization does not direct the projects developed to a more careful supervision, which considers the objectives set by the company and at the same time adheres to the requirements intended in the improvement programs.	1
6. Bureaucracy in improvement programs	It arises from the perspective that these programs bring, in their implementation, many procedures that must be fulfilled to achieve the expected results, which is often seen by employees as something time-consuming to be applied on a daily basis.	1
7. Continuity of team engagement in the defined process	In relation to the "Continued engagement of the team in the defined process", it is recurrent because the organization does not propose strategies to encourage employees in the continuation of the procedures that were pre-established.	1
8. Lack of / little knowledge of models by employees	It occurs when employees do not understand all the procedures described in certain models and cannot perceive the benefits they can provide. This fact causes the lack of interest of such individuals in not using the intended improvement model, which, consequently, causes the lack of knowledge of all the guidelines to be followed, directly harming the implementation of the SPI.	1
9. Different interpretations in relation to the models	Those involved may have different perceptions about the models, as a result of the reality and experience lived by these employees in each organization, as well as when the responsibilities and procedures to be carried out in the SPI are not clearly established.	1
10. Lack of consistent project portfolio planning	The neglect of this can directly affect the organization's results, since its correct application is seen as an effective tool in the analysis and quantification of the value of each project. Such benefits make it possible to prioritize projects that are more aligned with the company's objectives.	1
11. Lack of consistent planning by the top management of the organization	It happens when the organization does not establish a structured way to meet its future demands and needs in relation to impacts, intelligent and timely decision making.	1
12. Lack of model flexibility	It refers to the application context that is seen by those involved as something very rigid and complex, full of divisions, rules and procedures that they consider to be redundant and unnecessary for operation.	1

Based on the problems listed, in [31], it was possible to carry out a study more focused on understanding each problem. This understanding contributed to the mapping of gamification strategies to address or minimize the impacts that these problems cause during the implementation of SPI, from the point of view of teaching and learning.

3 Research methodology

In order to achieve the objectives of this research, a sequence of steps was established and followed. Thus, the methodology carried out in this work comprised the steps shown in Figure 1, described in the following sections: 1) Identify the SPI problems, 2) Identify the gamification elements, 3) Develop dynamics for the use of gamification elements, 4) Define dynamics that integrate all the gamified elements in relation to the problems, 5) Application of gamification for problem solving and 6) Analysis the studies data.

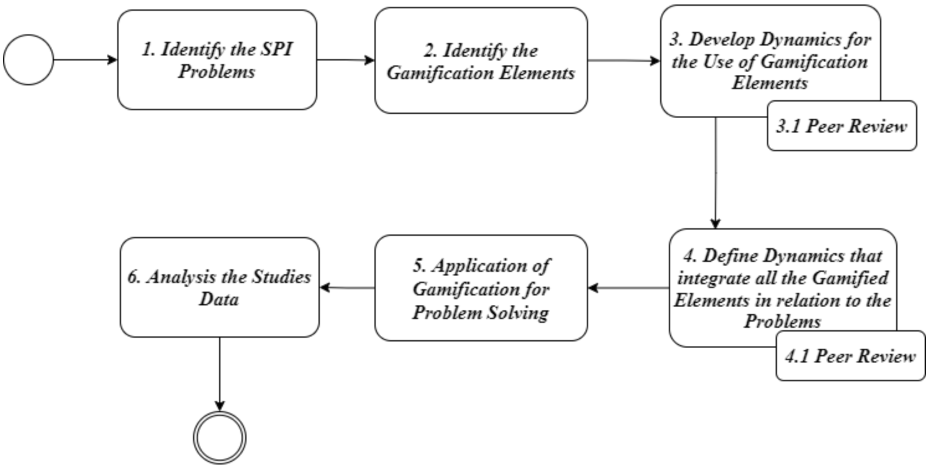

Fig. 1. Work execution steps

3.1 Step 1: Identify the SPI problems

As mentioned earlier, at this step, problems and difficulties were identified based on analyzes carried out on the results obtained in the literature review and in the application of a survey. In the review carried out, 54 studies were selected and included for analysis. As for the survey applied, an electronic form was made available to the research participants for a period of one month, in which 32 responses were obtained from the participants. The details of the problems or difficulties identification described in this step can be consulted in [31].

3.2 Step 2: Identify the gamification elements

In this step, the gamification elements used to minimize or treat the twenty SPI problems found in the previous step were identified and correlated. Thus, for its realization, it was necessary to study gamification concepts and elements that are addressed in the Octalysis Framework [17], and for each problem one or more elements were identified, the Core drive to which each element belongs, as well as the justifications for each problem. application of the elements, potentially capable of minimizing or solving the problems in question. The details of this step can be found in [32].

The Octalysis Framework is divided into eight Core Drivers, which represent basic and fundamental factors in games that provide the motivation to perform a variety of activities and discussions. Linked to the Core Drivers, there are elements or techniques to engage the participants, in this case are the game elements, which are factors capable of driving the participant differently, where some strategies stimulate from inspiration and training and others from the obsession and manipulation [17].

Table 4 presents the description of the elements that were mapped only for the problem "Culture change in the organization". However, in [32] contains the mapping carried out to the other problems, as well as the application justifications and the description of this information for all the elements used that make up the framework.

Table 4. Gamification elements mapped to the problem "Culture change in the organization"

Problem / Difficulty	Core Drive	Elements
Culture change in the organization.	1 - Epic Meaning & Calling	Narrative
	1 - Epic Meaning & Calling	Free lunch
	2 - Development & Accomplishment	Rockstar effect
	4 - Ownership & Possession	Build from scratch
	5 - Social Influence & Relatedness	Tutoria
	6 - Scarcity & Impatience	Appointments dynamics
	7 - Unpredictability & Curiosity	Glowing choice

3.3 Step 3: Develop dynamics for the use of gamification elements

In this step, isolated solutions were developed using the elements to deal with each specific problem. This step was developed according to the reasoning presented in the Octalysis Framework for the element mapped in the previous step, in which there was an in-depth study of the element that made it possible to structure strategies for the application of the element in the context of SPI, which must be used by organizations when these encounter situations in which problems occur. The isolated solutions were reviewed and evaluated by an expert in order to ensure the expected purpose of the application of the element in the context of gamification [33].

Table 5 summarizes how the selected gamification elements should be applied to problems, considering isolated solutions using the elements.

Table 5. Description of the strategy to be used according to elements

Elements	Description of application strategy
Narrative	It involves explaining the purpose of implementing the improvement process, dynamically to employees, including needs, reasons and expected results.
Build from scratch	It requires the involvement of employees in a more active way, in the structuring of the process in the organization, since they must contribute with suggestions and opinions in relation to what will be developed.
Tutoria	It occurs in the attributions, guidelines and information provided to those involved, by a person who has the competence to be an expert in SPI and / or to be an expert in Gamification.
Progress bars	It requires the creation of a Track of actions for the learning of those involved, and from this, those involved must be given a way to visualize their progress according to the fulfillment of the actions established for their training.
Free lunch	It occurs with the provision of rewards to employees related to the delivery of the demands that are under their responsibility in the SPI journey.

Rockstar effect	It creates a context of recognition of the work performed by the employee from the perspective of the team itself (internal perspective).
Glowing choice	It provide faster and more targeted guidance from another employee when they experience difficulties in performing their activities / demands.
Elitism	It promotes strategies to disseminate the benefits of adopting an improvement program in the organization, externally, in order to obtain a competitive advantage in the market for the organization.
Achievement Symbols	It applies of a strategy similar to that promoted with the loyalty card, where for each completed action there must be a series of rewards / awards to employees who effectively fulfill the deliveries necessary for the success of the improvement program.
List of Rewards / Lottery	Rewards must be made available to those involved when they complete their demands, using a digital roulette wheel, where the reward is linked to the luck of the employee.
Mystery Boxes / Random Rewards	It provides the employee with a bonus, when he manages to maintain an excellent performance in the deliveries established in relation to his demands. This bonus is a secret reward and without a predetermined time.
Appointments dynamics	It occurs with the disclosure to the hero of the performance of his actions, which favors a follow-up, in relation to the result that was obtained and expected, this strategy allows the hero to modify his positioning and seek better results.

In the solutions proposed with the gamification elements, a more careful analysis was carried out, by an expert in software engineering, of the strategies developed and the use of predefined gamified elements for SPI problems. This analysis took place with the completion of the peer review. Thus, the expert's considerations were based on the Octalysis Framework. The details of the isolated solutions for the use of elements to deal with each specific problem, as well as their review process by an expert at this stage, can be consulted in [33].

3.4 Step 4: Define dynamics that integrate all the gamified elements in relation to the problems

At this step, a dynamic was developed for those involved in the improvement initiatives, with the interrelated use of the gamification elements to the SPI problems listed. The dynamic includes the procedures, methods and materials necessary for full use in improvement initiatives [34].

The dynamics elaborated explores a context of heroes with an analogy to the Avengers movie, since the work carried out in organizations (commercial and academic), as well as in the context of the movie, depends on the performance and effort of the entire team to achieve the expected results. The heroes' journey is composed of a group of missions, arranged on the map of secret processes in Figure 2, and each mission contains tasks to be performed, specific materials to be used, as well as evaluative actions that must be carried out by the heroes to who can get points in each mission.

Fig. 2. Secret process map

There are three profiles involved in gamification dynamics: a) Operations Instructor (OI), whose competence is to be an expert in SPI and / or to be an expert in Gamification, b) Avengers (VG), which is the Organization's team of employees (commercial or academic), who act directly in the actions necessary to improve the desired process, c) Government Representatives (GR), who are representatives who work in the Organization's Senior Management who have a holistic view of the organization's needs and processes. Each mission has participants who act in its execution, according to the profiles previously exposed. Table 6 presents a summary of mission information.

Table 6. Brief description of the missions that make up the dynamics

Mission	Elements used	Evaluative actions
Mission 1 - Develop Strategies	i) Rockstar effect ii) Elitism iii) Narrative iv) Build from scratch	1. Fill in the Personalization Card 2. Complete the Experience Form 3. Suggestion (Contribution Card) 4. Presence
Mission 2 - Authorize Strategies	i) Build from scratch ii) Tutoria iii) Narrative	1. Analyze and Define Strategy 2. Define Complexity of Activities 3. Suggestion 4. Presence
Mission 3 – Train Hero	i) Tutoria ii) Progress bars	1. Participate in Training 2. Signal Training Satisfaction 3. Suggestion 4. Presence

Mission 4 – Develop Operations	i) Free lunch ii) Rockstar effect iii) Glowing choice iv) Achievement symbols v) List of rewards / Lottery vi) Mystery boxes	1. Develop Low Complexity Activity 2. Develop Medium Complexity Activity 3. Develop High Complexity Activity 4. Suggestion 5. Presence
Mission 5 - Evaluate Mission	i) Appointments dynamics ii) Progress bars	It does not apply, as it is a mission that provides an evaluation in relation to the performance obtained by the heroes with the "Evaluative Actions" present in missions 1, 2, 3, 4. (Quantitative Analysis) It also seeks to obtain feedback from those involved in relation to the motivational factor considering the ARCS Model [35]. (Qualitative Analysis)
Mission 6 – Evaluate Journey	No gamification elements were applied.	It does not apply, as it is a mission that seeks to obtain feedback from those involved in relation to the applied dynamics. (Qualitative Analysis)

The detailing and review process carried out in the dynamics by an expert in which an ID was assigned to each change request, a category to which the request belonged, the item to be adjusted, the comment that justified the reason for the adjustment and suggestion proposal, can be consulted in [34]. It is noteworthy that all the adjustments requested by the expert were implemented, which made it possible to complete the structuring of the dynamics.

3.5 Step 5: Application of gamification for problem solving

To evaluate the application of the proposed gamification dynamics, an Experience Report was carried out in the context of SPI, where we sought to evaluate the applicability of the dynamics as well as the effects of its use. Thus, to carry out the SPI dynamics, the Laboratory institutionalized since 2009 at a Federal University in Brazil, was selected.

Subsequently, the points of improvement that the laboratory needed were verified, so that the improvement model could be defined that would be adopted to meet the needs for improvement in the context of the research laboratory. Therefore, it was verified that the needs were supported from the implementation of the Customer and Market dimension belonging to the MOSE® Competence (Model Guiding for Business Success). The justifications and objectives for choosing the model are present in section 5 of this article.

As for the period of application of the dynamics, this occurred in the interval between 06/24/2021 to 07/29/2021, on Thursdays, from 3:00 pm to 6:00 pm. The meetings took place remotely through the Google Meet tool and with the necessary adaptations to the remote context, due to the restrictions imposed by the COVID-19 pandemic, with the application of social isolation measures. Table 7 presents the schedule followed with dates and definition of the missions that took place.

Table 7. Schedule used in the application of dynamics

Execution	Date	Description (Mission and Time)
E.1	06.24.2021	Mission 1 (3 hours)
E.2	07.01.2021	Mission 5 (30 minutes) and Mission 2 (2 and a half hours)
E.3	07.08.2021	Mission 5 (30 minutes) and Mission 3 (2 and a half hours)
E.4	07.15.2021	Mission 4 (3 hours)
E.5	07.22.2021	Mission 4 (3 hours)
E.6	07.29.2021	Mission 5 (1 hour) and Mission 6 (2 hours)

The dynamics was conducted with the voluntary participation of students / re-searchers who work in the Laboratory, considered as a small business unit. Table 8 contains descriptions of the participants' profile, as well as the code that will be used to designate each one of them during the presentation of the results. There was also one participant, in addition to the seven who accepted to participate, with the attribution of a Judge, who observed the dynamics, checking if the others involved were carrying out the activities. The Judge also filled in the score table according to the evaluative items of the missions. A detailed description of this step will be presented in Section 5 of this study.

Table 8. Description of the participants' profile

Participant code	Training	Research line	Professional activity	Time of experience in Software Engineering
H1	Master (attending)	Software Engineering	Technician	2 years
H2	PhD (attending)	Software Engineering	Technician	4 years
H3	Master (attending)	Software Engineering	Researcher	1 and a half year
H4	PhD (attending)	Software Quality	Professor	10 years
H5	PhD (attending)	Software Engineering	Researcher	4 years
H6	PhD (attending)	Software Engineering	Systems Analyst	4 years
H7	Master (attending)	Software Engineering	Researcher	5 years

3.6 Step 6: Analysis the studies data

The analysis of the data obtained in the Experience Report was carried out using the Evaluation Framework for Gamification in Software Engineering. The purpose of this framework is to provide a standard framework for the design of evaluation studies for gamification cases. The framework considers planning, execution, analysis and reporting of results. The framework used supports the production of empirical data that can be more easily compared [22].

The framework structure is based on the GQIM (Goal-Question-Indicator-Metric) model, which guides the design of evaluation metrics based on a top-down analysis of organizational objectives [36].

According to Monteiro et al. [22], the Framework is organized into evaluation phases and evaluation entities. The evaluation phases describe a sequence of decisions that guide the gamification design review and lead its designer to reflect on the evaluation goals, criteria, questions, required data and data analysis procedures. The evaluation entities are a set of these data, and their relationship, that need to be documented for the evaluation. The detailed description of the data summarization is addressed in Section 6 of this study.

4 Related works

Herranz et al. [37] present an approach to managing change in SPI initiatives, based on the use of gamification techniques to support SPI processes. The authors highlight change management as one of the important areas to be controlled. In this way, they direct greater care to managers, since their actions are essential in the improvement of the software process and their commitments and support are essential to obtain the benefits of a software process. However, the authors present a gamified approach more focused on top management, without addressing other gaps that are perceived during the implementation of the improvement, such as the issue of teaching and learning.

In Herranz et al. [38] a gamification structure was defined oriented to the needs of the organization and the groups of software professionals involved in a SPI initiative. To establish an adequate gamification framework, the authors emphasized the need to adapt the motivational factors of each of the software professional groups. Although the authors build a gamified structure to help different groups of professionals, the approach did not specify elements that should be used as possible solutions to the problems that professionals would face, since the structure to be used depends primarily on the initial study of the people who will be involved in the improvement initiative.

To validate the gamification framework presented earlier, Herranz et al. [39] used a structure adapted to the particularities of an organization and software professionals to encourage motivation. In this validation, a qualitative research methodology was employed through interviews that involved a total of 29 experts in gamification and SPI. The results of this study confirm the validity of the presented framework, its relevance in SPI and its alignment with the standard practices of gamification implementation in organizations. The results obtained in the study were relevant to support the use of the gamification approach in SPI, however the structure was adapted to the particularities of an organization and specific professionals, so it cannot be generalized to other organizations, since the authors are unaware of their needs. This perception is in opposition to what was exposed in the work previously, of creating a structure adapted according to the organization's scenario.

The study by Herranz et al. [40] aimed to bridge the gap between gamification in SPI and empirical evidence by presenting the implementation of the SPI gamification framework in a real environment. The framework validated in the authors' previous work was adjusted and implemented in a small Spanish software development organization, in a controlled experiment, focusing on a team competition (experimental group) to validate its effectiveness. The implementation results show that the application of the structure does not increase staff motivation in SPI tasks, although it contributes to improving their performance. Therefore, the authors point out that the results obtained are a consequence of the use of competitive game mechanics, which may have caused tension between the participants, and this fact can reduce motivation and fun.

As can be seen, none of the studies presented addresses a strategy with gamification elements aimed at each SPI problem, as they approach the problem with the gamification mechanism in a more generalized way to involve participants. Another point noticed in the studies is the absence of a more in-depth description regarding the mechanics and gamification components that were used, which can make it difficult to replicate the proposal and negatively impact the results of applying the structure in other organizations.

In this context, the present article is distinguished by presenting a strategy of using gamified elements, present in the Octalysis Framework, in relation to specific SPI problems, interrelating the use of each element to the context of the problem to favor teaching and learning of its treatment. It is noteworthy that the mapping did not seek to adapt to a specific size of organization, since the problems dealt with can occur in any organizational environment. Thus, to ensure the generalization and replication of the proposal, this study describes the elements that can be used when the organization is faced with such problems.

5 Gamification application strategy

This section presents the application report of gamification dynamics.

5.1 Planning

As mentioned in Section 3.5, the SPI dynamics was performed at the Laboratory belonging to a Federal University in Brazil. The group is formed by Brazilian professors / researchers, master's and doctoral students / researchers from the Graduate Program in Computer Science and graduation from the Faculty of Computing, which work in the research line of Software Engineering (SE) and Education. From this group, 7 employees in graduate training participated in the dynamic. This number of employees underpins the group as a small profile, which, according to Rouiller [41] is commonly represented when it has 2 to 25 employees and represents enterprises (commercial and academic) that normally, but not restricted, are in early stages of business and learning, demanding urgency for their own survival.

Although the group has existed for more than 10 years, it is possible to identify several problems that occur on a daily basis, among them we can highlight the following: a) Wear with customers due to the absence of clear agreements in relation to the goods and services that are provided, b) Loss of customers, c) Difficulties in understanding the market (or segment) in which it operates, d) Lack of clarity regarding the goods and services that are provided by the business unit (both internally and in relation to the market and/or demander), e) Customers dissatisfied due to lack of compliance (or lack of clarity) of agreements, f) Lack of awareness of which goods and / or products should no longer be in the business unit's portfolio, g) Lack of communication with the target audience, h) Inefficient marketing, i) Lack of knowledge of the availability of service at the business unit, j) Lack of preparedness to handle incidents that occur, including failure to handle recurring incidents. As explained in Section 3.5, the resolution of problems experienced in the laboratory is supported by the implementation of the Customer and Market dimension belonging to MOSE Competence.

The MOSE is composed of five competence dimensions: Society and Sustainability, Human Talent, Quality, Customer and Market and Innovation, however the problems experienced in the laboratory have support for resolution in the Customer and Market (CM) competence dimension, since that the dimension addresses issues related to the structuring of the enterprise to be able to satisfactorily serve its internal or external customers, the constant analysis of the market (and / or environment) and the impact of the goods and services generated in it. It also emphasizes that an enterprise must focus on generating value for itself and its customers [41].

In this context, the initial need to deal with the problems described above was highlighted, since they are recurrent in the routine of the team in the Laboratory, and the treatment of these problems is something that MOSE itself points out as substantial for an organization that is starting or already has some years of experience in the market, as it helps to remain competitive and innovative, in its offered services and/or produced goods.

In view of the above, the Experience Report carried out the implementation of the CM competence dimension, in the context of the Laboratory, considering the expected results in the Competence objectives of a small business unit.

The implementation of the CM dimension aimed to provide the Laboratory with the scope of improvements in its process, in relation to the quality of the goods and / or services provided, with the treatment or reduction of the problems that occur, since the main focus of this dimension it is the relationship between the business unit and its customers (internal or external to the enterprise) and with the market in which it operates (whether public or private), important factors for organizations that aim to be competitive and help to survive market instability.

It is noteworthy that the strategies structured in the dynamics, in Section 3.4, were not developed to be applied to a specific improvement model, since the objective of the gamification dynamics is precisely to be applicable to any model, favoring a substantive dynamic to organizations. Thus, in the Experience Report, MOSE was implemented in the context of the Laboratory.

To evaluate the results of gamification dynamics in the treatment of SPI problems, as mentioned in Section 3.6, the Framework for gamification evaluation by Monteiro et al. [22] was used. In this step, it was necessary to map information that is important for the evaluation Framework, such as: a) Contextualization of gamification, which is the definition of the gamified approach (with its dynamics, game elements, rules and emotions) of the context in which the approach is applied, b) Contextualization of the Evaluation, which is the definition of the actors of the gamified approach (participants) and the context in which the evaluation is carried out (scientific investigation method, duration, criteria and evaluation questions), c) Definition of Methods, which is the definition of data collection methods (Metrics, Indicators and instruments for data collection and analysis), d) Summarization of results, which is the collection of data and extraction of information to be analyzed (description and duration, samples - demography and size), e) Outcome Analysis, which is the analysis of data (results for evaluation questions and findings).

5.2 Execution

Firstly, there was an analysis in the context of the Laboratory in order to verify and delimit the scope and the problems experienced in the environment. In this, problems were observed that are dealt with in the Customer and Market dimension of the MOSE improvement model for small organizations, as explained in Section 5.1, for the application of the SPI dynamics.

Subsequently, the invitation was sent to the participants, containing the information and the purpose of the work. Upon acceptance, there was an initial collection of the participant's profile, with information on training, research line, current professional activity and time of experience in software engineering, presented in Section 3.5.

Therefore, meetings were scheduled with the group, using Google Calendar (a tool used to manage the dates and times of the meetings necessary to carry out the missions during the Gamification journey), every Thursday, at 3 pm to 6 pm, from 06.24.2021 to 07.29.2021, totaling six meetings, which were held via Google Meet (tool selected to carry out the necessary meetings to carry out the proposed missions in the gamification scenario). It is important to point out that the number of meetings was directed towards the implementation of a MOSE competence dimension, related to Customer and Market.

As for the materials needed to perform the procedures of each mission, they were made available as materials or as activities to participants in Google Classroom (a tool used to centralize and manage materials, deliverable during the dynamics). It is noteworthy that the dynamics were initially built for the context of face-to-face application, so they needed to be adapted for remote use with the use of tools that met the new reality for this first application, due to the restrictions imposed on organizations in the face of the COVID-19 pandemic.

Then, on 06.24.2021, the execution of the dynamic took place, in which the procedures belonging to Mission 1, covered in Section 3.4, were applied. In it, the procedures regarding internal exposure were adapted for synchronous presentations on Google Meet, and in materials available on Google Classroom regarding: the benefits and advantages of having an SPI model adopted in the organization, information related to institutional knowledge, the organization's strategic objectives in relation to the improvement model and about the rules and guidelines of the game to those involved.

The information exposed to those involved was intended to raise awareness of the importance of adopting the model, generate commitment to the procedures necessary to achieve the expected results for the improvement, as well as obtain suggestions for digital marketing strategies to reach the external public, as well as opinions in relation to what will be developed. These suggestions were collected as an activity in Google Classroom, using the Contribution Card.

In the execution of Mission 1, the participants had to develop the activities created in Google Classroom to assign a hero profile to another employee (Personalization

Card) and provide information regarding their degree of previous experience (Hero Experience Web Form). All these activities were assigned a score and a stipulated time for delivery before the execution of the next mission.

At the end, the room created to manage the SPI dynamics (Google Classroom) was consulted to verify the deliveries made in Mission 1 by the participants. There was also the collection of information related to the presence and suggestion noted by the Judge, which contributed to the completion of the scores in the performance worksheet (Google Worksheet, a tool used to make available to those involved the scores obtained in the actions carried out in the missions). The results obtained in Mission 1 were presented to those involved in Mission 5.

According to the map of secret processes, at the end of each mission it is necessary to carry out Mission 5 (see Section 3.4), so on 07.01.2021 Mission 5 initially took place with the presentation of information on the performance obtained by the heroes in Mission 1 , collected in the Performance Worksheet, and later feedback was obtained from those involved regarding the dynamics of actions established in Mission 1, considering ARCS Model (Attention, Relevance, Confidence, Satisfaction) from Keller [35], since the four categories present in the model represent the necessary conditions for a person to be motivated, that is, each one represents an aspect of motivation.

Subsequently, the execution of Mission 2 took place, initially passing on the instructions of the procedures that would occur in this mission, and later they were presented synchronously in Google Meet, and in materials available in Google Classroom: the summarized experience data of those involved obtained in the Web Form, the Track of learning they will follow on the training mission, the Hero Profile of each participant resulting from the Personalization Card. Still in this first moment, the suggestions proposed by those involved in the Contribution Card were read, and these suggestions were analyzed and selected together with those involved in a brainstorm.

Later, still in Mission 2, the presentation of the expected results of the implementation of the MOSE improvement model took place and there was also a time dedicated to providing guidance to remove doubts. After the presentation of the MOSE, those involved were asked to previously define activities in the Trello tool, through a ticket, of possible activities that, according to the knowledge obtained from the presentation, would make it possible to achieve the objectives expected by the model for the Customer and Market dimension, as well as pointing out a possible priority to the ticket (High, Medium or Low). It is noteworthy that this mission was not fully developed on this second day of execution, as the full definition of activities took place only with the completion of the training provided to those involved in Mission 3.

On the third day of execution (07.08.2021) Mission 3 began, initially passing on the instructions for the procedures that would occur in this mission. Then there was the presentation of the Track of Learning with the guidelines of the context that would be dealt with in the training. The training was then conducted by the Project Coordinator, who has extensive experience in the topics covered in the training related to the practices of the CM dimension, about Processes and Tools.

The laboratory employees who participated in the training were assigned a score on the Performance Worksheet. Another way established for those involved to score in this mission was the feedback at the end of the training actions in the Flag. It is important to mention that the flag was adapted in the remote structure to be performed in the Padlet tool (a tool used to obtain feedback from those involved from actions developed in the SPI dynamics).

With the completion of the training mission, it was possible to complete the remaining steps to complete Mission 2, so the participants finished defining the activities in Trello, identifying in each ticket created the CM objective they were meeting and, later, defining the priorities for each activity. In the end, each employee had to include himself in some ticket(s) to develop it in the next mission, thus assuming responsibility for that activity. In this mission, both the creation and prioritization steps of the activities were ways of providing points to those involved in the performance worksheet.

The knowledge acquired in the training can be monitored at the time of creating the activities in the tool, as it was possible to verify the application of what was passed on in the training, in this case in theory for practical application. This training progress was evaluated on the Power Level Meter (a work product that has the ability to measure the power level of each hero according to actions taken in the mission).

With the completion of the Mission, it was possible to prepare the material to develop Mission 5. Thus, on 15.07.2021, Mission 5 was initially carried out with the provision of the performance obtained by the heroes in Mission 2 and in Mission 3 with the presentation of information collected in the Performance Worksheet (Google Worksheet).

Next, Mission 4 began, and the instructions for the procedures that would take place in the mission were initially presented. In this mission, those involved developed tickets with the activities that were agreed in Mission 2 and, during the development of the tickets, they had access to the special operations that were part of this mission, described in [34]. This mission required more time to develop, as there was a change in the time that was planned from just one to two days, 07.15.2021 and 07.22.2021.

In Mission 4, participants used the Infinity Gauntlet (glove-shaped work product) to collect the Infinity Gems, according to the rules and deliverables of the activities present on Trello. In the remote context, the gloves were made available to those involved on a web page created in the Google Sites tool without any jewelry, and when deliveries were made, the jewelry was inserted into the gloves on the website. Employees who experienced difficulties in any activity could request help during meetings held on Google Meet via chat, voice or video, or in Classroom under "Announce something to the class". To the participants who helped, there was the delivery of jewelry to compose the Glove, but the delivery was conditioned to the feedback of the help carried out in the Flag (work product used by the heroes to evaluate the actions that are carried out in their training and help, that is, it allows for a feedback of actions taken) in the Padlet tool, because only with positive feedback would the jewel be granted to the employee who provided the help. The employees who validated the completed tickets were also provided with jewelry.

Regarding the recognition of the activities performed, an activity was created in Google Classroom for those involved to assign another employee the Recognition Card for their performance in the activities. The activities developed in this mission were stipulated a time for delivery before the execution of the next mission.

The last day of execution (29.07.2021) was initially dedicated to the steps of recognition and performance rewards to those involved in the dynamics belonging to Mission 4. The recognition cards were made available to those involved on a web page in the Google sites tool and the rewards displayed on App-Sorteos.com (it's a free online application to make random draws in an easy and fun way). The rewards occurred according to the performance obtained by the heroes in Mission 4 with the presentation of the information collected in the Performance Worksheet (Google Worksheet) exposed in Mission 5.

Finally, Mission 6 took place with a brainstorming session, considering solutions applied to SPI problems to obtain feedback from those involved. A SWOT analysis was also carried out to obtain a clear and objective view of what are the strengths, weaknesses, opportunities and threats in relation to the strategies established in the SPI dynamics to those involved in the organizational context.

5.3 Evaluation

After the conclusion of the SPI dynamics, the necessary information was collected to carry out the evaluation of the results, using the Framework for gamification evaluation by Monteiro et al. [22]. For the evaluation, it was necessary to define the evaluation criteria, questions, indicators and metrics. The defined evaluation criteria were: C01) Performance, with a focus on productively participating in the proposed activities throughout the dynamic, making the necessary deliveries efficiently, C02) Satisfaction, to have their expectations met in the activities, C03) Awareness, being aware of the responsibilities and consequences of the actions taken, C04) Engagement, collaboratively and proactively participating in the proposed activities, always involved and committed to the necessary deliveries, C05) Participation, being present and efficiently participating in the proposed activities, C06) Understanding, effectively understanding the instructions provided during the implementation of the improvement and C07) Positive Involvement, participating and engaging in the proposed activities, acting with promptness, collaboration and recognition of the work carried out by the people who belong to the group.

Therefore, considering the gamified elements and strategies developed for the twenty SPI problems, and the criteria exposed above, 72 questions were elaborated, and for each SPI problem there could be one or more questions to investigate. To answer these questions, 43 indicators were developed, related to 9 metrics. To understand all the issues, indicators and metrics related to the analysis of gamification elements and, later, to SPI problems, the file available at (https://zenodo.org/record/6299232#.YhpKS-jMI2w) was generated.

The answers to these questions help to answer the main question of the study "Did the gamified approach help to solve problems or difficulties in the implementation of SPI?".

The information collected in the dynamics was documented in data collection and analysis procedures, where data collection instruments were defined (Performance worksheet, Video of meetings, satisfaction script and SWOT Analysis) and quantitative data analysis procedures (data objective) and qualitative (subjective data) to answer the evaluation questions.

6 Data analysis

This section presents the data obtained from the use of the gamification evaluation framework in relation to SPI dynamics applied in the Experience Report of Laboratory. The analysis will be performed from each SPI problem.

6.1 Analysis of the problem 'Culture change in the organization'

For the problem of *Culture Change in the Organization*, 12 (twelve) questions were prepared to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, the 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the first question *(Q01 - Did the gamified approach promote joint participation of employees in activities regarding the analysis and definition of SPI problem solving strategies in the studied context?)*, we sought to analyze the criteria of **Performance (C01)** and **Participation (C05)** in the application of the element 'Build from scratch', considering both quantitative and qualitative data to obtain the result. Thus, the following deductive analyzes on criteria C01 and C05 were obtained:

- During Mission 2, all participants worked together in the activities of analysis and definition of strategies for the implementation of the desired improvement model, which favored a positive performance in the development of this demand. This is evidenced in the scores obtained, as the 7 (seven) participants reached the expected value in the activity of +30 points,
- It was observed in the moments developed in the dynamics that all the participants managed to develop the activities of analysis and definitions together, interacting to structure a backlog of activities that they considered necessary to achieve the improvement results.

Thus, the analysis carried out for the element 'Build from scratch' shows that the participants were able to work together, collaborating in the structuring of analysis activities and definitions of strategies that were established and adopted in the dynamics. Participation in the structuring process evidences the application and the expected result of the element 'Build from scratch'.

In the results of the application of the **'Narrative'** element, 3 (three) questions were analyzed *(Q02 - Did the gamified approach favor the employees' understanding of the necessary changes in the studied context?, Q03 - Did the employees identify necessary changes in the studied context? and Q04 - The employees made the necessary changes in the context studied?).* In these questions, we sought to analyze the criteria of **Performance (C01)**, **Participation (C05)** and **Engagement (C04)**, considering only quantitative data to obtain the result. It is noteworthy that there was an analysis of data in each question, as the result of the application, from the element to the problem, corresponds to the joint analysis of the results of these questions. This reasoning extends to the other elements that had more than one question analyzed. Thus, the following deductive analyzes on criteria C01, C05 and C04 were obtained:

- Participants were able to perform the necessary activities throughout the dynamic: in Mission 1, participants were able to obtain values in the range of 95 to 100 points, in Mission 2 the participants managed to obtain values in the range of 81 to 97 points, in Mission 3 they reached 90 points; in Mission 4 they managed to obtain values in the range of 150 to 220 points. It is noteworthy that there is a maximum value established only in missions 1, 2 and 3 equivalent to 100 points, as in Mission 4 there is no limit to the maximum amount of activities that the participant develops, as it depends on the demand established in the backlog of actions of organizational improvements. Therefore, even with oscillations in the values of the participants' scores, it is noteworthy that no participant was left without carrying out activities in the missions, so the realization of deliveries presupposes that there was an understanding of the employees about the necessary changes to achieve the improvement results,
- During the development of the missions, most participants were able to point out possible changes to improve the procedures adopted throughout the dynamics: in Mission 1 all participants provided suggestions, therefore, they scored in the mission, in Mission 2 only the participant H02 did not score, as he did not provide a suggestion, in Mission 3 there were no suggestions, as it is a mission focused on team training with guidance from the Senior Management representative who has more than 20 years of experience in software process improvement, providing training and consulting, in Mission 4 there were few suggestions, which can be justified by a more practical and interactive round in its development,
- The analyzed results involve the operations necessary to achieve the results in the context of the improvement present in Mission 4, in which all participants (H01, H02, H03, H04, H05, H06 and H07) managed to perform the activities present in Mission 4, obtaining respectively 210, 150, 210, 210, 190, 160 and 160 points (Total points per Operation). The fluctuations in the values of the participants' scores occurred because some performed activities that had a lower or higher value in relation to the others. The scores presented show that the participants did not fail to carry out the demands belonging to the activities backlog, that is, they remained engaged in fulfilling the necessary changes that were established in the mission's operations.

Thus, the analyzes carried out on the results of the 'Narrative' element show that the participants were able to identify and make the necessary changes in the context, this demonstrates that there was the development of demands for improvement, and this development was provided by guidelines and moments of incentives arranged in the scenario dynamics, which shows the application and expected result of the 'Narrative' element.

As for the application of the '**Tutoria**' element, 2 (two) questions were analyzed *(Q05 - Did the employees understand and participated in the guidelines regarding the heroes' action track? and Q06 - Were the employees satisfied with the instructions given?).* In these questions, we sought to analyze the criteria for **Participation (C05)**,

Understanding (C06) and **Satisfaction (C02)**, considering quantitative and qualitative data to obtain the results. Thus, the following deductive analyzes on criteria C05, C06 and C02 were obtained:

- The analyzed results belong to Mission 3, in which all the participants were present, acting in a participatory way in the moments dedicated to the guidelines that appear in the action track, participation favored the expected score for this activity equivalent to +30 points,
- During the development of the missions, it was observed that the participants developed the activities necessary to achieve the improvement results, which demonstrates the understanding of the guidelines present in the action track, as the knowledge acquired in the training (Mission 3) was applied in practical moments from other missions, tracked on the Power Gauge,
- In the activity of signaling satisfaction with the training, carried out in Mission 3, only the participant H06 did not score in this measure, all others developed and positively signaled the training actions, thus obtaining the score granted for this activity of +30 points,
- Participants provided positive feedback on the training provided, this was evidenced by the results collected in the Satisfaction Roadmap, where some reported that training is essential for understanding the context of improvement, others highlighted the importance of having a person to instruct with a high level of experience in the context of SPI, as it facilitates even more the understanding of the knowledge necessary for the implementation of the model.

The analyzes carried out on the results of the 'Tutoria' element show that the participants understood the guidelines provided in the actions track and the importance of participating in the training actions, since they were present and gave positive feedback on these actions. This result evidence the application and the expected result of the 'Tutoria' element, since the knowledge obtained, in the moments of orientation, contributed to the participants in the development of the demands for established improvements.

Regarding the application of the '**Free Lunch**' element, 2 (two) questions were analyzed *(Q07 - Did the gamified approach engage employees in carrying out activities in the context studied? and Q08 - Were the employees satisfied with the gamified approach used?).* In these questions, we sought to analyze the criteria of **Performance (C01)**, **Engagement (C04)** and **Satisfaction (C02)**, considering quantitative and qualitative data to obtain the results. Thus, the following deductive analyzes on criteria C01, C04 and C02 were obtained:

- The scores obtained, in Mission 4, by the participants (H01, H02, H03, H04, H05, H06 and H07), respectively 210, 150, 210, 210, 190, 160 and 160 points (Total points per Operation), shows that they remained engaged in fulfilling what was expected in the operations present in Mission 4, since they were able to perform the activities, as they did not fail to carry out the demands belonging to the backlog of activities necessary to achieve the results in the context of improvement,

- According to information obtained in the SWOT Analysis, the participants reported being satisfied with the proposed dynamics, highlighting difficulties in understanding at the beginning of the dynamics (Mission 1), but which were clarified during the application. Participants also showed that the use of gamification in the context of heroes in the SPI scenario stimulates people's participation.

The analyzes carried out on the results of the 'Free Lunch' element show that the participants complied with the demands of the improvement model, developing the necessary activities, which were present in the activities backlog, aiming for the recognition and / or reward provided by the approach gamified, and even gave positive feedback to this strategy. The participants' search for recognition and / or reward resulting from the fulfillment of activities evidences the application and expected result of the 'Free Lunch' element.

As for the application of the **'Rockstar Effect**' element, only 1 (one) question (*Q09- Did the employees recognize the quality of their colleagues' work while carrying out the activities?*) was analyzed, considering the analysis of the **Positive Involvement (C07)** criterion in quantitative data and qualitative to obtain the results. Thus, the following deductive analyzes on criterion C07 were obtained:

- At the end of Mission 4, the participants recognized the work developed by their colleagues and also received recognition for the work done, this recognition is evidenced in the Recognition Cards delivered. In this dynamic, all participants received cards, but the participant who received the most was H04 with a total of 5 cards and those who received the least amount were participants H02 and H06 with only 1 card,
- It was observed that in the application of the recognition dynamics there was a positive involvement among the participants, as they provided feedback regarding the quality of the work developed by their colleagues, strengthening the appreciation and consequently the engagement in the work performed by the team, since all the participants had their work recognized, being praised for what they performed.

In the analysis carried out, the results of the 'Rockstar Effect' element show that there was recognition of the work developed among the participants, this was symbolized in the delivery of Cards with positive feedback in relation to the work performed. The recognition generated evidence application and expected result by the element 'Rockstar Effect'.

Regarding the application of the '**Glowing Choice'** element, 2 (two) questions were analyzed *(Q10 - Did the employees work together in the development of activities? and Q11 - Did working together make the development of activities possible?).* In these questions, we sought to analyze the criteria of **Performance (C01)**, **Participation (C05)** and **Positive Involvement (C07)**, considering quantitative and qualitative data to obtain the results. Thus, the following deductive analyzes on criteria C01, C05 and C07 were obtained:

- In Mission 4, participants who requested help from another participant were H02, H03 and H07, which were able to work together and fulfill their demands, and participants who provided the help received +20 points for the assistance provided: H03 provided assistance received +20 points, H07 provided two aids and obtained + 40 points,
- It was observed in Mission 4 that participants H02, H03 and H07 managed, with the help provided by another participant, to develop their activities, since they provided satisfactory feedback from the help, so there was a positive involvement between the team members.

The analyzes carried out on the results of the 'Glowing Choice' element show that participants who requested help from another participant were able to work together and fulfill their demands, providing satisfactory feedback on the help provided. The strategy provided those involved with a resource to continue performing what was necessary to achieve the expected goals in times of difficulty, which shows the application and expected result of the 'Glowing choice' element.

For the application of the '**Appointments dynamics**' element, only 1 (one) question was analyzed *(Q12 - Was there an improvement in the participants' performance regarding the development of activities present in the dynamics through performance feedback?)* with the analysis of the **Performance (C01)**, **Awareness (C03)** and **Participation (C05)** criteria in quantitative data. Thus, the following deductive analyzes on criteria C01, C03 and C05 were obtained:

- Some participants had fluctuation in their performance in the rounds, some managed to increase their score, others reduced it: in Mission 1 the participants managed to obtain values in the range of 95 to 100 points, in Mission 2 the participants managed to obtain values in the range of 81 to 97 points, in Mission 3 they reached 90 points, in Mission 4 they managed to obtain values in the range of 150 to 220 points. However, it is noticeable that most of the participants became aware of improving their performance in the activities and consequently helped the team to fulfill the necessary deliveries.

In the analysis results for the 'Appointments dynamics' element, it is noticeable that when the score was shown to the participants, those with lower scores had a stimulus to improve the performance obtained in the missions, since the majority became aware and performed the activities to help the team, fulfilling the necessary deliveries, which demonstrates the application and result expected by the 'Appointments dynamics' element, as providing performance information made them proceed in order to improve their performance in the missions.

6.2 Analysis of the problem ‘Lack of knowledge in software engineering’

For the problem of *Lack of Knowledge in Software Engineering*, 4 (four) questions were elaborated to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, 5 (five) of the 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the '**Tutoria**' element, 2 (two) questions were analyzed *(Q13 - Did employees understand and participate in the guidelines regarding software engineering tutoring? and Q14 - Were employees satisfied with the software engineering guidelines passed?).* In these questions, we sought to analyze the criteria of **Satisfaction (C02)**, **Participation (C05)**, and **Understanding (C06)**, considering quantitative and qualitative data to obtain the results.

The deductive analyzes evidenced in the Questions Q05 and Q06 are based as data for the questions Q13 and Q14, since the tutoria in Software Engineering was inserted in the Action Track.

Therefore, the analyzes carried out on the results of the 'Tutoria' element demonstrate that the participants understood the guidelines and the importance of participating in the training actions, since they were present and gave positive feedback on these actions. In these actions, the necessary knowledge was provided to develop the activities to achieve the results of the improvement. The participants' performance evidences the application and the expected result of the 'Tutoria' element, since the knowledge obtained, in the moments of orientation, was applied by the participants in the development of the demands for established improvements.

For the application of the '**Progress Bars**' element, only 1 (one) question was analyzed *(Q15 - Did the software engineering tutoring help in the correct performance of the activities in the studied context? If not, why?)* with the analysis of the **Performance (C01)**, **Participation (C05)** and **Understanding (C06)** criteria in quantitative data. Thus, the following deductive analyzes on criteria C01, C05 and C06 were obtained:

- The accomplishment and the results obtained in the activities necessary to the context of the improvement, shows that there was an understanding of the employees about the knowledge necessary to perform the activities and achieve the improvement results. The performance worksheet is made available to the participants, with information on the types of activities and scores obtained. Activities required the application of knowledge acquired in training for their development, and all participants scored in this mission (Mission 4): participants (H01, H02, H03, H04, H05, H06 and H07) and their respective scores, 220, 160, 240, 220, 205, 170 and 215 points (Total Hero Points).

The results of the analysis of this element show that the participants were able to follow the progress of the level of knowledge acquired in the training, because in the practical moments, the participants were measured and provided feedback on the application of the acquired knowledge, from the fulfillment of the activities established in the missions. This strategy of measuring and providing performance monitoring evidence the application and the expected result of the 'Progress Bars' element.

As for the application of the '**Glowing choice**' element, only 1 (one) question *(Q16 - Did the gamified approach instigate help among employees in solving activities in the context studied in situations of doubts, lack of knowledge or expertise?)* was analyzed, considering the analysis of the criteria of **Performance (C01)**, **Participation (C05)** and **Positive involvement (C07)** in quantitative and qualitative data to obtain the results.

The deductive analyzes evidenced in the Questions Q10 and Q11 are based on data for the questioning Q16, since they deal with situations in which the participant finds it difficult to understand or perform the activities assigned to them in the dynamics in relation to the model, the tools used, lack of knowledge in software engineering or even lack of necessary technical knowledge.

The results of this element show that participants who requested help from another participant were able to work together and fulfill their demands, providing satisfactory feedback on the help provided. The strategy provided those involved with a resource to continue performing what was necessary to achieve the expected goals in times of difficulties due to the lack of necessary knowledge in software engineering, which shows the application and expected result of the 'Glowing choice' element.

6.3 Analysis of the problem 'Lack of understanding of stakeholder responsibilities'

For the problem of Lack of *Understanding of Stakeholder Responsibilities*, 5 (five) questions were elaborated to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, 6 (six) of 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the '**Narrative**' element, only 1 (one) question (*Q17 - Did the employees understand the functions of each role within the gamified approach explained?*) was analyzed, considering the analysis of the **Understanding (C06)** criterion in qualitative data to obtain the results. Thus, the following deductive analysis was obtained on criterion C06:

- It was observed in Mission 4 that the participants were able to develop the activities necessary to achieve the expected results in the context of the desired process improvement, as they did not fail to participate and comply with the deliveries of the demands, which demonstrates the understanding of the role that each one had to play to achieve the improvement results.

The analysis carried out on the results of the 'Narrative' element shows that the participants were able to understand the role they had to play in the SPI dynamics, considering the context of heroes, since each one developed their skills and competences in the activities in order to help achieve what is expected in implementing the improvement. The proposed scenario allowed the participants to understand the importance of their performance in the activities proposed in the dynamics, this evidences the application and expected result of the 'Narrative' element.

In the application of the '**Tutoria**' element, 2 (two) questions were analyzed *(Q18 - Did employees commit to playing the roles assigned to them? and Q19- Did employees engage in performing the roles assigned to them?).* In these questions, we sought to analyze the criteria of **Awareness (C03)** and **Engagement (C04)**, being considered qualitative data in the analysis. Thus, the following deductive analyzes on criteria C03 and C04 were obtained:

- It was observed in mission 4 that the participants were able to develop the activities necessary for the context of the desired process improvement, that is, they did not fail to participate in the delivery of demands, acting consciously to fulfill the activities present in the backlog, which demonstrates the understanding of the importance and commitment to fulfilling the necessary demands to perform,
- Participants reported, in the Satisfaction Roadmap, that the way in which the information was passed on clarified the responsibility structure of each one. And they pointed out as a positive factor, not having the imposition to develop a specific activity, allowing the participants to select to develop the activities that they had more affinity or even knowledge, generating in those involved a sense of responsibility in carrying out the activities. Others ones reported that the imposition of demands can cause people to become demotivated, and the way in which it was passed on in the dynamics made the participants more comfortable and engaged in carrying out the deliveries.

The results show that the participants understood the guidelines regarding responsibility and the importance of participation in the development of activities, as they did not fail to deliver the demands, acting consciously to fulfill what was established in the activities backlog. The participants provided positive feedback to the responsibility guidelines as they reported that there was no enforcement structure to develop the demands, each one worked on the activity they had the most skill or competence to perform. The orientation and understanding of responsibility evidences the application and the expected result of the 'Tutoria' element.

Regarding the application of the '**Glowing choice**' element, 2 (two) questions were analyzed *(Q20 - If there was low engagement in fulfilling roles, did the employees work as a team to compensate for this absence? and Q21 - Did working together allow the development of activities?)*, considering the analysis of the criteria of **Performance (C01)**, **Participation (C05)** and **Positive Involvement (C07)** in quantitative and qualitative data to obtain the results.

The deductive analyzes evidenced in the Questions Q10 and Q11 are based on data for the questioning Q20 and Q21, since they deal with situations in which the participant finds it difficult to understand or perform the activities assigned to them or assumed as responsibility in the dynamics in relation to the model.

The results of this element show that participants who requested help from another participant were able to work together and fulfill their demands, providing satisfactory feedback on the help provided. The strategy provided those involved with a resource to continue performing what was necessary to achieve the expected goals in times of difficulties due to the lack of understanding of the responsibilities in the SPI activities, which shows the application and expected result of the 'Glowing choice' element.

6.4 Analysis of the problem 'Lack of support tools'

For the problem of *Lack of Support Tools*, 6 (six) questions were elaborated to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, 5 (five) of 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

For the element '**Build from scratch**' 2 (two) questions *(Q22 - Did the gamified approach promote the joint participation of employees in the activities to propose suggestions for tools to be used in the context of SPI? and Q23 - In the gamified approach were obtained/collected suggestions for tools from employees to help in the context of SPI?)* were analyzed, and in these we sought to analyze the criteria of **Performance (C01)** and **Participation (C05)**, considering both quantitative and qualitative data to obtain the result. Thus, the following deductive analyzes on criteria C01 and C05 were obtained:

- It was observed in the development of the dynamics that the participants gave suggestions regarding tools, and these were always discussed by the team in order to verify the opinion of all those responsible for achieving the improvement.
- During the development of missions 1 and 2, most participants were able to suggest possible tools to improve the procedures adopted and achieve the expected results in the implementation of the improvement: in Mission 1 all participants provided suggestions, so everyone scored in these missions (+10 points), in Mission 2 the participants H02, H06 and H07 did not score, as they did not provide a suggestion, the others managed to obtain a good performance in this demand (+ 10 points).

The results of this element show that the participants were able to work together, collaborating with suggestions for tools to be adopted throughout the dynamic, these suggestions were discussed by the team in order to verify the relevance of use by all those responsible for achieving the improvement. Participation in the structuring process evidences the application and expected result of the 'Build from scratch' element.

In the application of the '**Tutoria**' element, 2 (two) questions were analyzed (*Q24 - Did the employees understand the guidelines regarding the tools used in the context of MPS? and Q25 - Were the employees satisfied with the instructions given?*). In these questions, we sought to analyze the criteria of **Satisfaction (C02)**, **Participation (C05)** and **Understanding (C06)**, considering quantitative and qualitative data in the analysis.

The deductive analyzes evidenced in the Questions Q05 and Q06 are based as data for the questions Q24 and Q25, since the tutoring in Tools to support the context of improvement was inserted in the Action Track.

The results show that the participants understood the guidelines and the importance of participating in the training actions, since they were present and gave positive feedback on these actions. In these actions, information was passed on in relation to the tools necessary to develop the improvement activities. The participants' performance evidences the application and the expected result of the 'Tutoria' element, since the knowledge obtained, in the moments of orientation, was used in the handling of the tools during the development of the demands for established improvements.

As for the application of the '**Glowing choice**' element, 2 (two) questions were analyzed (*Q26 - Was there employee engagement in working as a team to compensate for the difficulty in using the tools necessary to carry out the activities? and Q27 - Working together enabled the development of activities?*), considering the analysis of the criteria of **Performance (C01)**, **Participation (C05)** and **Positive involvement (C07)** in qualitative data to obtain the results.

The deductive analyzes evidenced in the questions Q10 and Q11 are based on data for the questioning Q26 and Q27, since they deal with situations in which the participant feels difficulty in understanding and handling the tools used in the activities to be developed in the dynamics in relation to the model.

The results of this element, according to the application already described, show that the participants were able to work together and fulfill their demands, providing satisfactory feedback on the help provided. The strategy provided those involved with a resource to continue performing what was necessary to achieve the expected objectives in times of difficulties due to the lack of understanding regarding the tools used to implement SPI activities, which shows application and expected result by the ' Glowing Choice' element.

6.5 Analysis of the problem 'Lack of / Little commitment from top management'

For the problem of *Lack of / Little Commitment of Top Management*, 3 (three) questions were elaborated to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, 4 (four) of 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the '**Narrative**' element, only 1 (one) questioning (Q28 - Do senior management representatives understand the importance of commitment to their role within the explained gamified approach?) was analyzed, considering the analysis of the criteria for **Participation (C05)** and **Understanding (C06)** in qualitative data to obtain the results. Thus, the following deductive analyzes on criteria C05 and C06 were obtained:

- The senior management representative was present, participating and accompanying the team in missions 1, 2, 3. This demonstrates the understanding of the importance in relation to their participation and commitment in the approach with the team, being noticeable that their presence generated a greater commitment of participants regarding the development of demands.

The analysis carried out on the results of the 'Narrative' element shows that there was participation and monitoring of the senior management representative, in the moments of guidance and support to the team in the missions, demonstrates the understanding of the importance in relation to their participation and commitment in the approach with the team. Therefore, his presence and performance strengthened the relevance and commitment of the implementation of the improvement to the other participants, this evidences the application and expected result of the 'Narrative' element.

In the application of the '**Tutoria**' element, 2 (two) questions were analyzed (*Q29 - Were senior management representatives aware of the benefits that their work with the team would promote to the gamified approach? and Q30 - Top management representatives committed to performing and fulfilling responsibility for commitment to the role played?*). In these questions, we sought to analyze the criteria of **Awareness (C03)** and

Engagement (C04), being considered qualitative data in the analysis. Thus, the following deductive analyzes on criteria C03 and C04 were obtained:

- It was observed in the gamified approach that there was an understanding and awareness of the benefits caused by the performance and commitment of the Senior Management Representative in the approach with the team, since he was present, participating and accompanying the team in missions 1, 2, 3. This demonstrates the understanding of the benefits caused by their participation and commitment in the approach, being noticeable that their presence generated a greater commitment of the participant in the development of demands,
- Participants reported, in the Satisfaction Guide, that the participation of senior management was extremely important for the dynamics, as it was possible to see them working together with the team, which generated motivation for the group. This performance of the representative further highlighted to the team the importance of what they were developing for the organizational context.

The results show that the senior management representative was present, participating and accompanying the team in the missions, which emphasized the commitment to support the team to achieve the expected results. This demonstrates the understanding of the benefits caused by their participation and commitment to the approach with the team. The team reported that the representative's involvement generated more motivation for the group. Therefore, the understanding, commitment and performance of the senior management representative in the missions evidences the application and the expected result of the 'Tutoria' element.

6.6 Analysis of the problem 'Little support from employees'

For the problem *Little Support from Employees*, 7 (seven) questions were elaborated to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, 6 (six) of 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the '**Narrative**' element, only 1 (one) question (*Q31 - Did employees understand the importance and benefits of the SPI context, in which commitment to the role they assume within the explained gamified approach is essential?*) was analyzed, considering the analysis of **Engagement (C04)** and **Understanding (C06)** criteria in qualitative data to obtain the results. Thus, the following deductive analyzes on criteria C04 and C06 were obtained:

- It was observed that in missions 1, 2, 3 and 4 the participants developed the necessary activities to achieve the expected results in the desired process improvement, the development of these activities demonstrates that there was an understanding of the importance and commitment to fulfilling the necessary demands in the SPI context.

The analysis performed on the results of the 'Narrative' element demonstrates that the participants developed the necessary activities to achieve the expected results in the context of the desired process improvement, which demonstrates the understanding regarding the importance of their participation and commitment in the gamified approach of heroes, which required a collective effort to fulfill the demands established in the approach. Therefore, the context of the approach contributed to the understanding of the relevance of each one's performance and the commitment to the implementation of the improvement for the participants, this evidences application and expected result by the 'Narrative' element.

In the application of the '**Tutoria**' element, 3 (three) questions were analyzed (*Q32 - Did the employees understand, in the guidelines passed on, the importance of commitment to the role they assume within the gamified approach to achieve improvement?, Q33 - The employees committed to performing and fulfill the responsibility regarding the commitment to the role played? and Q34 - Were the employees satisfied with the instructions given?*). In these questions, we sought to analyze the criteria of **Performance (C01)**, **Satisfaction (C02)**, **Engagement (C04)**, **Participation (C05)** and **Understanding (C06)** considering quantitative and qualitative data in the analysis. Thus, the following deductive analyzes on criteria C01, C02, C04, C05 and C06 were obtained:

- It was observed in Mission 4 that the participants understood and managed to develop the activities structured in this mission with the expected commitment, as they did not fail to participate in the delivery of demands, which demonstrates the understanding of the role that each one had to play to achieve the results of improvement,
- The realization of deliveries presupposes that there was an understanding of the responsibilities and commitment to the role played, since the demands in Mission 4 were fulfilled with the expected and necessary commitment in the context of SPI: the participants (H01, H02, H03, H04, H05 , H06 and H07) scored, respectively, 210, 150, 210, 210, 190, 160 and 160 points (Total points per Operation),
- In the results obtained in Mission 3, only the participant H06 did not score in this measure, the others developed and positively signaled the training actions, obtaining a score of +30 points for this activity,
- Participants provided positive feedback to the moments of guidance and training, this was evidenced by the use of the Satisfaction Roadmap, where some reported that training is essential for understanding the improvement, and consequently, motivating support in the context of the improvement implementation.

The results show the understanding of the guidelines provided to the participants in relation to responsibility and the importance of acting in the development of activities, as they did not fail to deliver the demands, acting consciously to fulfill the established activities. It is noteworthy that the participants provided positive feedback to the responsibility guidelines. Therefore, the application and the expected result of the 'Tutoria' element are evidenced in the guidelines, understanding of the responsibilities and performance of those involved in the approach.

Regarding the application of the '**Free Lunch**' element, 2 (two) questions were analyzed (*Q35 - Did the gamified approach engage employees in the commitment and fulfillment of activities in the context studied? and Q36 - Were the employees satisfied with the gamified approach used?*). In these questions, we sought to analyze the criteria of **Performance (C01)**, **Satisfaction (C02)** and **Engagement (C04)**, considering quantitative and qualitative data to obtain the results.

The deductive analyzes evidenced in the questions Q07 and Q08 are based on data for the questioning Q35 and Q36, since in these questions the engagement and satisfaction of the participants to fulfill the activities are investigated, in order to acquire rewards in the context of the dynamics.

The analyzes carried out on the results of the 'Free Lunch' element show that the participants complied with the demands of the improvement model, developing the necessary activities, in order to have the recognition and / or reward provided by the gamified approach, and also provided feedback positive for this strategy. The participants' search for recognition and / or reward based on the fulfillment of activities evidences the application and expected result of the 'Free Lunch' element.

In the application of the '**Achievement Symbols**' element, only 1 (one) question (*Q37 - Did the employees recognize the quality of work and commitment of their colleagues during the performance of the activities?*) was analyzed, considering the analysis of the criterion of **Positive involvement (C07)** in quantitative and qualitative data to obtain the results. Thus, the following deductive analysis was obtained on criterion C07:

- At the end of Mission 4, the participants recognized the work developed by their colleagues and were also recognized for the work carried out, this recognition is evidenced in the Recognition Cards delivered, which portray symbols that are conquered by the recognition of the work, all participants received cards, however, the participant who received the most was H04 with a total of 5 cards and those who received the least amount were participants H02 and H06 with only 1 card,
- It was observed that in the application of the dynamics, the delivery of the achievement symbols considering recognition of the work, generated positive involvement among the participants, as they provided feedback regarding the quality of the work developed by their colleagues, strengthening the appreciation and consequently the engagement in the work performed by the team.

The analysis performed on the results in the element shows that there was recognition of the work developed among the team members, symbolized in the delivery of recognition cards with positive feedback related to the quality of the work performed by these members. The attribution of the recognition card for the work developed shows application and expected result by the 'Achievement Symbols' element.

6.7 Analysis of the problem 'Employee turnover'

For the problem *Employee Turnover*, 6 (six) questions were elaborated to be answered, according to the application of the gamification elements mapped to deal with this problem. In this problem, 6 (six) of 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the '**Tutoria**' element, 3 (three) questions were analyzed (*Q38 - Did the employees understand the importance of the training carried out for the im-*

provement of technical knowledge that consequently favor the achievement of the expected results in the SPI implementations?, Q39 - The employees are committed and were able to perform the necessary activities during the SPI implementation? and Q40 - Were the employees satisfied with the training opportunities provided?). In these questions, we sought to analyze the criteria of **Satisfaction (C02)**, **Engagement (C04)**, **Participation (C05)** and **Understanding (C06)** considering quantitative and qualitative data in the analysis.

The deductive analyzes evidenced in the questions Q32, Q33 and Q34 are based as data for the questioning Q38, Q39 and Q40, since in these questions they are asked about the understanding of the importance of the training provided, as well as the engagement and satisfaction of the participants in carrying out the activities present in the context of the dynamics, in this case fundamental to avoid the rotation of the people involved in the implementation.

The results show that the participants were able to understand the guidelines provided and the importance of participating in the training actions, since they were present and gave positive feedback on these actions. The knowledge provided motivated the participation and commitment in the development of activities, as they did not fail to make the necessary deliveries, remaining until the end of the application of the approach. The participants' performance evidences the application and the expected result of the 'Tutoria' element, since the knowledge obtained, in the moments of orientation, was applied by the participants in the development of the demands for established improvements.

Regarding the application of the '**Free Lunch**' element, only 1 (one) question was analyzed (*Q41 - Did the gamified approach engage employees to maintain commitment and performance in the necessary activities during the implementation of SPI?*). In this questioning, we sought to analyze the criteria of **Performance (C01)** and **Engagement (C04)**, considering quantitative data to obtain the results. Thus, the following deductive analysis on criteria C01 and C04 was obtained:

- The scores obtained, in Mission 4, by the participants (H01, H02, H03, H04, H05, H06 and H07), respectively 220, 150, 240, 220, 205, 170 and 215 points (Total Hero points), shows that the participants remained engaged in fulfilling what was expected in the activities present in Mission 4, since they were able to perform the activities, as they did not fail to carry out the demands belonging to the backlog of activities necessary to achieve the results in the context of improvement and consequently obtain recognition and reward for the work developed.

The analyzes carried out on the application of the 'Free Lunch' element show that the participants complied with the demands of the improvement model, developing the necessary activities with commitment, as they did not fail to carry out the demands present in the activities backlog, aiming for recognition and / or reward provided by the gamified approach, remaining until the end of the application of the SPI dynamics and still giving positive feedback to this strategy. The participants' search for recognition and / or reward resulting from the fulfillment of activities evidences the application and expected result of the 'Free Lunch' element.

As for the application of the '**Rockstar Effect**' element, only 1 (one) question (*Q42 - Did the employees recognize the commitment and performance of the activities of their colleagues while carrying out the activities?*) was analyzed, considering the analysis of the criterion of **Positive Involvement (C07)** on quantitative and qualitative data to obtain the results.

The deductive analyzes evidenced in the question Q09 are based on data for the questioning Q42, since in these questions the commitment to recognize the work performed among the team members is investigated.

In the analysis carried out on the results of the 'Rockstar Effect' element, they show that there was recognition of the work developed among the participants, symbolized in the delivery of Cards with positive feedback in relation to the work performed, the initial explanation of this strategy motivated the realization of demands and contributed to the permanence of the participants until the end of the application of the SPI dynamics. The recognition generated evidences application and expected result by the element 'Rockstar Effect'.

In the application of the '**List of rewards / lottery**' element, only 1 (one) question (*Q43 - Were the employees satisfied with the gamified approach used?*) was analyzed, considering the analysis of the **Satisfaction (C02)** criterion in qualitative data. Thus, the following deductive analysis was obtained on the C02 criterion:

- According to information obtained in the SWOT analysis, participants reported being satisfied with the dynamic proposal of recognition and rewards for the work developed by employees. Participants also showed that the use of gamification in the context of heroes in the SPI scenario stimulates people's participation.

The results show that the participants reported being satisfied with the rewards strategy provided by the gamified approach, since this strategy motivated the fulfillment of demands and contributed to the permanence of the participants until the end of the application of the SPI dynamics, which evidences the application and result expected by the 'List of rewards / lottery' element.

6.8 Analysis of the problem 'Lack of / Little qualified human resources'

For the problem *Lack of / Little Qualified Human Resources*, 4 (four) questions were created to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, 6 (six) of 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the '**Tutoria**' element, 2 (two) questions were analyzed (*Q44 - Did the employees understand the guidelines given to qualify the knowledge necessary for the SPI context? and Q45 - The employees were satisfied with the guidelines provided during the qualification moments regarding the knowledge needed in the context of SPI?*). In these questions, we sought to analyze the criteria of **Satisfaction (C02)**, **Participation (C05)** and **Understanding (C06)** considering quantitative and qualitative data in the analysis.

The deductive analyzes evidenced in the questions Q05 and Q06 are based as data for the questions Q44 and Q45, since they show the understanding and satisfaction of the guidelines present in the Action Track, aimed at the qualification of those involved in the implementation.

The results show that the participants were able to understand the guidelines and the importance of participating in the training actions, since they were present and gave positive feedback on these actions. In these actions, the necessary knowledge was provided to develop the activities to achieve the results of the improvement. The participants' performance evidences the application and the expected result of the 'Tutoria' element, since the knowledge obtained, in the moments of orientation, was applied by the participants in the development of the demands for established improvements.

For the application of the ' **Progress Bars** ' element, only 1 (one) question was analyzed (*Q46 - Did the guidelines provided help in the correct performance of activities in the context of SPI? If not, why?*) with the analysis of the **Performance (C01)** and **Awareness (C03)** criteria in quantitative data.

The deductive analyzes evidenced in Q15 are based on data for the questioning C46, which deal with whether the guidelines and training helped in carrying out the activities necessary to implement the improvement.

The results of the analysis of this element show that the participants were able to follow the progress of the level of knowledge acquired in the training, because in the practical moments, the participants were measured and provided feedback on the application of the acquired knowledge, from the fulfillment of the activities established in the dynamics of gamification. This strategy of measuring and providing performance monitoring evidences the application and the expected result of the 'Progress Bars' element.

As for the application of the '**Glowing choice**' element, only 1 (one) question (*Q47 - Did the gamified approach instigate help among employees to develop activities in the context of SPI in situations of doubts and lack of knowledge?*) was analyzed, considering the analysis of the **Performance (C01)**, **Participation (C05)** and **Positive Involvement (C07)** criteria in quantitative and qualitative data to obtain the results.

The deductive analyzes evidenced in the questions Q10 and Q11 are based on data for the questioning Q47, since they deal with situations in which the participant finds it difficult to understand or perform the activities assigned to them in the dynamics in relation to the model.

The results of this element show that participants who requested help from another participant were able to work together and fulfill their demands, providing satisfactory feedback on the help provided. The strategy provided those involved with a resource to continue performing what was necessary to achieve the expected goals in times of difficulties due to the lack of necessary knowledge in software engineering, which shows the application and expected result of the 'Glowing choice' element.

6.9 Analysis of the problem 'Focus on certification instead of focusing on improvement'

For the problem Focus on *Certification instead of Focus on Improvement*, 3 (three) questions were elaborated to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, 4 (four) of 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the '**Narrative**' element, only 1 (one) question (*Q48 - Did the employees understand the benefits resulting from an SPI implementation for the development of their demands in the organizational routine, acting with commitment in the delivery of their activities?*) was analyzed, considering the analysis of **Engagement (C04)** and **Understanding (C06)** criteria in qualitative data to obtain the results. Thus, the following deductive analysis on criteria C04 and C06 was obtained:

- It was observed during the development of the missions that there was an understanding of the benefits and a commitment to fulfilling the necessary demands in the context of SPI, due to the participants having developed the necessary activities to achieve the expected results in the desired process improvement.

The analysis carried out on the results of the 'Narrative' element shows that the participants developed the activities necessary to achieve the expected results in the context of the desired process improvement, so the realization of the demands for improvement demonstrates that there was an understanding of the benefits and the importance of adopting the model. It is noteworthy that the development of demands was provided by guidelines and moments of incentives provided in the scenario of the SPI dynamics, which shows application and expected result by the 'Narrative' element.

For the element '**Build from scratch**' 2 (two) questions (*Q49 - Did the gamified approach promote the joint participation of employees in proposing suggestions for activities and points for improvement to be used in the context of SPI? and Q50 - In the gamified approach were obtained /suggestions collected from employees to help the context of SPI?*) were analyzed, and in these we sought to analyze the criteria of **Performance (C01)** and **Participation (C05)** considering both quantitative and qualitative data to obtain the result. Thus, the following deductive analyzes on criteria C01 and C05 were obtained:

- It was observed in the development of the dynamics that the participants gave suggestions in relation to new procedures and points of improvement that could be incorporated in the organizational context of the laboratory to achieve the improvement,
- During the development of the missions, the participants were able to suggest possible strategies to improve the adopted procedures and achieve the expected results in the implementation of the improvement: in Mission 1 all participants provided suggestions, therefore, they scored in the mission, in Mission 2 only the participant H02 did not score, as he did not provide a suggestion, in Mission 3 there were no suggestions, as it is a mission focused on team training with guidance from the Sen-

ior Management representative who has more than 20 years of experience in software process improvement, providing training and consulting, and in Mission 4 there were few suggestions, which can be justified by a more practical and interactive round in its development.

The results of this element show that the participants were able to work together, collaborating in the establishment of the activities that were adopted in the dynamics. Participation in the structuring process evidences the application and expected result of the 'Build from scratch' element of involving them in the development stage to clarify the benefits and increase ownership in the process, in order to facilitate the implementation of the improvement.

6.10 Analysis of the problem 'Lack of government incentive'

In the application of the '**Elitism**' element to the problem Lack of Governmental Incentive only 1 (one) question was analyzed (*Q51 - Did the gamified approach promote visibility and contribute with external incentives to the organization's context?*) with the analysis considering only 2 (two) of 7 (seven) evaluation criteria, **Engagement (C04)** and **Positive Involvement (C07)**, in qualitative data. Thus, the following deductive analysis on criteria C04 and C07 was obtained:

- Participants created marketing strategies to disseminate information about the work developed by the group, this dissemination promoted a positive interaction with external people, who showed interest in what is developed by the laboratory group, with likes, views, comments and interest in participating in the laboratory. group.

The results of applying this element show that the participants contributed to the development of strategies within the organizational context to help promote the visibility, which is expected by the application of the 'Elitism' element. Thus, the dissemination structured by the group favored a positive interaction with external people, attracting the interest of people to participate or contribute to the work developed by the group.

6.11 Analysis of the problem 'Lack of knowledge of the importance of models by the market'

The problem *Lack of Knowledge of the Importance of Models by the Market* analyzed, as well as the questioning Q51 factors directed to external perspectives of the work developed in the organizational context, thus, there was only the application of the 'Elitism' element in the questioning (*Q52 - Did the gamified approach promote visibility and contribute with external incentives to the organization's context?*) with the analysis considering only 2 (two) of 7 (seven) evaluation criteria, **Engagement (C04)** and **Positive involvement (C07)**, in qualitative data. Thus, the following deductive analysis on criteria C04 and C07 was obtained:

- Participants created strategies to publicize the work developed in line with the improvement model, which allowed for the recognition of the work developed by the group by people outside the laboratory. Another factor that led to recognition was the amount of work developed and disseminated by the group, and even the form of work followed by the group's members in the laboratory.

The results of this element show that the participants created strategies to disseminate the work developed, adhering to the improvement model, to promote visibility, a factor that is expected in the application of the 'Elitism' element. The dissemination strategies created contributed to the recognition and interest of external people in relation to what is developed in the group's work routine.

6.12 Analysis of the problem 'Reduction in consulting hours as a way to reduce costs'

The problem *Reduction in Consulting Hours as a Way of Reducing Costs* analyzed only the application of the '**Narrative**' element in a questioning (*Q53 - Organization's stakeholders understood the importance of carrying out the objectives or practices present in the improvement model, acting in a way that meet and develop what is expected to achieve the results in the model?*) with the analysis considering only 2 (two) of 7 (seven) evaluation criteria, **Awareness (C03)** and **Understanding (C06)**, in qualitative data. Thus, the following deductive analysis on criteria C03 and C06 was obtained:

- It was observed during the development of the missions that there was an understanding of the importance of implementing the improvement practices, since the participants were aware of acting in a committed way in fulfilling the necessary demands in the context of SPI, evidenced in the development and delivery of the activities necessary to achieve the expected results in the desired process improvement.

The results of this element show that the participants developed the necessary activities to achieve the expected results in the desired process improvement, the development of these activities demonstrates the understanding of the importance of implementing and that there was a commitment to fulfill the demands present in the gamified approach. It is noteworthy that the development of demands was provided by guidelines and moments of incentives provided in the scenario of the SPI dynamics, which shows application and expected result by the 'Narrative' element.

6.13 Analysis of the problem 'Lack of / Few projects to validate an improvement program'

The problem *Lack of / Few Projects to Validate an Improvement Program* analyzed only the application of the '**Tutoria**' element in a questioning (*Q54 - The collaborators understood the importance and the need to develop and structure consistent projects / services to contribute to the implementation of SPI?*) with the analysis considering only 2 (two) of 7 (seven) evaluation criteria, **Awareness (C03)** and **Understanding (C06)**, in qualitative data. Thus, the following deductive analysis on criteria C03 and C06 was obtained:

- It was observed during the development of the missions that there was an understanding of the importance of structuring and implementing projects / services in order to contribute to the improvement practices, as the participants acted consciously and committed to fulfilling the necessary demands in the context of SPI, evidenced in the development and delivery of the activities necessary to achieve the expected results in the desired process improvement.

The results of this element show that the participants understood the guidelines and the importance of establishing necessary demands to achieve the expected results in the desired process improvement. The participants' performance in the SPI approach evidences the application and the expected result of the 'Tutoria' element, since the knowledge obtained, in the moments of orientation, was applied by the participants in the development of the demands for established improvements.

6.14 Analysis of the problem 'Bureaucracy in improvement programs'

For the problem of *Bureaucracy in Improvement Programs*, 4 (four) questions were elaborated to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, 4 (four) of 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the '**Narrative**' element, only 1 (one) question (*Q55 - Did the employees understand the relevance of implementing the improvement and the need to adopt the necessary measures in the context of the model to be implemented?*) was analyzed, considering the analysis of the **Understanding (C06)** criterion in qualitative data to obtain the results.

The deductive analyzes evidenced in the question Q53 are based on data for the questioning Q55, since they deal with situations related to the understanding of those involved regarding the understanding of the need to implement the necessary practices in relation to the improvement model.

The analysis carried out on the results of the 'Narrative' element demonstrates that the participants developed the necessary activities to achieve the expected results in the context of the improvement, this demonstrates that there was an understanding of the benefits and importance of adopting the model. It is noteworthy that the motivation for the development of demands was provided by guidelines and moments of incentives and clarifications provided in the scenario of the SPI dynamics, which shows the application and expected result of the 'Narrative' element.

For the '**Build from scratch**' element, a questioning (*Q56 - Did the gamified approach provide a collaborative environment, in which employees could contribute by providing strategies to help achieve the expected results in the context of improvement?*) was analyzed, in which we sought to to analyze the **Performance (C01)** and **Participation (C05)** criteria, considering the quantitative data to obtain the result. Thus, the following deductive analysis on criteria C01 and C05 was obtained:

- The performance worksheet shows that during the development of the missions, the participants were able to suggest possible strategies to structure and contribute to the achievement of the expected results in the implementation of the improvement: in Mission 1 all participants provided suggestions, therefore, they scored in the mission, in Mission 2 only the participant H02 did not score, as he did not provide a suggestion, in Mission 3 there were no suggestions, as it is a mission focused on team training with guidance from the Senior Management representative who has more than 20 years of experience in software process improvement, providing training and consulting, and in Mission 4 there were few suggestions, which can be justified by a more practical and interactive round in its development.

The results of this element show that the participants were able to work collaboratively in establishing the activities that were adopted in the dynamics. Participation in the structuring process evidences the application and expected result of the 'Build from scratch' element of involving them in the development stage to clarify the benefits and increase ownership in the process, providing an environment of contribution and not obligations, in the to facilitate the implementation of the improvement.

In the application of the '**Tutoria**' element, only 1 (one) question was analyzed (*Q57 - Did the employees understand, in the guidelines passed on, the need and importance of adopting and aligning the organization's activities to the context of the improvement program?*). In this questioning, we sought to analyze the criteria of **Engagement (C04)** and **Understanding (C06)** being considered qualitative data in the analysis. Thus, the following deductive analysis on criteria C04 and C06 was obtained:

- It was observed during the development of the missions that there was an understanding of the importance of structuring procedures and practices in the context of improvement, as the participants were committed to fulfilling the demands necessary for the SPI context, evidenced in the development and delivery of the activities necessary for achieve the expected results in the desired process improvement.

The results show that the participants were able to understand the guidelines related to the needs to implement the improvements and the importance of being committed to the development of activities, as they did not fail to deliver the demands, acting consciously to fulfill what was established in the backlog. of activities. Therefore, the application and the expected result of the 'Tutoria' element are evidenced in the guidelines, understanding of needs and in the performance obtained by those involved in the approach.

In the '**Mystery boxes**' element, only 1 (one) question was analyzed (*Q58 - Did the dynamics of recognition and rewards resulting from the performance and delivery of activities promote the performance and participation of the employee in the implementation of the improvement?*), in which we sought to analyze the **Performance (C01)** and **Participation (C05)** criteria, considering the quantitative data to obtain the result. Thus, the following deductive analysis on criteria C01 and C05 was obtained:

- The scores obtained in Mission 4, in which the moments of recognition and rewards occurred by the participants (H01, H02, H03, H04, H05, H06 and H07), respectively

220, 150, 240, 220, 205, 170 and 215 points (Total Hero points), shows that the participants remained engaged in fulfilling what was expected in the activities present in Mission 4, since they were able to perform their activities, carrying out the demands belonging to the backlog of activities necessary to achieve the results in the context of improvement and consequently have the possibility of being recognized and rewarded for the work carried out.

The results of this element show that moments of recognition and / or rewards were provided to the participants for the work developed, this strategy contributed to the fulfillment of the demands of the improvement model, as the participants did not fail to carry out the deliveries present in the activities backlog, aiming for the recognition and / or reward provided by the gamified approach. Therefore, the participants' search for recognition and/or reward resulting from the fulfillment of activities evidences the application and expected result of the 'Mystery Boxes' element.

6.15 Analysis of the problem 'Continuity of team engagement in the defined process'

For the *Continuity of Team Engagement in the Defined Process* problem, 3 (three) questions were created to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, 5 (five) of 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the ' **Tutoria** ' element, 2 (two) questions were analyzed (*Q59 - Did the training dynamics and guidance provided to employees contribute to the understanding and engagement of employees in the development and achievement of expected results in the context of SPI? and Q60 - Do employees satisfied with the instructions given?*). In these questions, we sought to analyze the criteria of **Satisfaction (C02)**, **Engagement (C04)**, **Participation (C05)** and **Understanding (C06)** considering quantitative and qualitative data in the analysis.

The deductive analyzes evidenced in the questions Q05 and Q06 are based as data for the questions Q59 and Q60, since they show the understanding and satisfaction of the guidelines present in the Action Track, aimed at the qualification of those involved and continuity in the work developed in the implementation.

The results show that the participants were able to understand the guidelines related to maintaining responsibility, participation and commitment in the development of activities, as they did not fail to deliver the demands, acting consciously to fulfill what was established in the activities backlog. It is noteworthy that the participants provided positive feedback to the guidelines of responsibilities which must be integrated in order to maintain the improvements in the organizational context. Therefore, the application and the expected result of the 'Tutoria' element are evidenced in the guidelines, understanding of the responsibilities and performance of those involved in the approach.

For the application of the '**Appointments dynamics**' element, only 1 (one) question was analyzed (*Q61 - Provide performance feedback to employees, did it contribute to the realization and adjustments of improvements in the activities performed by those* *involved?*) with the analysis of the **Performance (C01)** and **Participation (C05)** criteria in quantitative data. Thus, the following deductive analysis on criteria C01 and C05 was obtained:

- Participants were able to monitor their performance in the rounds, in the Performance Worksheet, some managed to increase their score, others reduced it: in Mission 1 participants managed to obtain values in the range of 95 to 100 points, in Mission 2 the participants managed to obtain values in the range of 81 to 97 points, in Mission 3 they reached 90 points, in Mission 4 they managed to obtain values in the range of 150 to 220 points. However, it is noticeable that most of the participants became aware of improving their performance in the activities and consequently helping the team to fulfill and continue the improvement strategies.

In the analysis results for the 'Appointments dynamics' element, it is noticeable that when showing the score to the participants, those with lower scores had a stimulus to improve the performance obtained in the missions, since most became aware and performed the activities to help the team, fulfilling the necessary deliveries. Therefore, the strategy of providing performance information can contribute to the engagement of participants in maintaining or improving their performance in the activities, which highlights the application and expected result of the 'Appointments dynamics' element.

6.16 Analysis of the problem 'Lack of / Little knowledge of models by employees'

For the problem *Lack of / Little Knowledge of Models by Employees*, 4 (four) questions were elaborated to be answered, according to the application of the gamification elements mapped to address this problem. In this problem, the 7 (seven) evaluation criteria defined in the context of dynamics were used in the analysis.

In the application of the '**Narrative**' element, a questioning was used (*Q62 - Did the employees understand the importance of knowing the practices present in the improvement model, in order to develop what is expected to achieve the results in the model?*) with the analysis considering the evaluation criteria for **Awareness (C03)**, **Engagement (C04)** and **Understanding (C06)** in qualitative data.

The deductive analyzes evidenced in the question Q53 are based on data for the questioning Q62, since they deal with situations related to the understanding of those involved regarding the understanding of the need and importance of implementing the necessary practices in relation to the improvement model.

The results of this element show that the participants developed the necessary activities to achieve the expected results in the desired process improvement, so the realization of the improvement demands demonstrates that there was an understanding of the benefits and the importance of adopting the quality model. It is noteworthy that the development of demands was provided by guidelines and moments of incentives provided in the scenario of the SPI dynamics, which shows application and expected result by the element 'Narrative'.

In the application of the '**Tutoria**' element, 2 (two) questions were analyzed (*Q63 - Did the employees understand the guidelines regarding the improvement model used in the context of SPI? and Q64 - Were the employees satisfied with the instructions* *given?*). In these questions, we sought to analyze the criteria of **Satisfaction (C02)**, **Participation (C05)** and **Understanding (C06)**, considering quantitative and qualitative data in the analysis.

The deductive analyzes evidenced in the questions Q05 and Q06 are based as data for the questions Q63 and Q64, since they show the understanding and satisfaction of the guidelines present in the Action Track, related to the improvement model used in the implementation.

The results show that the participants were able to understand the guidelines and the importance of participating in the training actions, since they were present and gave positive feedback on these actions. In these actions, the necessary knowledge was provided to develop the activities to achieve the results of the implementation of the improvement model. The participants' performance evidences the application and the expected result of the 'Tutoria' element, since the knowledge obtained, in the moments of orientation, was applied by the participants in the development of the demands for established improvements.

Regarding the application of the '**Glowing choice**' element, a questioning was analyzed (*Q65 - Did the gamified approach instigate help among employees in the development of activities in the context of SPI in situations of doubts and lack of knowledge regarding the improvement model adopted?*), considering the analysis of the criteria of **Performance (C01)**, **Participation (C05)** and **Positive involvement (C07)** in qualitative data to obtain the results.

The deductive analyzes evidenced in the questions Q10 and Q11 are based on data for the questioning Q65, since they deal with situations in which the participant finds it difficult to understand or perform the activities related to the improvement model used.

The results of this element show that the participants worked together fulfilling their demands, and provided satisfactory feedback on the help provided. The strategy provided those involved with a resource to continue performing what was necessary to achieve the expected objectives in times of difficulties due to the lack of knowledge necessary to implement the improvement model, which shows the application and expected result of the ‘Glowing choice’ element.

6.17 Analysis of the problem 'Different interpretations in relation to the models'

For the problem *Different Interpretations in Relation to the Models*, 3 (three) questions were elaborated to be answered, according to the application of the mapped gamification elements, and only 3 (three) of 7 (seven) evaluation criteria defined for the dynamics context were used.

In the application of the '**Narrative**' element, a questioning was used (*Q66 - Did the dynamics used in the approach provide necessary information to employees to understand the practices present in the improvement model?*) with the analysis only of the **Understanding (C06)** evaluation criterion in data qualitative. Thus, the following deductive analysis was obtained on criterion C06:

- It was observed during the development of the missions that the participants were able to develop the necessary activities to achieve the expected results in the desired process improvement. Therefore, the development of these activities demonstrates that the strategies present in the dynamics made it possible to understand, develop and fulfill the demands necessary for the SPI context.

The results of this element show that there was an understanding of the benefits and importance of adopting the quality model by the participants, as they developed the necessary activities to achieve the expected results in the desired process improvement. This positioning was provided by guidelines, clarifications and moments of incentives provided in the scenario of the SPI dynamics contributed to the development of demands, which evidences the application and expected result of the 'Narrative' element.

In the application of the '**Tutoria**' element, 2 (two) questions were analyzed (*Q67 - Did the employees understand the guidelines regarding the improvement model used in the context of SPI? and Q68 - Were the employees satisfied with the instructions given?*). In these questions, we sought to analyze the criteria of **Satisfaction (C02)**, **Participation (C05)** and **Understanding (C06)**, considering quantitative and qualitative data in the analysis.

The deductive analyzes evidenced in the questions Q05 and Q06 are based as data for the questions Q67 and Q68, since they show the understanding and satisfaction of the guidelines present in the Action Track, related to the improvement model used in the implementation .

The results show that the participants were able to understand the guidelines and the importance of participating in the training actions, since they were present and gave positive feedback on these actions. In these actions, the necessary knowledge was provided to develop the activities to achieve the results of the implementation of the improvement model, thus providing what was expected by the 'Tutoria' element, since the knowledge obtained in the moments of orientation, was efficiently applied by the participants in the development of demands.

6.18 Analysis of the problem 'Lack of consistent project portfolio planning'

For the problem *Lack of Consistent Project Portfolio Planning*, only 1 (one) question (*Q69 - Did the collaborators understand the importance and need to develop and structure consistent projects / services that can contribute to the context of improvement implementations?*) of the application of the '**Tutoria**' element was analyzed, considering only the evaluation criteria of **Awareness (C03)** and **Understanding (C06)** in quantitative and qualitative data.

The deductive analyzes evidenced in question Q54 are based on data for the questioning Q69, since they deal with situations related to understanding the importance of structuring and implementing projects/services in order to contribute to improvement practices.

The results show that the participants were able to understand the guidelines related to maintaining responsibility, participation and commitment to structuring and fulfilling the necessary activities in the context of SPI, as they did not fail to deliver the demands, acting consciously to fulfill what was established in the activity backlog. Therefore, the application and the expected result of the 'Tutoria' element are evidenced in the guidelines, understanding of the responsibilities and performance of those involved in the approach.

6.19 Analysis of the problem 'Lack of consistent planning by the top management of the organization'

For the problem Lack of *Consistent Planning by the Top Management of the Organization*, 2 (two) questions were elaborated to be answered, and 4 (four) of 7 (seven) evaluation criteria defined in the context of the dynamics were used in the analysis.

For the '**Build from scratch**' element, a questioning (*Q70 - Did the gamified approach promote the provision of suggestions by top management to employees regarding the necessary measures in the context of the model to be implemented?*) to analyze the **Performance (C01)** and **Participation (C05)** criteria, considering the quantitative data to obtain the result. Thus, the following deductive analysis on criteria C01 and C05 was obtained:

- During the development of the missions, the participants were able to point out possible changes to improve the procedures adopted throughout the dynamics, the Senior Management Representative also provided suggestions, however, he acted more in directing the discussions regarding the suggestions provided by those involved, acting as a moderator of the suggestions: in Mission 1 all the participants provided suggestions, therefore, they scored in the mission, in Mission 2 only the participant H02 did not score, as he did not provide a suggestion, in Mission 3 there were no suggestions, as it is a mission focused on team training with guidance from the Senior Management representative who has more than 20 years of experience in software process improvement, providing training and consulting, and in Mission 4 there were few suggestions, which can be justified by a more practical and interactive round in its development.

The results of this element show that the participants were able to work collaboratively with suggestions to improve the procedures adopted throughout the dynamic, the senior management representative also provided suggestions, however he acted more in directing the discussions regarding the suggestions provided. Participation in the structuring process evidences the application and expected result of the 'Build from scratch' element of involving them in the development stage to clarify the benefits and increase ownership in the process, and provide an environment of contribution and not obligations, in order to facilitate the implementation of the improvement.

In the application of the '**Tutoria**' element, only 1 (one) question was analyzed (*Q71 - Did employees and senior management representatives understand the importance and need to plan necessary and consistent measures considering the context of improvements in the implementation of SPI?*). In this questioning, we sought to analyze the criteria of **Awareness (C03)** and **Understanding (C06)** considering quantitative and qualitative data in the analysis. Thus, the following deductive analysis on criteria C03 and C06 was obtained:

- It was observed that the senior management representative was present, participating and accompanying the team in missions 1, 2, 3. This demonstrates the understanding of the importance of their participation and commitment in the approach with the team, being noticeable that their presence generated a commitment greater of the participant in the demands. The other participants developed the necessary activities in missions 2 and 4 to achieve the improvement results, which demonstrates the understanding of the guidelines related to the improvement context, as well as the understanding of the importance of commitment and fulfillment of the necessary demands to be performed.

The results show that the senior management representative was present, participating and accompanying the team, this demonstrates the understanding of the importance of his participation and commitment to the approach with the team, being noticeable that his presence generated a greater commitment to the participants in the accomplishment of the demands. Therefore, the application and the expected result of the 'Tutoria' element are evidenced in the guidelines, understanding of needs and in the performance obtained by those involved in the approach.

6.20 Analysis of the problem 'Lack of model flexibility'

For the problem *Lack of Model Flexibility*, only 1 (one) question (*Q72 - Did the dynamics used in the approach provide the necessary information to employees to understand the practices present in the improvement model?*) was analyzed, considering the evaluation criteria of **Awareness (C03)** and **Understanding (C06)** for application of the 'Narrative' element in qualitative data. Thus, the following deductive analysis on criteria C03 and C06 was obtained:

The deductive analysis evidenced in the question Q66 is based as data for the questioning Q72, since they investigate whether the strategies proposed in the gamified dynamics allow the understanding and importance of implementing the necessary activities to achieve the expected results in the improvement desired process.

The results of this element show that the participants developed the necessary activities to achieve the expected results in the desired process improvement. The realization of the improvement demands demonstrates that there was an understanding of the practices present in the improvement model, which were necessary to implement the improvement. The participants' awareness was a consequence of the guidelines, clarifications and moments of incentives provided in the scenario of the SPI dynamics, which shows the application and expected result of the 'Narrative' element.

7 Discussion

The results obtained in Section 6, in which there was a detailed analysis of the application of the element to the problem, contributed to justify whether the element or group of elements that was used minimized or treated the SPI problem to which it was related.

Thus, the evidence collected from the gamified strategies applied to the problem of 'Resistance to cultural change' demonstrate that the participants were able to develop what was necessary to achieve the results, always engaged and participatory in the development of demands, with no resistance from the collaborators. in relation to the improvements required in the desired model for the context of the organization, which proves the understanding regarding the importance and benefits that the implementation of the model brings to the organizational routine.

The evidence collected from the gamified strategies applied to the problem of 'Lack of Knowledge in Software Engineering' demonstrate that the participants understood and applied the knowledge acquired in the moments dedicated to training, guidance and assistance, as they efficiently developed what was necessary for the achievement of improvement results.

As for the evidence collected from the application of gamified strategies to the problem of 'Lack of understanding of the stakeholder responsibilities', it proves that the participants were able to understand and perform the responsibilities that each one had to perform in relation to the necessary demands to achieve the results expected by the model.

For the problem 'Lack of a Support Tool', the evidence collected, from the gamified strategies applied, demonstrate that the participants contributed to the definition of tools to support the execution of the activities, as well as they understood the use of the tools, applying the knowledge obtained in the training, because efficiently developed what was needed to achieve the improvement results.

We can observe that in the application of gamified strategies to the problem of 'Lack of / little commitment from the Top Management', the top management representative was involved in the actions with the team, which contributed to the engagement and performance of the participants, as it made the stakeholders realized the importance of implementing what is expected by the improvement model.

As for the evidence collected from the gamified strategies applied to the problem of 'Little support from employees', it shows that the participants understood the importance of implementing the improvement and were aware of the responsibility that each one had to assume in the dynamics to develop what was established to achieve the SPI results.

In the problem of 'Employee turnover', we can observe that the application of gamified strategies contributed to the engagement and support of the participants, as it made those involved remain motivated throughout the implementation to perform what was expected by the improvement model.

In the problem of 'Lack of / little qualified human resources', the evidence collected from the gamified strategies applied demonstrate that the participants understood and applied the knowledge acquired in the moments dedicated to training, guidance and assistance, as they efficiently performed what was necessary to achieve it improvement results.

Regarding the problem 'Focus on certification instead of focusing on improvement', it was noticeable that in the application of gamified strategies, participants were able to understand the importance and benefits that improvement provides to the work environment, as they collaborated by sharing suggestions and discussing solutions to help team to achieve the results provided by the model.

The application of gamified strategies to the problem of 'Lack of Governmental Incentive' was noticeable that the participants were able to create dissemination strategies that made it possible to achieve the results expected by the improvement model, with the exposure of the work developed by the team, which provided interest and recognition to the external audience.

Thus, as in the previous problem, it was noticeable that the gamified strategies applied to the problem of 'Lack of Knowledge of the Importance of Models by the Market' motivated the participants to create dissemination strategies which made it possible to achieve the results expected by the model used, with the exposure and recognition of the work developed by the team to the external public, which demonstrates the importance of adopting improvement models to provide visibility and recognition in what is developed by the group.

As for the application of the gamified strategy to the problem of 'Reduction in consulting hours as a way to reduce costs', it was noticeable that it promoted the participants' understanding of the importance of implementing what the model proposes and the benefits that the improvement provides to the work environment, because they performed the activities necessary to achieve the results expected by the model.

The application of the gamified strategy to the problem of 'Lack of / few projects to validate an improvement program' provided the participants with guidance and incentive to structure and carry out the necessary demands in the context of improvement.

The gamified strategies applied to the problem of 'Bureaucracy in improvement programs' demonstrate that the participants understood and were aware of how important it is to implement the improvements, this was noticeable when they provided suggestions and contributed to the definitions of the activities that the team had to perform to achieve the result of improvement, that is, they acted in the structuring of the necessary demands, they were not submitted to work on a ready demand.

As the gamified strategies applied to the problem of 'Continuity of Team Engagement in the Defined Process' demonstrate that participants understood and were aware of how important it is to implement and maintain the results of improvement in the organizational environment, the use of feedback from activities was an incentive to further improve the work performed by each team member, making it possible to continue what has been established.

The gamified strategies applied to the problem of 'Lack of / little knowledge of the models by the collaborators' show that the participants understood the importance of implementing the model and applied the knowledge acquired in the moments of training, guidance and assistance to develop what was necessary for the achieve improvement results.

The gamified strategies applied to the problem of 'Different interpretations in relation to the models' provided the participants with an understanding of the model that was implemented, since they were able to apply the acquired knowledge to practical moments, thus being fundamental to achieving the improvement results.

As for the problem of 'Lack of consistent Project Portfolio planning', it was noticeable in the results that the application of the gamified strategy provided the participants with guidance and incentive to structure and carry out the demands for improvement in line with the organization's objectives and needs.

The application of gamified strategies to the problem of 'Lack of consistent planning by the organization's top management' promoted the participants' understanding and incentive to plan and establish activities that meet the demands for improvements as well as their organizational needs.

The application of the gamified strategy to the problem of 'Lack of flexibility of the models' favored the understanding of the participants of the information necessary to guide the implementation of the model, as the participants contributed to structuring and developing activities that met the demands for improvements as well as their needs. organizational. Therefore, they were not submitted to work on an already established demand, with strategies that were not suitable for the organization's scenario.

The results obtained in the application of the elements to the problems help to answer the main question of the study "Did the gamified approach help to solve the problems or difficulties in the implementation of SPI", in which it is concluded that the approach developed and applied to the 20 (twenty) problems that occur in the context of SPI contributed significantly to solving the problems, as those involved were able to perform the necessary activities to obtain the desired result, motivated and aware of the importance and benefits that the implementation of SPI promotes to the organization. Therefore, the problems were assisted by the gamification dynamics, which demonstrates that the use of the approach can help in solving problems or difficulties experienced in SPI implementations.

8 Threats to validity

According to Wöhlin et al. [42] it is necessary to identify threats to the validity of a study, as such threats can impact or limit the results of the feasibility study. Thus, in the next subsections, the threats addressed in this study will be presented.

8.1 Internal validity

Threats to internal validity are procedures, treatments or experimental experiences of participants that threaten the researcher's ability to draw correct inferences from data about the population in an experiment [43].

In the study, a threat to internal validity related to maturation was identified. Its existence occurs because the researcher cannot limit the search for external knowledge to those involved in the implementation of improvement. As a way of trying to reduce this influence, support materials were made available to participants in Google Classroom, an environment that made it possible to centralize and manage materials, to assist in the understanding and development of the demands necessary for the context of improvement. As well as the availability of the researcher to answer questions and assist any member of the Laboratory team outside the meeting hours.

8.2 External validity

Threats to external validity highlight external events that can hamper the analysis and generalizations of study results [43]. Thus, the execution of the study took place only in one scenario, in the Laboratory. The scenario is composed, among other aspects, by the size, the profile of the team, the capacity of the processes and its maturity in terms of continuous improvement of its organizational processes. Therefore, the sampling has low representation, given the many possibilities of application of the approach in different scenarios of software process improvement, which configures a restriction to the generalization of the results obtained.

Therefore, it is recommended that the results be generalized to the approximate number of participants present in the study, which, according to Rouiller [41], fits into the context of a small organization, commonly represented by 2 to 25 employees.

8.3 Construct validity

The construction validity, for Travassos, Gurov and Amaral [44] considers the relationships between theory and observation, that is, if the treatment reflects the cause well and the result reflects the effect well.

The problem present in this study regarding construction validity is related to the participant not having the effectiveness in learning provided in the dynamics to have the ability to develop the necessary demands to fulfill the activities to achieve the results of the process improvement, this can occur from of the excess or inadequacy of explanation in the context of the dynamics. To address this threat, moments of guidance, assistance and collaborative development of demands among participants were provided throughout the dynamic. As for the amount and form of transfer of information, they were reviewed and structured to be clearer and more objective to minimize doubts about the understanding of the participants.

8.4 Conclusion validity

Conclusion validity should consider which aspects may impair the analysis and interpretation of the collected inputs [42]. A threat present in the study is the relationship of the participants' heterogeneity regarding the level of knowledge needed throughout the dynamics, which could compromise the validity of the study. To minimize this threat, the Laboratory was chosen, in which the participants could be undergraduate and graduate students who work in the context of Software Engineering, but in the case of the Study, only graduate students were volunteers. In addition, if there were difficulties in relation to knowledge, a set of documents, guidelines and training were carried out in order to standardize information and the application of the approach.

9 Conclusion

This work presented the results obtained from an Experience Report in the application of a proposal for a solution to SPI problems from the use of gamification elements suitable for the treatment of recurring problems or difficulties in SPI implementations, in the context of teaching and learning. The results obtained in the study were analyzed using the Evaluation Framework for Gamification in Software Engineering, which provides a standard framework for the design of evaluation studies for gamification cases.

The results of this work can be considered significant, since the expected results with the application of the elements to the problems were favorable to treat or minimize the problems experienced in the context of SPI, since those involved were able to perform the necessary activities to obtain the desired result, motivated and aware of the importance and benefits that the implementation of SPI promotes to the organization. However, due to threats to validity, the results cannot be generalized to any situation.

As future work, we intend to replicate the experience report in another small organization in order to compare the results obtained in the applications. And, later, apply and analyze the results in medium or large organizations to validate the effectiveness of the dynamics in a scenario with more participants.

10 Bibliographical references

[1] Montoni, M. (2010). Uma investigação sobre os fatores críticos de sucesso em iniciativas de melhoria de processos de software. Tese de D.Sc., Universidade Federal do Rio de Janeiro-UFRJ, Rio de janeiro, Brasil. https://doi.org/10.5753/sbqs.2011.15393

[2] Schots, N. C. L., Santos, G., Cerdeiral, C., Cabral, M., Cabral, R., Schots, M., Nunes, E., & Rocha, A. R. (2011). Lições Aprendidas em Implementações de Melhoria de Processos em Organizações com Diferentes Características. In: VII Workshop Anual do MPS, WAMPS 2011, pp. 84-93, Campinas, Brasil.

[3] Associação Brasileira das Empresas De Software – ABES. (2020). Mercado Brasileiro de Software - Panorama e Tendências. Brazil.

[4] García, I., Pacheco, C., Mendoza, E., Calvo-Manzano, J. A., Cuevas, G., & San Feliu, T. (2012). Managing The Software Process With A Software Process Improvement Tool In A Small Enterprise. Journal Of Software: Evolution and Process; 481–491. https://doi.org/10.1002/smr.504

[5] Mendes, F. F., Nascimento, H. A. D., Fernandes, P. G., Nunes, R. S., & Mota, C. C. (2010). Implantação de Melhoria de Processos em um Setor de Produção de Software de uma Universidade Federal. In: IX Simpósio Brasileiro de Qualidade de Software. Belém - PA. Anais do IX Simpósio Brasileiro de Qualidade de Software, p. 359-365. https://doi.org/10.5753/sbqs.2010.15445

[6] Mathiassen, L., Ngwenyama, O. K., & Aaen, I. (2005). Managing change in software process improvement. IEEE Software, v. 22, n. 6, p. 84-91. ISSN ISSN: 0740-7459. https://doi.org/10.1109/MS.2005.159

[7] Bayona, S., Calvo-Manzano, J. A., & Feliu, T. S. (2012). Critical Success Factors in Software Process Improvement: A Systematic Review. 12th International Conference, SPICE 2012, Palma, Spain, May 29-31. https://doi.org/10.1007/978-3-642-30439-2_1

[8] Mendes, F. F., Oliveira, J. L., Fernandes, P. G., & Souza, A. S. (2007). Análise de Riscos na Implantação de Melhorias de Processos de Software. In: ProQualiti-Qualidade na Produção de Software, v. 3, nro. 3, pp. 25-32.
[9] Merriam, S. B. (2009). Qualitative Research: a Guide to Design and Implementation. San Francisco, CA: Jossey-Bass.
[10] Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does Gamification Work? – A Literature Review of Empirical Studies on Gamification. In proceedings of the 47th Hawaii International Conference on System Sciences, Hawaii, USA, January 6-9. https://doi.org/10.1109/HICSS.2014.377
[11] Cook, W. (2012). Five Reasons Why You Can't Ignore GAMIFICATION. MWorld, v. 11, n.3, p. 42-44, Fall2012. ISSN 15402991.
[12] Iacono, S., Vallarino, M., & Vercelli, G. V. (2020). Gamification in Corporate Training to Enhance Engagement: An Approach. International Journal of Emerging Technologies in Learning (iJET), 15(17), pp. 69–84. https://doi.org/10.3991/ijet.v15i17.14207
[13] Werbach, K. & Hunter, D. (2012). For the win: how game thinking can revolutionize your business. Philadelphia: Wharton Digital Press.
[14] Liu, Z.-Y., Shaikh, Z. A., & Gazizova, F. (2020). Using the Concept of Game-Based Learning in Education. International Journal of Emerging Technologies in Learning (iJET), 15(14), pp. 53–64. https://doi.org/10.3991/ijet.v15i14.14675
[15] Dorling, A. & Mccaffery, F. (2012).The Gamification of {SPICE}. Software Process Improvement and Capability Determination, pp. 295–301. https://doi.org/10.1007/978-3-642-30439-2_35
[16] Hebecker, R. & Regenbrecht, H. (2011). Visual surveys with purposeful games. Information Design Journal, v. 19, n.3, p. 259-271. https://doi.org/10.1075/idj.19.3.08heb
[17] Chou, Y. (2016). Actionable Gamification - Beyond Points, Badges, and Leaderboards. Octalysis Media.
[18] Burke, B. (2015). Gamificar: como a gamificação motiva as pessoas a fazerem coisas extraordinárias. Traduzido por: Sieben Gruppe. São Paulo: DVS Editora.
[19] Hamari, J. & Koivisto, J. (2015). Why do people use gamification services?. International Journal of Information Management. 35. 419–431. https://doi.org/10.1016/j.ijinfomgt.2015.04.006
[20] Deterding, S. (2012). Gamification: designing for motivation interactions. vol. 19, no. 4, pp. 14–17. https://doi.org/10.1145/2212877.2212883
[21] Palaniappan, K. & Md Noor, N. (2022). Gamification Strategy to Support Self-Directed Learning in an Online Learning Environment. International Journal of Emerging Technologies in Learning (iJET), 17(03), pp. 104–116. https://doi.org/10.3991/ijet.v17i03.27489
[22] Monteiro, R. H. B., De Almeida Souza, M. R., Oliveira, S. R. B., Dos Santos Portela, C., & De Cristo Lobato, C. E. (2021). The diversity of gamification evaluation in the software engineering education and industry: Trends, comparisons and gaps. In 2021 IEEE/ACM 43rd International Conference on Software Engineering: Software Engineering Education and Training (ICSE-SEET), pages 154–164. IEEE.
[23] Moreira, R. T. (2008). Uma Abordagem para melhoria do processo de Software baseada em medição. Dissertação (Mestrado). Recife: CIN/ UFPE/Mestrado em Ciência da Computação. https://doi.org/10.5753/sbqs.2009.15502
[24] Minghui, W., Jing, Y., & Chunyan, Y. (2004). A methodology and its support environment for benchmark-based adaptable software process improvement. V. 6, pp. 5183-5188, The Hague, Netherlands.
[25] Niazi, M., Wilson, D., & Zowghi, D. (2005). A maturity model for the implementation of software process improvement: An empirical study. Journal of Systems and Software, v. 74, n. 2 SPEC ISS, pp. 155-172. https://doi.org/10.1016/j.jss.2003.10.017
[26] Pressman, R. S. (2002). Engenharia de Software. 6 ed. Rio de Janeiro: McGraw-Hill.

[27] Baddoo, N. & Hall, T. (2002). Motivators Of Software Process Improvement: An Analysis Of Practitioners' Views. The Journal Of Systems And Software, 62, Issue 2. https://doi.org/10.1016/S0164-1212(01)00125-X
[28] Habib, M., Ahmed, S., Rehmat, A., Khan, M. J., & ShamaiL, S. (n.d.). (2008). Blending Six Sigma and CMMI - An Approach to Accelerate Process Improvement in SMEs. Framework, 386-391 p. https://doi.org/10.1109/INMIC.2008.4777768
[29] Birk, A. & Pfahl, D. (2002). A Systems Perspective on Software Process Improvement. In: Proceedings of the 4th International Conference on Product Focused Software Process Improvement, v. 2559, pp. 4-18, Dec. https://doi.org/10.1007/3-540-36209-6_4
[30] Silva, J. P. S., Dall'oglio, P., Crespo, S., & Gluz, J. C. (2010). Uma Abordagem Prática para Implementação da Garantia da Qualidade de Processo e de Produto. In: Anais do VI Simpósio Brasileiro de Sistemas de Informação, Marabá, PA.
[31] Soares, E. M. & Oliveira, S. R. B. (2020a). An Analysis of Problems in the Implementation of Software Process Improvement: a Literature Review and Survey. In: 17th CONTECSI - International Conference on Information Systems and Technology Management.
[32] Soares, E. M. & Oliveira, S. R. B. (2020b). A Solution Proposal for Software Process Improvement Problems from the Use of Gamification. In: 17th CONTECSI - International Conference on Information Systems and Technology Management.
[33] Soares, E. M. & Oliveira, S. R. B. (2021a). Problem in SPI: An Analysis of Gamification Elements for a Proposed Resolution. In: 16th International Conference on Software Technologies (ICSOFT).
[34] Soares, E. M. & Oliveira, S. R. B. (2021b). Aplicação dos Elementos de Gamificação para Resolução dos Problemas de Melhoria do Processo de Software no Contexto de Ensino e Aprendizagem. In: XX Brazilian Symposium on Computer Games and Digital Entertainment (SBGames), 2021, Gramado - RS.
[35] Keller, J. M. (2000). How to integrate learner motivation planning into lesson planning: The ARCS model approach. VII Semanario, Santiago, Cuba, February.
[36] Park, R. E., Goethert, W. B., & Florac, W. A. (1996). Goal-Driven Software Measurement - A Guidebook. Software Engineering Institute, Carnegie Mellon University, Pittsburgh, PA 15213.
[37] Herranz, E., Colomo-palacios, R., & De Amescua-Seco, A. (2013). Towards a New Approach to Supporting Top Managers in SPI Organizational Change Management. In Proceedings of CENTERIS 2013 - Conference on ENTERprise Information Systems / ProjMAN 2013 - International Conference on Project MANagement, Procedia Technology, Volume 9, pp. 1-1372, Lisbon, Portugal. https://doi.org/10.1016/j.protcy.2013.12.014
[38] Herranz, E., Colomo-Palacios, R., De Amescua-Seco, A., & Yilmaz, M. (2014). Gamification as a disruptive factor in software process improvement initiatives. Journal of Universal Computer Science, 20(6), 885–906.
[39] Herranz, E., Colomo-Palacios, R., De Amescua-Seco, A., & SáncheZ-Gordón, M. L. (2016). Towards a Gamification Framework for Software Process Improvement Initiatives: Construction and Validation. Journal of Universal Computer Science, 22(12), 1509-1532.
[40] Herranz, E., Guzman, J., De Amescua-Seco, A., & Larrucea, X. (2018). Gamification for software process improvement: A practical approach. IET Software, vol. 13, pp. 112–121.
[41] Rouiller, Ana C. (2017). MOSE®: Base de Competências. https://doi.org/10.1049/iet-sen.2018.5120
[42] Wöhlin, C., Runeson, P., Höst, M., Ohlsson, M., Regnell, B., & Wesslén, A. (2000). Experimentation in Software Engineering: An Introduction. Norwell, USA, Kluwer Academic Publishers. https://doi.org/10.1007/978-1-4615-4625-2
[43] Creswell, J. W. (2010). Projeto de pesquisa: métodos qualitativo, quantitativo e misto. Tradução Magda Lopes. 3 ed. Porto Alegre: ARTMED, 296 páginas.
[44] Travassos, G. H., Gurov, D., & Amaral, E. A. G. (2002). Introdução à Engenharia de Software Experimental. Coppe/UFRJ, Rio de Janeiro, Relatório Técnico: RT-ES590/02.

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Influence of Quality Development Over College Students' Entrepreneurial Competency

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Abstract—At present, the entrepreneurship of college students is rarely successfully. It is of great significance to reasonably evaluate college students' entrepreneurial competency, and discuss how to improve their entrepreneurial performance. The existing studies only focus on specific jobs, and emphasize on theoretical research. There is little report on the empirical quantification and effective promotion of the evaluation model, or on the effects of quality development training. Therefore, this paper explores the influence of quality development over college students' entrepreneurial competency. Firstly, the indices of college students' entrepreneurial competency were examined under the effect of quality development. The research contents were combined with the features of the entrepreneurship of college students, the training requirements of quality development, and the current background of society, politics, and economics, producing a reasonable composite evaluation index system. Next, the composite weights of the evaluation indices were solved by the hierarchical structure model and dominant feature recognition model of college students' entrepreneurial competency. On this basis, the dominant feature recognition model was established for college students' entrepreneurial competency under quality development planning. Through experiments, the proposed evaluation index system was proved scientific, and the entrepreneurial competency was evaluated for an entrepreneurial team of college students.

Keywords—quality development, entrepreneurship of college students, entrepreneurial competency

1 Introduction

Quality development training stimulates the personal potential of college students. Through the training, college students become more proactive and skillful in communication, and more capable of overcoming difficulties. In addition, quality development training promotes the teamwork spirit of college students, arouses their interests in entrepreneurship, and improves their psychological qualities, resulting in a good entrepreneurial competency [1-7].

With a good command of professional knowledge, college students are enthusiastic about and motivated for entrepreneurship. The national support policies bring many opportunities and challenges to their entrepreneurship [8-15]. By starting up a business, college students can apply the various cultural knowledge acquired on campus, and realize their own values and social values [16-18]. According to *China Youth Daily*, the success rate for the entrepreneurship of college students is as low as 1% on average. Thus, it is of great significance to reasonably evaluate college students' entrepreneurial competency, and discuss how to improve their entrepreneurial performance.

Ji [19] studied the training of college students' capabilities of employment and entrepreneurship, and explores the docking platform for college and enterprise talents in the context of Internet Plus. Focusing on the files of college students' innovation ability information, they presented a keyword extraction algorithm based on the graph model to mine the innovation potential of college students.

It is very important to evaluate the innovation and entrepreneurship education for college students. After analyzing the current research of the quality evaluation for innovation and entrepreneurship education, Zhou and Zhou [20] constructed an evaluation index system for the quality of college students' innovation and entrepreneurship education, which covers 21 indices. In addition, an evaluation model was built on extenics, and eight colleges in Ningbo were empirically studied, before providing corresponding suggestions.

With the rapid development of information technology, college students need to master basic professional qualities, as well as a certain innovation and entrepreneurship ability. Otherwise, it is impossible for college students to meet the talent needs of the market, not to mention the requirements of China's development in the current stage. Gao [21] examined how to cultivate college students' innovation and entrepreneurship capability in the era of the Internet, with the hope to aid college education, and enable colleges to train generations of high-quality talents for the rapid development of the society.

There are many challenges to college students' innovation and entrepreneurship. Big data analysis and innovation and entrepreneurship can complete each other's advantages. Against this background, Hu [22] analyzed the concepts and connotations of college students' innovation and entrepreneurship from the angle of economic transformation, and provided the training strategies for college students' innovation and entrepreneurship through big data analysis.

As the Internet gradually penetrates our lives and work, more and more working modes are available. For college students, job hunting is no longer the only way to employment. They can also live a decent life through innovation and entrepreneurship. In this context, Hu [23] emphasized that the Internet Plus offers new possibilities for training college students into innovation and entrepreneurship talents efficiently, and discovered that the merger of colleges provides opportunities for college students to transform into applied talents.

The existing studies on college students' entrepreneurial competency have very similar theoretical natures and connotations. Most scholars only focused on specific jobs, and emphasized on theoretical research. There is little report on the empirical quantification and effective promotion of the evaluation model, or on the effects of quality development training.

Therefore, this paper explores the influence of quality development over college students' entrepreneurial competency. Section 2 examines the indices of college students' entrepreneurial competency under the effect of quality development, and combines the research contents with the features of the entrepreneurship of college students, the training requirements of quality development, and the current background of society, politics, and economics, producing a reasonable composite evaluation index system. Section 3 solves the composite weights by the hierarchical structure model and dominant feature recognition model of college students' entrepreneurial competency, and establishes the dominant feature recognition model for college students' entrepreneurial competency under quality development planning. Through experiments, the proposed evaluation index system was proved scientific, and the entrepreneurial competency was evaluated for an entrepreneurial team of college students.

2 Evaluation model

Quality development training is an experiential learning mode, which evolves from traditional outward training. Facing the entrepreneurship education of college students, the training goal of quality development expands from pure physical training to the learning of cultural knowledge related to entrepreneurship, the improvement of intrinsic qualities, involving psychological training and personality training, and the training of entrepreneurial skills and management/marketing abilities. Through the participation of quality development training, the psychological tolerance of college students is enhanced, the innovative thinking is inspired, and the entrepreneurial leaders and teams are re-positioned.

In view of the traditional theory on the iceberg model, the features of entrepreneurship of college students, and the training requirements of quality development, this paper summarizes college students' entrepreneurial competency into three dimensions (the learning of cultural knowledge related to entrepreneurship, the improvement of intrinsic qualities, involving psychological training and personality training, and the training of entrepreneurial skills and management/marketing abilities), and establishes an iceberg model (Figure 1).

Fig. 1. The iceberg model

Through quality development training, the college students engaged in entrepreneurship will experience a significance improvement in the following indices of entrepreneurial competency:

For the college students engaged in entrepreneurship, the improvement of intrinsic qualities mainly covers three indices, namely, the improvement of personal charisma, the enhancement of psychological quality, and the cultivation of perseverance and dedication spirits. The college students with integrity, affinity, leadership skills, and enterprise spirit are more likely to forge a cohesive entrepreneurial team; the college students, who are confident, optimistic, independent, and tough, are rarely subjected to external interference, or give up in the process of entrepreneurship; the college students, who devote all their energy to entrepreneurship, bear hardships, and stand hard work, are very likely to achieve entrepreneurial success.

For the college students engaged in entrepreneurship, the learning of cultural knowledge mainly involves three indices, namely, the learning of professional knowledge, the learning of management knowledge, and the learning of general knowledge. The college student with much professional and industry knowledge about entrepreneurship can quickly adapt to the changes and development in the field of entrepreneurship; the college students with the knowledge in management, accounting, operation, and marketing can guarantee the normal operation of their start-up companies, and get used to the market rhythm of supply and demand; the college students with knowledge in laws, tax, and policies, as well as various basic cultural knowledge and common sense of life will cope with emergences more aptly, and their companies will be good at resisting risks.

For the college students engaged in entrepreneurship, the training of entrepreneurial skills and management/marketing abilities mainly covers six indices: improvement of innovation ability, improvement of risk management ability, improvement of team-building ability, improvement of marketing ability, improvement of information gathering ability, and improvement of opportunity recognition ability. The college students capable of innovative thinking and reverse thinking are good at solving problems in the key links of the entrepreneurial process, including technology and sales. The college students with a strong capacity of overall planning, clear goals, and the ability to prepare alternative plans, can streamline company management, expose weak links, and make problems easier to solve. The college students, who take the lead and treat everyone fairly in the entrepreneurial process, are more likely to build a harmonious and long-lasting entrepreneurial team. The college students, who fully understand the industry trends, consumer needs, product competitiveness, and product defects, and who choose marketing methods and strategies properly, can obtain profits by marketizing products. The college students, who boast various connections, do well in drawing conclusions and making analysis, and excel in interpersonal communication, are more likely to acquire the latest information about the market or policies, and to solicitate help from cooperative companies or individuals. The college students, who are sensitive to market changes, logical in handling affairs, as well as calm and decisive, tend to identify hidden entrepreneurship opportunities.

Through the above analysis (Figure 2), this paper combines the research contents with the features of the entrepreneurship of college students, the training requirements of quality development, and the current background of society, politics, and economics, producing a reasonable composite evaluation index system. The college students' entrepreneurial competency needs to be evaluated by the following principles:

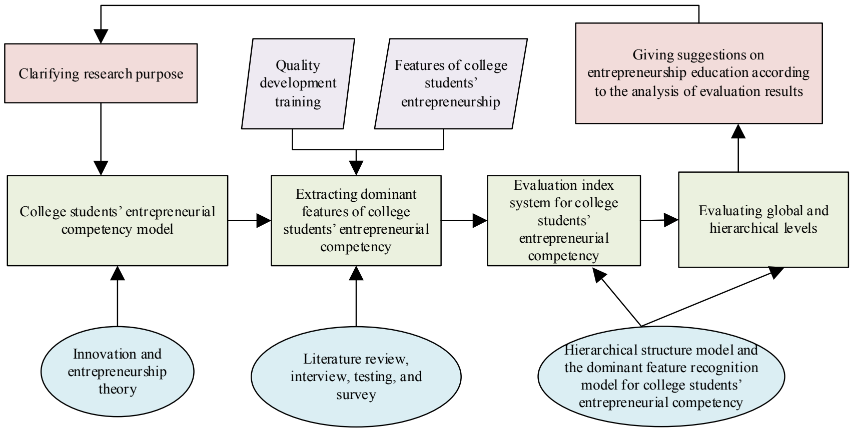

Fig. 2. Evaluation and analysis flow of college students' entrepreneurial competency

1. Clarify the research purpose through the analysis on external environment, and the innovation and entrepreneurship theory, and build an evaluation model for college students' entrepreneurial competency for the new era.
2. Extract the features of the entrepreneurship of college students, and analyze the dominant features, according to the time features and entrepreneurship features of college students, and the requirements of quality development training. Through literature review, interview, testing, and survey, the existing research results are sorted out and summed up. Highlight the prominent problems in view of the current practice of entrepreneurship of college students.
3. Set up a composite evaluation index system, quantify the global and hierarchical results, and provide effective suggestions on the entrepreneurship education of college students. Figure 3 shows the established index system.

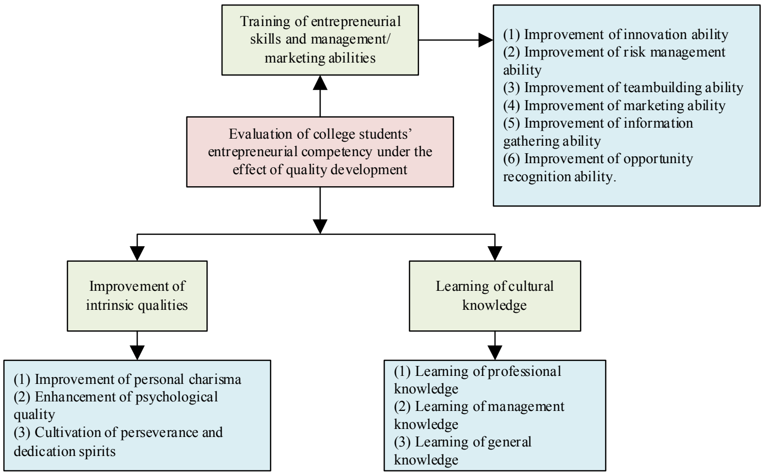

Fig. 3. Composite evaluation index system

3 Dominant feature recognition

3.1 Composite weight

Under the effect of quality development, the evaluation of college students' entrepreneurial competency involves multiple indices. The importance of each index is represented by a weight, which determines the final result of evaluation. Therefore, the key to the evaluation of college students' entrepreneurial competency under quality development is determining the weight coefficients of evaluation indices. The weight coefficients must be sufficiently objective. In this paper, the composite weight of each index is solved by the hierarchical structure model, and the dominant feature recognition model for college students' entrepreneurial competency.

Suppose m college students $O=\{O_1,O_2,...,O_m\}$ are surveyed, and the evaluation index system of entrepreneurial competency contain n indices, $TS=\{TS_1,TS_2,...,TS_n\}$. Let $k_{ij}(i=1,2,...,m;\ j=1,2,,,n)$ be the score given by college student O_i to the j-th index TS_j. Then, the $m\times n$ scores given by m college students can form an evaluation matrix $EX=(k_{ij})_{m\times n}$.

According to the evaluation needs, the scores of all entrepreneurial competency indices are nondimensionalized, turning $X=(k_{ij})_{m\times n}$ into $R=(a_{ij})_{m\times n}$. The linear mapping can be adopted: $a_{ij}=k_{ij}-k_j^{min}/k_j^{max}-k_j^{min}$. Every element in EX satisfies $0<b_{ij}<1$.

Let ω_{ij} be the weight of the j-th dominant index for the i-th subject. To optimize the index weight for the subject, this paper determines the weight ω_{ij} based on the L2-normdistance. The optimal solution can be expressed as: $a^*_j=(a^*_1,a^*_2,...,a^*_n)'=max_{1\leq j\leq m}\{a_{ij}\}$, $j=1,2,...,n$. The college students' entrepreneurial competency can be measured by the following function:

$$\delta\left(a_i, a^*\right) = \sqrt{\sum_{j=1}^{o} \omega_{ij}^2 \left(a_i^* - a_i\right)^2} \tag{1}$$

To display the maximum score of entrepreneurial competency for each subject, this paper ranks the college students' entrepreneurial competency by the difference between the score and the preset expectation. Under quality development planning, the dominant features of college students' entrepreneurial competency can be expressed as:

$$\begin{aligned} &\delta_i^2\left(a_i, a*\right) = min\left\{\sum_{j=1}^{n} \omega_{ij}^2 \left(a_j^* - a_{ij}\right)^2\right\} \\ &s.t.: \sum_{j=1}^{n} \omega_{ij} = 1, \omega_{ij} \geq 0 \\ &i = 1, 2, ..., m; j = 1, 2, ..., n \end{aligned} \tag{2}$$

The recognition model was solved by the Lagrange multiplier algorithm. For the indices making the objective function of quality development zero, the index weights add up to one; the weights of the other indices are zero. When the objective function contains no index weight that equals zero, the calculation formula can be expressed as:

$$\begin{aligned} &\omega_{ij}^* = \frac{\mu^*}{\left(a_i^* - a_{ij}\right)^2}, i = 1, 2, ..., m \\ &\mu^* = \frac{1}{\sum_{j=1}^{o} \frac{1}{\left(a_i^* - a_{ij}\right)^2}} \end{aligned} \tag{3}$$

The recognition model (2) has an optimal solution. However, when a college student only prefers one of the entrepreneurial competency indices, i.e., only when $a_{ij0=a*j0}$, and $e \leq j_0 \leq n$, the proposed model will have an extreme solution $\{\omega_{ij0}=1; \omega_{il}=0 | l \neq j_0\}$. Thus, the evaluation index structure $\omega*_i=(\omega*_{i1},\omega*_{i2},...,\omega*_{ip})^T$, $\omega*(i=1,2,...,m)$ reflecting the dominant features of college students' entrepreneurial competency manifests the entrepreneurial competency of each subject, under the known evaluation index system, and the known objectives of quality development.

Next, hierarchical analytic process (AHP) was employed to assign a weight to each evaluation dimension of college students' entrepreneurial competency, and the weight of each entrepreneurial competency index. In this way, an analysis model for the entrepreneurial competency of the college student entrepreneurial team can be established, which consists of a goal layer, a criteria layer, and an alternative layer. The goal layer is the specific evaluation problem for college students' entrepreneurial competency. Thus, the three dimensions of college students' entrepreneurial competency, namely, the learning of cultural knowledge, the improvement of intrinsic qualities, and the training of entrepreneurial skills and management/marketing abilities, were taken as the criteria layer; the more specific indices of competency improvement were added to the alternative layer.

The index weights were determined by the AHP in the following steps: Firstly, relevant experts were invited to carry out pairwise comparison between the four dimensions and 12 alternatives in the evaluation index system. The judgement matrix was constructed according to the evaluation scale. Suppose the decision is affected by M evaluation criteria or alternatives. Let x_{ij} be the relative importance of index i to index j. Then, the judgement matrix can be established as:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1M} \\ x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2M} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{i1} & x_{i1} & \cdots & x_{ij} & \cdots & x_{iM} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{M1} & x_{M1} & \cdots & x_{M1} & \cdots & x_{MM} \end{bmatrix} \tag{4}$$

The importance x_{ij} satisfies the following equation:

$$x_{ij} = 1 / x_{ji} \tag{5}$$

This paper chooses the square root method to compute the eigenvectors and maximum characteristic roots of the eigenmatrix. The product of the elements in each row of the matrix can be calculated by:

$$N_i = \prod_{j=1}^{M} a_{ij} \tag{6}$$

The M-th root Q^*_i of N_i can be calculated by:

$$Q_i^* = \sqrt[M]{N_i} \tag{7}$$

The eigenvector of the matrix is the vector Q obtained by normalizing Q^*_i:

$$Q_i = \frac{Q_i^*}{\sum_{i=1}^{M} Q_i^*} \tag{8}$$

$$Q = \begin{bmatrix} Q_1 & Q_2 & Q_3 & \cdots & Q_M \end{bmatrix}^T \tag{9}$$

The maximum characteristic root can be calculated by:

$$\mu_{max} = \sum_{i=2}^{M} \frac{XQ_i}{MQ_i} \tag{10}$$

The weights of the evaluation indices, which were obtained by the hierarchical structure model and the dominant feature recognition model, were superimposed, and averaged to obtain the composite weights of the evaluation indices for college students' entrepreneurial competency.

3.2 Dominant feature recognition model

The proposed evaluation index system for college students' entrepreneurial competency is a manifestation of the hierarchy. Let h_{ilj} be the index value of college student O_i; h^*_{lj} be the college student's preference for entrepreneurial competency corresponding to the index. Under the quality development planning, the dominant feature recognition model for college students' entrepreneurial competency from the goal layer to the alternative layer can be expressed as:

$$\begin{aligned} & min\delta_i\left(h_i, h^*\right) = \sum_{l=1}^{b}\sum_{j=1}^{x_l}\omega_{lj}^2\left(h_{lj}^* - h_{ilj}\right)^2 \\ & s.t.\sum_{l=1}^{b}\sum_{j=1}^{x_l}\omega_{lj} = 1 \\ & \omega_{lj} \geq 0, l = 1,2,...,b, j = 1,2,....,x_l \end{aligned} \tag{11}$$

The dominant feature recognition model from the criteria layer to the alternative layer can be given as:

$$\begin{aligned} & min\delta_{il}^2\left(h_i, h^*\right) = \sum_{j=1}^{x_l}\mu_{lj}^2\left(h_{lj}^* - h_{ilj}\right)^2 \\ & s.t.\sum_{j=1}^{x_l}\mu_{lj} = 1 \\ & \mu_{lj} \geq 0, j = 1,2,....,x_l \end{aligned} \tag{12}$$

The optimal solution $\mu^*_{il}=(\mu^*_{il1},\mu^*_{il2},...,\mu^*_{il}{}^{xl})$ to the model is based on the index values of subject O_i. The dominance of O_i in the entrepreneurial competency on the alternative layer can be judged by the l-th index of the criteria layer. The subject can be expressed as $(Y^*_{il})^2=\sum^{x}_{lj=1}(\mu^*_{ilj})^2(a^*_{lj}-a^*_{ilj})^2$. Based on the index values of subject O_i, the dominant feature recognition model from the angle of the goal layer can be expressed as:

$$\begin{aligned} & min\delta_{il}^2\left(h_i, h^*\right) = \sum_{j=1}^{x_l}\mu_{lj}^2\left(h_{lj}^* - h_{ilj}\right)^2 \\ & s.t.\sum_{j=1}^{x_l}\mu_{lj} = 1 \\ & \mu_{lj} \geq 0, j = 1,2,....,x_l \end{aligned} \tag{13}$$

Through cluster analysis, this paper processes the dominant features of the college students' entrepreneurial competency on each layer of indices. Each class of goal layer indices is denoted as l_x=1, 2,...,l_X. Each class of criteria layer indices is denoted as l_y=1,2,...,l_Y. Based on the recognized dominant features, the dominance of indices on each layer can be obtained. For the l-th criteria layer index, the dominance under the weight structure of the l_y-th class can be expressed as:

$$b_{lly} = \frac{1}{m}\sum_{i=1}^{m}\sqrt{\sum_{j=1}^{o_n}\left(\mu_{ill_y}^{*}\right)^2\left(h_{ijl}-h_{jl}^{*}\right)^2},\ j=1,2,...,o_n \tag{14}$$

For the goal layer indices, the dominance in each class can be calculated by:

$$c_x = \frac{1}{m}\sum_{i=1}^{m}\sqrt{\sum_{l=1}^{n}\left(\lambda_{l_x}^{*}\right)^2\left(b_{il}-b_{l}^{*}\right)^2} = \frac{1}{m}\sum_{i=1}^{m}\sqrt{\sum_{l=1}^{n}\sum_{j=1}^{o_n}\left(\lambda_{l_x}^{*}\right)^2\left(\mu_{il}^{*}\right)^2\left(h_{jil}-h_{jl}^{*}\right)^2} \tag{15}$$

4 Experiments and results analysis

This paper defines the common method variance (CMW) as the system error arising from the intrinsic features of data source, survey environment, and research purpose for the evaluation of college students' entrepreneurial competency. The CMW can be viewed as the artificial common variance between the evaluation result of college students' entrepreneurial competency and the reference value. In this paper, the evaluation samples of college students' entrepreneurial competency undergo the CMW test, by the Harman's one-factor test. That is, all evaluation indices were subjected to the same exploratory factor analysis. The CMW test results on the evaluation data are shown in Table 1. The extracted principal components could explain 75.24% of all evaluation indices. Therefore, our evaluation indices do not have a serious CMW, and the evaluation data can be further analyzed.

Table 1. CMW test results on the evaluation data

Component		1	2	3	4	5	6
Initial eigenvalue	Total	11.058	4.052	3.168	3.058	2.103	1.926
	% of variance	25.184	9.638	7.421	6.825	4.192	4.368
	Cumulative % of variance	27.835	38.295	42.058	51.284	58.968	55.263
Extracted sum of squared loadings	Total	13.052	4.157	3.629	3.153	2.684	1.928
	% of variance	23.168	9.475	7.062	6.184	4.627	4.905
	Cumulative % of variance	28.192	37.428	44.518	52.639	55.715	56.283
Component		**7**	**8**	**9**	**10**	**11**	**12**
Initial eigenvalue	Total	1.481	1.827	1.936	1.213	1.447	3.122
	% of variance	3.052	3.948	2.174	2.938	3.412	7.561
	Cumulative % of variance	61.482	66.937	67.481	72.053	63.582	47.466
Extracted sum of squared loadings	Total	1.052	1.697	1.362	1.485	1.442	3.598
	% of variance	3.627	3.095	2.618	2.472	3.797	7.487
	Cumulative % of variance	63.015	66.257	69.315	72.168	65.685	48.562

Drawing on the analysis in the preceding section, the weights and consistency test results of the alternative layer can be obtained (Table 2).

Table 2. Weights and consistency test results of the alternative layer

	Eigenvector	Maximum characteristic root	*CI*	*RI*	Consistency test results
Improvement of personal charisma	0.5384	3.8241	0.0157	0.5938	*CR*=0.0152 *CR*<0.3 passing the consistency test
Enhancement of psychological quality	0.1457				
Cultivation of perseverance and dedication spirits	0.3926				
Learning of professional knowledge	0.6271	3.9153	0.0362	0.5285	*CR*=0.0418 *CR*<0.5 passing the consistency test
Learning of management knowledge	0.1295				
Learning of general knowledge	0.2853				
Improvement of innovation ability	0.1485	3.4286	0.0849	0.5618	*CR*=0.0625 *CR*<0.2 passing the consistency test
Improvement of risk management ability	0.2953				
Improvement of teambuilding ability	0.5748				
Improvement of marketing ability	0.6145				
Improvement of information gathering ability	0.1842				
Improvement of opportunity recognition ability	0.5413				

Note: CR and RI are short for consistency ratio and random consistency index, respectively.

As shown in Table 2, the *CR* values (0.0152) of improvement of personal charisma, enhancement of psychological quality and cultivation of perseverance and dedication spirits were smaller than 0.3, passing the consistency test. The *CR* values (0.0418) of learning of professional knowledge, learning of management knowledge, and learning of general knowledge were smaller than 0.5, passing the consistency test. The *CR* values (0.0625) of improvement of innovation ability, improvement of risk management ability, improvement of teambuilding ability, improvement of marketing ability, improvement of information gathering ability, and improvement of opportunity recognition ability were smaller than 0.2, also passing the consistency test. Finally, the composite weights of the evaluation indices can be calculated for college students' entrepreneurial competency (Table 3).

Table 3. Calculated composite weights

Criteria layer	Weight	Alternative layer	Weight	Composite weight
Improvement of intrinsic qualities	0.2521	Improvement of personal charisma	0.2162	0.0545
		Enhancement of psychological quality	0.5385	0.1357
		Cultivation of perseverance and dedication spirits	0.2453	0.0618
Learning of cultural knowledge	0.3229	Learning of professional knowledge	0.4182	0.135
		Learning of management knowledge	0.3248	0.1048
		Learning of general knowledge	0.257	0.0829
Training of entrepreneurial skills and management/marketing abilities	0.425	Improvement of innovation ability	0.1842	0.0782
		Improvement of risk management ability	0.1748	0.0742
		Improvement of teambuilding ability	0.1526	0.0648
		Improvement of marketing ability	0.1955	0.083
		Improvement of information gathering ability	0.1347	0.0572
		Improvement of opportunity recognition ability	0.1582	0.0672

Based on the evaluation data on college students' entrepreneurial competency, this paper quickly divides the scores of college students' entrepreneurial competency into different classes through rapid clustering. During the clustering, the dominant features of college students' entrepreneurial competency were divided into classes. Table 4 shows the clustering results for criteria layer indices.

Table 4. Clustering results for criteria layer indices

Class	Weight structure			Number of students in the class	Proportion in all students
	Improvement of intrinsic qualities	*Learning of cultural knowledge*	*Training of entrepreneurial skills and management/marketing abilities*		
1	3.625	2.156	2.859	74	51.2
2	0.842	1.639	2.453	26	17.4
3	0.251	0.326	9.158	26	18.4
4	0.625	7.952	1.485	22	16.3

Table 5 summarizes the memberships for entrepreneurial competency of a college student entrepreneurship team. It can be seen that, the entrepreneurial competency was strongly strong for member A, slightly strong for member B, ordinary for members C and D, and slightly weak for member E. These evaluation results are basically consistent with the entrepreneurial competency and development situation of the current members of the team: A and B are team leaders with relatively strong entrepreneurial performance. The other members performed slightly worse in entrepreneurship, and may leave the team and find jobs. The main reason is that the other members lack dominant features of entrepreneurial competency, which directly support further entrepreneurial activities.

Table 5. Summary of memberships for entrepreneurial competency of a college student entrepreneurship team

Code		A	B	C	D	E
Comment membership	Strongly strong	0.3269	0.2518	0.2963	0.0748	0.1329
	Slightly strong	0.2715	0.3748	0.2961	0.2264	0.1926
	Ordinary	0.1436	0.1924	0.3637	0.3169	0.2849
	Slightly weak	0.0749	0.0485	0.08	0.2635	0.2846
	Strongly weak	0.0748	0.1362	0.0948	0.1621	0.3743

5 Conclusions

This paper explores the influence of quality development over college students' entrepreneurial competency. After a thorough discussion about the indices of college students' entrepreneurial competency, the authors designed a reasonable composite evaluation index system, which combines the research contents with the features of the entrepreneurship of college students, the training requirements of quality development, and the current background of society, politics, and economics. Based on the hierarchical structure model and dominant feature recognition model of college students' entrepreneurial competency, the composite weights of the evaluation indices were solved, and the dominant feature recognition model was established for college students' entrepreneurial competency under quality development planning. Through experiments, the CMV of the evaluation data was tested, the weights of criteria layer indices were calculated, the consistency test results were obtained, and the composite weights were solved. The results demonstrate the scientific nature of the proposed evaluation model. During the clustering, the dominant features of college students' entrepreneurial competency were divided into classes. Then, the authors summed up the memberships for entrepreneurial competency of a college student entrepreneurship team.

6 References

[1] Galkina, E.E., Sorokin, A.E. (2020). Quality management and sustainable economic development. Russian Engineering Research, 40(7): 577-578. https://doi.org/10.3103/S1068798X2007014X

[2] Lee-Post, A., Pakath, R. (2019). Numerical, secondary big data quality issues, quality threshold establishment, & guidelines for journal policy development. Decision Support Systems, 126: 113135. https://doi.org/10.1016/j.dss.2019.113135

[3] Zhang, Z., Wu, J., Wei, F. (2019). Refurbishment or quality recovery: joint quality and pricing decisions for new product development. International Journal of Production Research, 57(8): 2327-2343. https://doi.org/10.1080/00207543.2018.1516904

[4] Xu, L., Peng, X., Pavur, R., Prybutok, V. (2020). Quality management theory development via meta-analysis. International Journal of Production Economics, 229: 107759. https://doi.org/10.1016/j.ijpe.2020.107759

[5] Jo, J., Jo, B., Kim, J., Kim, S., Han, W. (2020). Development of an IoT-based indoor air quality monitoring platform. Journal of Sensors, 2020: 8749764. https://doi.org/10.1155/2020/8749764

[6] Bidault, F., Castello, A. (2019). The dynamics of relational quality in co-development alliances. International Journal of Technology Management, 81(1-2): 24-50. https://doi.org/10.1504/IJTM.2019.10022052

[7] Naidu, N.V.R., Mallikarjuna, S. (2015). Development of mathematical model for quality-cost optimization. Proceedings - 21st ISSAT International Conference on Reliability and Quality in Design, 17-21.

[8] Zhang, J., Cao, W., Zeng, P. (2014). A study on the relationship among entrepreneurship education, social capital and college students' entrepreneurial intention. In 2014 IEEE International Conference on Granular Computing (GRC), 367-373. https://doi.org/10.1109/GRC.2014.6982866

[9] Ji, Z., Zhao, X. (2014). Analyzing elements of the employment and entrepreneurship practice education of college students. Journal of Chemical and Pharmaceutical Research, 6(7): 803-807.

[10] Hou, Y., Liu, D., Yang, S. (2016). Construction of e-commerce entrepreneurship curriculum system for college students: An information entrepreneurship perspective. International Journal of U-and E-Service, Science and Technology, 9(11): 251-262. https://www.earticle.net/Article/A293295

[11] Zhou, Y. (2017). An optimized research on entrepreneurship education of college students and foundry enterprise practice. Boletín Técnico, 55(10): 546-552.
[12] Sui, F.M., Chang, J.C., Hsiao, H.C., Su, S.C. (2017). A study on entrepreneurial education regarding college students' creative tendency, entrepreneurship self-efficacy and entrepreneurial motivation. In 2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 850-854. https://doi.org/10.1109/IEEM.2017.8290012
[13] Sun, L., Jiao, K., Wang, R. (2016). The evaluation of college students' entrepreneurship ability based on AHP method. International Journal of Advanced Media and Communication, 6(2-4): 246-261. https://doi.org/10.1504/IJAMC.2016.080971
[14] Li, L., Li, M., Zhao, W.Z., Gao, L. (2015). Study on technology entrepreneurship mode of engineering college students. International Journal of Simulation--Systems, Science & Technology, 16(5B): 12.1-12.5. https://doi.org/10.5013/IJSSST.a.16.5B.12
[15] Ji, Z., Zhao, X. (2014). Analyzing elements of the employment and entrepreneurship practice education of college students. Journal of Chemical and Pharmaceutical Research, 6(7): 803-807.
[16] Hua, S.Y., Ren, Z.W. (2020). "Online + Offline" Course Teaching Based on Case Teaching Method: A Case Study of Entrepreneurship Education Course, International Journal of Emerging Technologies in Learning,15(10): 69-85. https://doi.org/10.3991/ijet.v15i10.13999
[17] Tian, X. (2013). Establishment of policy support system for college students' entrepreneurship in Suzhou. International Journal of Emerging Technologies in Learning (iJET), 8(5): 27-31. https://doi.org/10.3991/ijet.v8i5.2995
[18] Ma, L., Lan, Z.Z., Tan, R. (2020). Influencing Factors of Innovation and Entrepreneurship Education Based on the Theory of Planned Behavior, International Journal of Emerging Technologies in Learning, 15(13): 190-206. https://doi.org/10.3991/ijet.v15i13.15345
[19] Ji, C.X. (2021). Cultivation of college students' employment and entrepreneurship ability of agriculture and forestry engineering major under the background of internet plus. Forest Chemicals Review, 131-141.
[20] Zhou, Y., Zhou, H. (2022). Research on the quality evaluation of innovation and entrepreneurship education of college students based on Extenics. Procedia Computer Science, 199: 605-612. https://doi.org/10.1016/j.procs.2022.01.074
[21] Gao, R. (2021). Research on the cultivation of college students' innovative and entrepreneurship ability based on the internet technology. In Journal of Physics: Conference Series, 1992(2): 022048. https://doi.org/10.1088/1742-6596/1992/2/022048
[22] Hu, Q. (2021). Research on the cultivation strategy of college students' innovation and entrepreneurship based on big data analysis from the perspective of economic transformation. In Journal of Physics: Conference Series, 1915(3): 032083. https://doi.org/10.1088/1742-6596/1915/3/032083
[23] Hu, B. (2021). School-enterprise cooperation college students' innovation and entrepreneurship improvement under the" internet" perspective. In 2021 4th International Conference on Information Systems and Computer Aided Education, 1131-1134. https://doi.org/10.1145/3482632.3483099

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Influence of Self-Regulated Strategy Development on the Performance of Virtual Reality-Based Teaching in Online Learning

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Abstract—Virtual reality technology has been fully integrated into the field of education. Such technology has become the focus of online learning that uses efficient and advanced virtual reality technology to improve the efficiency of learners. Online learning also gives full play to the characteristics of free learning time, flexible location, and free learning pace. Although online learning also easily leads to low efficiency due to physical isolation, it can effectively improve the performance of virtual reality-based teaching by using the self-regulated strategy development (SRSD) model. Based on this model, an experiment was conducted on online teaching course for first-year linguistics students of a provincial graduate school in China to test the influence of the model on the performance of virtual reality-based teaching in online learning. Results show that after the SRSD model, a significant difference is observed between pretest scores and post-test scores of graduate students in the experimental group ($t=-4.925$, $p=0.000$). A significant difference is observed between pretest self-regulation and post-test self-regulation of graduate students in the experimental group ($t=-7.505$, $p=0.000$). Finally, significant differences are observed between the experimental and control groups in the improvement of post-test scores and post-test self-regulation. Conclusions are of important reference value for enriching the application of the SRSD model in virtual reality-based teaching, improving the self-regulation ability of students, and improving the performance of learners by adopting a model more suitable for the characteristics of online teaching.

Keywords—online learning, self-regulated strategy development model (SRSD), virtual reality, experimental research

1 Introduction

The means of education informatization represented by emerging technologies such as virtual reality have fully penetrated online teaching, making online learning a good choice to overcome the time and space segmentation between teachers and learners. Especially during the COVID-19 pandemic, the vast majority of universities in China have conducted online teaching, comprising teaching forms such as online live teaching, online video teaching, virtual reality-based teaching, and massive online open classes. The massive shift into online teaching leads to a lack of self-discipline or positive learning attitudes of students due to the virtual reality-based teaching environment. In the context of globalization, fully learning from information technology is necessary to strengthen cooperation in the field of education. Especially under the background of rapid development of the Internet, the concept of traditional teaching is also facing the effect of different educational concepts in different countries, and the demand for more efficient and personalized learning anytime and anywhere is increasing sharply.

To solve the problem of low efficiency in traditional teaching, creating and adopting various new teaching modes in online teaching, such as virtual reality-based teaching, as well as increasing the initiative and adaptability of schools to the development of online education, is necessary. At present, for online learning in various colleges and universities in China, more teachers provide detailed tasks for each class by using virtual reality-based teaching and require students to complete these specific tasks combined with unit themes, class design, and homework design. Then, the teachers gradually establish a knowledge system. However, because virtual reality-based teaching has been separated from the normal classroom teaching environment, the network channel makes introduces difficulties or even precludes teachers from effectively monitoring the learning status of students and providing feedback on their learning progress. The amount, difficulty, and length of teaching content may cause students to lose concentration in online learning.

As key talent resources in China's higher education system, the ability of many graduate students has not been completely improved due to the selection mechanism of graduate students in China. They lack self-efficacy and confidence, and put more emphasis on examination but cannot apply it to practical scenarios. Therefore, additional educational theories are needed to improve the ability of graduate students. In developed countries such as the United States and those in Europe, teachers built a rich teaching background with self-regulated strategy development (SRSD). They effectively promoted the interaction between teachers and students, as well as students and students, through methods such as group discussion, teacher demonstration, student memory, and peer support. They completed teaching tasks by constructing a scientific and reasonable teaching stage, improving the adaptability and flexibility of the entire teaching process.

SRSD mode teaching has a very clear process, which is fundamentally different from other types of cognition teaching modes. The SRSD mode allows students to correctly understand the teaching intention of teachers. Each teaching step has a very clear demonstration process so that learners can clarify the teaching objectives. Given that teaching under the SRSD mode emphasizes teacher-student interaction and student-student interaction, it can effectively solve the problem of low emotional input of learners in virtual reality-based teaching. Therefore, the emotional support of teachers and classmates can better promote the learning input of online learners. By adopting scientific teaching rules, learners can develop good learning rules, which can break through the subjectivity of the random daily learning of online learners so that they can more abide by the learning schedule in online learning. The SRSD mode has reasonable time arrangements and progress requirements by considering the learning needs of different learning levels. Learners can arrange their learning times in accordance with factors such as their learning ability and cognitive input. They enter the next stage after achieving their learning goals in one stage. The adoption of the SRSD teaching mode in virtual reality-based teaching has a more extensive implementation space and application value.

Despite the wide use of SRSD in the educational practice of developed countries, it is not widely used in China. In particular, studies on how to adopt this SRSD for students in China are limited. Therefore, under the SRSD mode, teachers are the guide in the classroom. Through innovative teaching mode, such as virtual reality-based teaching, teachers can achieve efficient teaching guidance in online learning. They can also adopt appropriate teaching strategies to strengthen the interaction of virtual reality-based teaching, improve the performance of learners in the classroom, and promote the learning performance of online learners.

2 Literature review

The self-regulated development mode has been rapidly developed and widely applied since it was proposed by western scholars in the 1960s. In particular, the self-regulated development mode proposed by Graham et al. [1] plays a very important role. This theory has been studied in teaching abroad for more than 20 years. The SRSD teaching model is a high-quality teaching guidance model that is completed through six teaching stages. It mainly improves learners' mastery of knowledge through the construction of knowledge background, discussion, teacher demonstration, memory, support, and independent expression. SRSD can achieve self-regulation by allowing learners to strengthen the application of learning strategies. Although this theory was first proposed for the purpose of learning with disabilities, it also has been widely applied in other disciplines, along with the continuous improvement and enrichment of the theory.

Later, a large number of scholars conducted extensive research on the application of the SRSD model, especially abroad and in developed countries. Limpo et al. [2] performed a comparative experiment, in which a total of 109 students received planning guidance based on the SRSD model, while 83 students received standard teaching guidance. The results showed that the students who adopted SRSD could write longer and better articles than could those students in the control group. Graham et al. [3] demonstrated that the SRSD model could make collaborative strategies clearer and more standardized, and they suggested that speech-language pathologists should apply the SRSD model to children with teaching difficulties. Gillespie et al. [4] indicated that the implementation of the SRSD teaching model can provide a better learning experience for students with autism and improve their learning effectiveness. McKeown et al. [5] found that SRSD can effectively improve the learning emotions of learners and skills of students with emotional and behavioral disorders (EBD). Chen et al. [6] demonstrated the effectiveness of SRSD in promoting the development of students' review ability. Ray et al. [7] used the SRSD model to study the effectiveness of argumentative teaching for the ACT for senior high school students with disabilities or students at risk of learning difficulties. Their results showed that the SRSD model could effectively improve the effect on students' learning process.

McKeown et al. [8] found that students have a higher recognition of SRSD. Peltier et al. [9] demonstrated that the SRSD model plays an obvious role in improving the learning effect of learners in reading, writing, and mathematics. Harris et al. [10] showed that when teachers implemented SRSD teaching, the performance of students' learning in the story and opinion articles had significant and meaningful changes. Teachers and students believed that SRSD had social validity. Santangelo et al. [11] used SRSD to conduct a case study on teaching story grammar strategies to fifth-grade students. They found that students who received SRSD significantly improved their skills. Graham et al. [12] demonstrated that SRSD teaching also improved the knowledge of students. Peer support could also enhance SRSD teaching by increasing the planning knowledge of students and improving their generalization ability in information and narrative learning. Zumbrunn et al. [13] analyzed the effectiveness of the SRSD teaching mode on the learning skills and knowledge of six first-grade students. They found that SRSD is beneficial to their learning, and their knowledge has been significantly improved.

Sexton et al. [14] believed that SRSD has an obvious effect on promoting the learning level of students with learning difficulties. Miller et al. [15] indicated that the SRSD teaching mode improved the overall learning performance of students in opinion articles. Zito et al. [16] found that the SRSD teaching mode plays an important role in improving self-regulation and learning strategies for students with excellent academic performance. Baghbadorani et al. [17] adopted SRSD and non-SRSD models in two universities. They found that the SRSD model could significantly improve persuasive learning ability. Harris et al. [18] found a significant effect on improving learning ability in more complete, longer, and better learning through the application of SRSD in teaching strategies to students with attention deficit hyperactivity disorder. Ennis et al. [19] believed that SRSD is a teaching method that has been proved successful for students with EBD. They found a functional relationship between SRSD teaching and the learning performance of students, which could be measured by summarizing elements, quality, and total words.

Schneider et al. [20] conducted a comparative test on the learning skills of four boys with Asperger's syndrome. They found that SRSD can significantly improve the fluency and quality of learning. Hagaman et al. [21] believed that SRSD is the mainstream model to address the learning ability of students at different levels and improve their learning levels of students. The results of Asaro-Saddler et al. [22] demonstrated that SRSD methods can significantly improve learning quality, and older students can benefit more from the intervention. Popham et al. [23] proved the effectiveness of SRSD reading intervention for disabled students in a school environment.

Virtual reality is a computer environment that helps users create a virtual world and obtain simulation experience. It gives users an immersive interactive experience. The sense of presence obtained through immersion is a main driving force for the application of virtual reality in teaching. In virtual reality-based teaching, virtual reality can simulate the unreachable scenes in the real world, enable learners to participate in the virtual observation and natural interaction of abstract concepts, and improve learners' cognition and understanding of abstract things. Virtual reality has a good application prospect for teaching form innovation

The literature shows that based on extensive teaching studies, many scholars had carried out many relevant studies to continuously improve SRSD. These studies combined different learning styles and strategies, widely connected cognitive factors of students, and considered different objects at different age levels [24-25]. However, empirical studies on how to use the SRSD model efficiently in virtual reality-based teaching are extremely limited. Therefore, this study chose the SRSD model, which has an extensive research foundation, to conduct research on the teaching of graduate students, aiming to accumulate more empirical research materials for the SRSD model and expect to have certain guiding significance for improving the virtual reality-based teaching of students.

3 Methodology

Based on the SRSD model, this study scientifically analyzed the performance of virtual reality-based teaching of postgraduates with or without the SRSD model. Quantitative analysis of collected data was performed using the statistical software SPSS 22.0, including independent sample T-test, correlation analysis, and paired sample T-test [26].

3.1 Research objects

This study used samples of first-grade graduate students majoring in linguistics from Guangzhou Institute of Technology in China. This experiment comprised two classes, of which one was an experimental class and the other was a control class. To increase the reliability of the experimental results, the members of the research group undertook the teaching work in two classes: an experimental class and a control class.

3.2 Research steps

The course "Business communication" for graduate students majoring in linguistics was used as a score marker. In this course, virtual reality technology was used to simulate a real business negotiation environment. A self-regulated questionnaire was used to obtain the score. Course scores and self-regulated scores were converted into the range of 0-100 points. The research steps are as follows. The first step is the pretest of learning performance and self-regulation. The students were randomly divided into classes when they entered school. To increase the reliability and validity of this experiment, they must conduct a pretest on their course scores and self-regulation to test whether significant differences occurred in "Business communication." The independent sample T-test was performed on the data results.

The second step is the teaching experiment. The SRSD mode was used in the experimental class, and the conventional virtual reality-based teaching mode was used in the control class. The experimental and the control groups underwent the virtual reality-based teaching of the "Business communication" course for eight weeks. Afterward, the post-test was conducted. This study performed a self-regulated questionnaire and test for the experimental group and the control group again by using the two-paired sample T-test method.

4 Results analysis

4.1 Pretest scores and pretest self-regulation

Table 1 shows that the t-test (independent sample t-test) was used to study the difference between two items of pretest scores and pretest self-regulation. The table shows no significant differences in pretest scores and pretest self-regulation for all different samples (p>0.05). This finding means that all different samples are consistent in the pretest scores and pretest self-regulation without any difference. Therefore, the scores and self-regulation ability in the experimental and control classes before the experiment were at the same level, ensuring the consistency of subjects with those before the experiment without any individual differences.

Table 1. Pretest scores and pretest self-regulation

Items	Groups	Sample size	Average	Standard deviation	Mean difference	D-value 95% CI	*t*	*df*	*p*
Pretest scores	Control	25	70.86	5.76	0.29	-3.195 ~ 3.779	0.168	48	0.867
	Experiment	25	70.57	6.48					
	Total	50	70.72	6.07					
Pretest self-regulation	Control	25	70.41	7.13	-1.3	-5.687 ~ 3.095	-0.593	48	0.556
	Experiment	25	71.7	8.27					
	Total	50	71.06	7.67					

$^{*}p$<0.05, $^{**}p$<0.01

4.2 Correlation analysis

This experiment investigated the following three aspects: 1. whether a correlation exists between learning performance and self-regulation, 2. whether a significant difference exists between the SRSD and conventional teaching models on the influence of students, and 3. whether a significant difference exists between the experimental and control groups in self-regulation ability after adopted different teaching modes.

Table 2 shows that the correlation coefficient between pretest score and pretest self-regulation was 0.981 and had a significant difference at 0.01. Thus, a significant positive correlation was found between pretest scores and pretest self-regulation. The correlation coefficient between post-test score and post-test self-regulation was 0.976 and had a significant difference at 0.01. Thus, a significant positive correlation was observed between post-test scores and post-test self-regulation.

Table 2. Correlation coefficient

Pearson	Pretest score	Pretest self-regulation	Pearson	Post-test score	Post-test self-regulation
Pretest score	1	-	Post-test score	1	-
Pretest self-regulation	0.981**	1	Post-test self-regulation	0.976**	1

*p<0.05, **p<0.01

4.3 Paired sample T-test

Table 3 shows a significant difference between the pretest and post-test scores of students in the control group at 0.05 (t=−2.520, p=0.019). The average value of the pretest score (70.48) was significantly lower than that of the post-test score (75.52). A significant difference was found between pretest self-regulation and post-test self-regulation in the control group at 0.01 (t=−4.494, p=0.000), and the average value of pretest self-regulation (69.28) was significantly lower than that of post-test self-regulation (77.36).

Table 3. The paired t-test analysis result

Group	Item	Pair (average value ± standard deviation)		D-value (Pair 1-Pair 2)	*t*	*p*
		Pair 1	*Pair 2*			
Control group	Pretest score vs Post-test score	70.84± 5.70	75.52± 6.17	-4.68	-2.52	0.019*
	Pretest self-regulation vs Post-test self-regulation	69.28± 6.01	77.36± 6.10	-8.08	-4.494	0.000**
Experimental group	Pretest score vs Post-test score	70.56± 6.52	79.48± 6.35	-8.92	-4.925	0.000**
	Pretest self-regulation vs Post-test self-regulation	67.96± 7.04	82.16± 6.46	-14.2	-7.505	0.000**

*p<0.05, **p<0.01

A significant difference was observed between the pretest and post-test scores in the experimental group at 0.01 (t=−4.925, p=0.000), and the average value of the pretest score (70.56) was significantly lower than that of the post-test score (79.48). A significant difference was found between pretest self-regulation and post-test self-regulation in the experimental group at 0.01 (t=−7.505, p=0.000), and the average value of pretest self-regulation (67.96) was significantly lower than that of post-test self-regulation (82.16).

In findings, the paired sample T-test results showed a significant difference in terms of the improved range of post-test results and pretest results of score and self-regulation ability in the control group (p<0.05) after eight weeks each of different modes of virtual reality-based teaching in online learning. The results of the experimental group were the same as those of the control group, indicating that the traditional models and SRSD models play an important role in promoting virtual reality-based teaching. The post-test scores of the students in both classes have been improved compared to pretest scores, indicating that the virtual reality-based teaching guidance of students in both classes is helpful to improve their scores. Compared with the control class, the scores of the SRSD experiment class have been improved more, indicating a significant difference.

Direct and clear guidance on the virtual reality-based teaching process of students can greatly help to improve the ability of students. The main reason for this finding is that, through the guidance of the SRSD model, students could have a better understanding of the virtual reality-based teaching process required by teachers and better regulate their learning process so that they can skillfully use strategies to ensure learning quality. In addition, the strategy guided by the SRSD model provides learners with a learning blueprint. Learners can make full use of the blueprint, gradually promote it according to the teaching mode, and complete tasks one by one during the process. Compared with the traditional virtual reality-based teaching mode, students had a more detailed understanding of their learning process, and they could use strategies to improve their learning level, Students are the core of the whole learning process, turning the virtual reality-based teaching by teachers into a learning process for students. Teaching responsibility can be transferred from being purely from teachers to students themselves, inspiring learning initiative and the desire of learners for knowledge.

In the process of gaining comprehensive learning skills, students can not only undertake responsibility purely but also enjoy many benefits. Under the SRSD model, the whole learning process focuses on the needs of students, from paper structure analysis to teacher demonstration and then to mutual discussion with classmates. Therefore, the whole teaching link could meet the demands of students, fundamentally improving their learning enthusiasm.

4.4 Difference between post-test self-regulation and post-test score

Table 4 shows that all post-test scores in the experimental and control groups were significant ($p<0.05$), meaning that different teaching methods have different post-test scores. Different teaching modes had significant effects on post-test scores at 0.05 ($t=-2.237$, $p=0.030$). The average value of post-test scores in the control group (75.52) was significantly lower than that in the experimental group (79.48). All post-test self-regulation in the experimental and control groups was significant ($p<0.05$). This finding indicates that different teaching methods have different post-test self-regulation at 0.01 ($t=-2.786$, $p=0.008$), and the average value of post-test self-regulation in the experimental group (82.61) was significantly higher than that in the control group (77.08). Therefore, the two models can promote students, but the SRSD model is superior to the conventional model. The main reason for this result is that learners can make full use of the time before class to accumulate knowledge and make preliminary preparations for class tasks under the SRSD model.

Table 4. Difference between post-test self-regulation and post-test score

	Classification (average value ± standard deviation)		***t***	***p***
	Control (n=25)	***Experiment (n=25)***		
Post-test score	75.52±6.17	79.48±6.35	-2.237	0.030*
Post-test self-regulation	77.08±6.27	82.16±6.62	-2.786	0.008**

$^{*}p$<0.05, $^{**}p$<0.01

During the process of virtual reality-based teaching, learners can effectively realize self-regulation and adopt more suitable learning strategies for learning practice. Through the reasonable arrangement of time, scientific development of learning objectives, and increased consistency with teaching plans, learners can carry out self-evaluation more automatically after the completion. Teacher evaluation and peer mutual evaluation will also encourage learners to check whether they have mastered learning skills.

5 Teaching implications

5.1 Strengthen self-regulation of learners and adopt appropriate learning strategy

Virtual reality-based teaching is a complex process involving planning before teaching, adjustment during teaching, and modification after teaching. In the actual virtual reality-based teaching process, students, especially those with poor learning skills, often ignore the planning before learning stage and abandon the modification after learning stage. They also lack an understanding and good control over the whole virtual reality-based teaching process. In online teaching classes, students understand the problem of the composition with the help of teachers, but they often cannot correct their problems in the next composition and repeat their mistakes. Therefore, teachers work hard but students gain less knowledge. Virtual reality-based teaching guidance based on the SRSD model teaches students to use strategy, gives students enough opportunities to exercise, transfers the responsibility of improving learning to students themselves, constantly improves their online learning methods, and increasingly increases their sense of self-efficacy.

5.2 Encourage the interaction between teachers and students as well as students and students to promote emotional communication

In traditional virtual reality-based teaching, teachers often cannot take good care of the learning needs of students. Some of them lack real guidance. Often, virtual reality-based teaching classes are turned into the computer game. Some teachers are more eager to imbue students with knowledge and skills, but they cannot take care of the needs of students. Here, students have not fully mastered such a strategy and cannot use virtual reality scientifically. Therefore, online teaching classes should make full use of teacher-student interaction and student-student interaction, giving students enough opportunities to confirm their understanding of classroom content with teachers and peers. Such an approach can effectively improve the efficiency of virtual reality-based teaching in online learning. The SRSD model puts more emphasis on help from peers and teachers. Especially in the demonstration and discussion stage, students can learn considerably from peers and teachers and further stimulate their learning motivation.

5.3 Encourage learners to explore their personalized learning methods

Virtual reality-based teaching in online learning is a complex process and requires the full participation of different roles. The teaching guidance of the SRSD model requires that teachers give different types of help to different students in virtual reality-based teaching. Learners should also have the opportunity to seek help from peers and strengthen their interaction with their peers. To better evaluate the learning status of students, the SRSD teaching model supports students and teachers to truly control the learning process through establishing archives and other diversified ways. They can also use learning records to analyze the learning effect of different learners. In particular, in virtual reality-based teaching, the integration of the SRSD model with big data technology can help students to achieve the teaching goals and see their progress, improve their enthusiasm for learning, and finally improve their scores.

6 Conclusion

Virtual reality-based teaching is not only diversified but also updated in real-time. Students can master the latest learning materials and actively participate in the search and selection of learning resources under the instruction of teachers. Thus, virtual reality-based teaching in online learning becomes the mainstream mode in the context of the current epidemic. Owing to the spatial separation between teachers and students as well as students and students in virtual reality-based teaching in online learning, learning performance has attracted considerable attention. The learning performance of learners can be effectively improved with the SRSD model. Based on the SRSD model, this paper experimented with first-grade linguistics students in a provincial graduate school in China to test the influence of the SRSD model on the performance of virtual reality-based teaching in online learning. The results showed that the course score and self-regulation ability of students in the experimental and control groups have been improved. However, the degree of improvement in these two aspects was significantly different between the two groups. Further research is suggested to be made on the influence of the SRSD model on self-efficacy, thinking ability, and application of learning strategy of students.

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8 References

[1] Graham, S., Harris, K. R. (1987). Improving composition skills of inefficient learners with self-instructional strategy training. Topics in Language Disorders. 7(4), 66-77. https://doi.org/10.1097/00011363-198709000-00008
[2] Limpo, T., & Alves, R. A. (2014). Implicit theories of writing and their impact on students' response to a SRSD intervention. British Journal of Educational Psychology, 84(4), 571-590. https://doi.org/10.1111/bjep.12042
[3] Graham, S., Harris, K. R. (1999). Assessment and intervention in overcoming writing difficulties: An illustration from the self-regulated strategy development model. Language, Speech, and Hearing Services in Schools, 30(3), 255-264. https://doi.org/10.1044/0161-1461.3003.255
[4] Gillespie Rouse, A., Kiuhara, S. A. (2017). SRSD in writing and professional development for teachers: Practice and promise for elementary and middle school students with learning disabilities. Learning Disabilities Research & Practice, 32(3), 180-188. https://doi.org/10.1111/ldrp.12140
[5] McKeown, D., FitzPatrick, E., Sandmel, K. (2014). SRSD in practice: Creating a professional development experience for teachers to meet the writing needs of students with EBD. Behavioral Disorders, 40(1), 15-25. https://doi.org/10.17988/0198-7429-40.1.15
[6] Chen, J., Zhang, L. J., Parr, J. M. (2021). Improving EFL students' text revision with the Self-Regulated Strategy Development (SRSD) model. Metacognition and Learning, 1-21. https://doi.org/10.1007/s11409-021-09280-w
[7] Ray, A. B., Graham, S., Liu, X. (2019). Effects of SRSD college entrance essay exam instruction for high school students with disabilities or at-risk for writing difficulties. Reading and Writing, 32(6), 1507-1529. https://doi.org/10.1007/s11145-018-9900-3
[8] McKeown, D., Brindle, M., Harris, K. R., Graham, S., Collins, A. A., Brown, M. (2016). Illuminating growth and struggles using mixed methods: Practice-based professional development and coaching for differentiating SRSD instruction in writing. Reading and Writing, 29(6), 1105-1140. https://doi.org/10.1007/s11145-016-9627-y
[9] Peltier, C., Garwood, J. D., McKenna, J., Peltier, T., Sendra, J. (2021). Using the SRSD instructional approach for argumentative writing: A look across the content areas. Learning Disabilities Research & Practice, 36(3), 224-234. https://doi.org/10.1111/ldrp.12255
[10] Harris, K. R., Lane, K. L., Graham, S., Driscoll, S. A., Sandmel, K., Brindle, M., Schatschneider, C. (2012). Practice-based professional development for self-regulated strategies development in writing: A randomized controlled study. Journal of Teacher Education, 63(2), 103-119. https://doi.org/10.1177/0022487111429005
[11] Santangelo, T., Harris, K. R., Graham, S. (2008). Using self-regulated strategy development to support students who have "trubol giting thangs into werds". Remedial and special education, 29(2), 78-89. https://doi.org/10.1177/0741932507311636

[12] Graham, S., Harris, K. R., Mason, L. (2005). Improving the writing performance, knowledge, and self-efficacy of struggling young writers: The effects of self-regulated strategy development. Contemporary educational psychology, 30(2), 207-241. https://doi.org/10.1016/j.cedpsych.2004.08.001
[13] Zumbrunn, S., Bruning, R. (2013). Improving the writing and knowledge of emergent writers: The effects of self-regulated strategy development. Reading and Writing, 26(1), 91-110. https://doi.org/10.1007/s11145-012-9384-5
[14] Sexton, M., Harris, K. R., Graham, S. (1998). Self-regulated strategy development and the writing process: Effects on essay writing and attributions. Exceptional Children, 64(3), 295-311. https://doi.org/10.1177/001440299806400301
[15] Miller, K. M., Little, M. E. (2018). Examining the effects of SRSD in combination with video self-modeling on writing by third grade students with learning disabilities. Exceptionality, 26(2), 81-105. https://doi.org/10.1080/09362835.2017.1283622
[16] Zito, J. R., Adkins, M., Gavins, M., Harris, K. R., Graham, S. (2007). Self-regulated strategy development: Relationship to the social-cognitive perspective and the development of self-regulation. Reading & Writing Quarterly, 23(1), 77-95. https://doi.org/10.1080/10573560600837693
[17] Baghbadorani, E. A., Roohani, A. (2014). The impact of strategy-based instruction on L2 learners' persuasive writing. Procedia-Social and Behavioral Sciences, 98, 235-241. https://doi.org/10.1016/j.sbspro.2014.03.412
[18] Harris, K. R., Graham, S., Friedlander, B., Laud, L. (2013). Bring powerful writing strategies into your classroom! Why and how. The Reading Teacher, 66(7), 538-542. https://doi.org/10.1002/TRTR.1156
[19] Ennis, R. P. (2016). Using self-regulated strategy development to help high school students with EBD summarize informational text in social studies. Education and Treatment of Children, 39(4), 545-568. https://doi.org/10.1353/etc.2016.0024
[20] Schneider, A. B., Codding, R. S., Tryon, G. S. (2013). Comparing and combining accommodation and remediation interventions to improve the written-language performance of children with Asperger syndrome. Focus on Autism and Other Developmental Disabilities, 28(2), 101-114. https://doi.org/10.1177/1088357613475811
[21] Hagaman, J. L., Luschen, K., Reid, R. (2010). The "RAP" on reading comprehension. Teaching exceptional children, 43(1), 22-29. https://doi.org/10.1177/004005991004300103
[22] Asaro-Saddler, K., Moeyaert, M., Xu, X., Yerden, X. (2021). Multilevel meta-analysis of the effectiveness of self-regulated strategy development in writing for children with ASD. Exceptionality, 29(2), 150-166. https://doi.org/10.1080/09362835.2020.1850457
[23] Popham, M., Adams, S., Hodge, J. (2020). Self-regulated strategy development to teach mathematics problem solving. Intervention in School and Clinic, 55(3), 154-161. https://doi.org/10.1177/1053451219842197
[24] Lim, C., Ab Jalil, H., Ma'rof, A., Saad, W. (2020). Peer learning, self-regulated learning and academic achievement in blended learning courses: A structural equation modeling approach. International Journal of Emerging Technologies in Learning, 15(3), 110-125. https://doi.org/10.3991/ijet.v15i03.12031
[25] Suartama, I., Setyosari, P., Sulthoni, S., Ulfa, S., Yunus, M., Sugiani, K. (2021). Ubiquitous learning vs. electronic learning: a comparative study on learning activeness and learning achievement of students with different self-regulated learning. International Journal of Emerging Technologies in Learning, 16(3), 36-56. https://doi.org/10.3991/ijet.v16i03.14953

[26] Nuñez Ramírez, M. A., Wendlandt Amezaga, T. R., Álvarez Medina, M. T. (2016). The relationship between organizational culture and knowledge management in Tequila companies from Mexico. International Journal of Advanced Corporate Learning, 9(1), 44-50. https://doi.org/10.3991/ijac.v9i1.5748

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Satisfaction of University Students with Teaching Performance, When Applying Virtual Teaching in the Context of COVID-19

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Abstract—This article aims to analyze the satisfaction of university students from the perspective of teaching performance, in face-to-face (2019-II) and virtual (2020-I) teaching-learning, due to the health emergency, declared in Peru, by COVID-19. These results will allow the Public University to implement continuous improvement plans in the teaching-learning development of the virtual environment. When performing the comparative analysis, it was determined that the careers that present the greatest satisfaction in 2020 - I, are business administration with 82.97% and systems engineering with 78.07%. Then it was identified that the indicators that present a greater negative variation are "The quality of the development of classes and activities" with 5.88%, and "Treatment of students during class", with 2.49%. With these results it can be indicated that the satisfaction of the students has presented a slight positive variation towards the teaching performance when applying the virtual modality.

Keywords—student satisfaction, teaching performance, virtual teaching

1 Introduction

The analysis of satisfaction at the university level is a subject that has been widely investigated, however the current global context is immersed, due to the COVID-19 pandemic, therefore it is more than necessary to identify the effects that are occurring in the university teaching and learning process. In [1], the author points out that the progress of a country depends to a great extent on the educational quality offered by universities, which can be measured through student satisfaction.

In the same line of opinion in [2], the author points out that university satisfaction is conceived as a pleasant state that largely depends on the conditions in which professional development takes place. In relation to the teacher and his performance, in [3], the author points out that there are undoubtedly many factors that are related to university quality, and as such it represents a key and relevant factor for the teaching and learning process.

In this regard, in [4], the author points out that perception studies on teacher performance are very useful, since they contribute to improving teacher professional development, in a situation of competitiveness and technological development.

In relation to the above in [5], the author establishes that the process of evaluating the perception of teacher performance is about carrying out an evaluation of a learning act, fundamentally to understand and transform the professional practices of the teacher to the benefit of student. As indicated in [6], the existence of an evaluation system allows the continuous improvement of educational quality and the detection of relevant aspects to improve.

But, everything cited above is in a context of non-existence of a COVID-19 pandemic, in this regard in [7], the author points out that quickly, almost without realizing it, the pandemic transformed the teaching process, from strongly defined models to almost improvised models very dependent on the internet. In the same line of opinion in [8], the author points out that the pandemic has revealed the weaknesses of the system to adapt face-to-face teaching to virtual mode.

In [9], the author also points out that the universities had to migrate urgently, and from the challenges they were already facing in their face-to-face mode, this hasty transition has subjected them to a stress test, showing today many deficiencies, one of these is the teaching performance under this context.

In this regard, in [10], the author points out that, although technological changes occur at an impressive speed, changes in the routines of the university teacher must be gradually modulated because a deficient use, didactically speaking of technological tools, affects perception of student satisfaction.

In addition, in [11], the author points out that, in this context, the expectations of students who use the virtual modality demand that universities develop an approach towards the quality of education, systematically evaluating the educational model to achieve the greatest level of student satisfaction.

In this sense, the purpose of this article is to analyze the findings of the satisfaction of university students towards teaching performance, when teaching was with the face-to-face modality and when it was changed to the virtual modality, due to the declared health emergency in Peru, by COVID-19. For which, initially, the results obtained from the indicators that make up the variable of teacher performance, by professional school; thus determining the professional school that presents the greatest satisfaction. To later identify in a general way, the indicators with negative variation. Finally, the margin of increase or decrease of satisfaction will be determined.

2 Research methodology

The comparative analysis to determine the satisfaction of the students was carried out in two different academic semesters, in the 2019-II semester, with the face-to-face modality and the 2020-I semester, when the virtual modality was applied, in a Public University of Peru.

Likewise, the population will be composed of students from the seventh to the tenth cycle of 5 professional schools. On the other hand, the sample under study will be made up of the entire population, since it was possible to apply the data collection instrument, through a survey, to the entire student population, this in order to achieve greater precision in the obtaining results.

It should be noted that in the data collection instrument, the data are dichotomous, that is, the alternatives are dissatisfied and satisfied. As described in Table 1, the research sample is detailed.

Table 1. Research population and sample

Population (Students)	2019-II	2020-I
Systems Engineering	149	146
Electronic Engineering and Telecommunications	136	172
Environmental Engineering	147	177
Business Administration	135	155
Mechanical and Electrical Engineering	107	172

The data collected were subjected to a validity analysis using Cronbach's alpha, using the SPSS. Which determined that the coefficient in the 2019-II semester is 0.849 and in the 2020-I semester it is 0.921, according to statistical theory, it means that the data collected presents excellent reliability. Therefore, the research results are presented safely and reliably.

The following figure shows the indicators of teacher performance that have been considered in the satisfaction survey. These indicators are part of the data collection instrument, used and validated in research carried out in the context of the health emergency, as evidenced in [12] and [13]. It should be noted that the application of the data collection instrument was carried out at the end of the academic semesters; this criterion is used with the purpose that the student has a greater spectrum of experiences acquired based on the teaching performance in the context of virtual teaching.

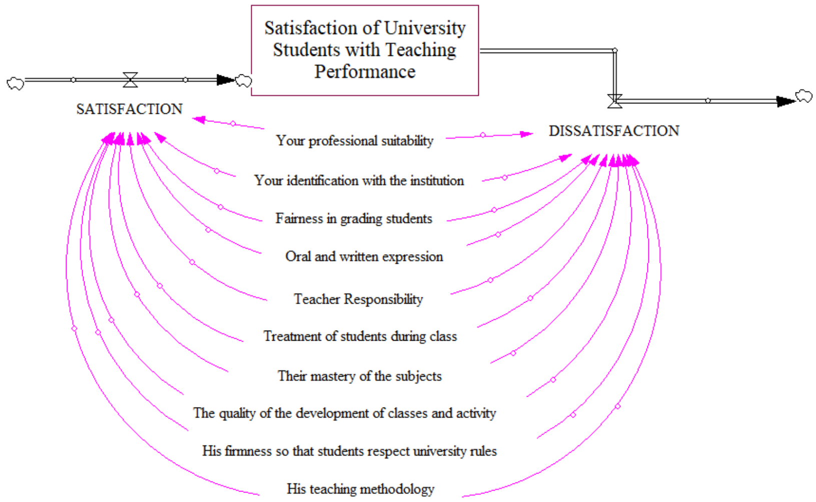

Fig. 1. Modeling according to the students' satisfaction or dissatisfaction perspective

3 Results and discussion

3.1 Results of the investigation

In Figure 2, you can see the results of the comparative analysis of the satisfaction of the 10 indicators, for the 2019-II semester and the 2020-I semester.

As can be seen, the business administration career presents the highest percentage of satisfaction with 82.97% in the 2020-I semester and 83.85% in the 2019-II semester. Likewise, the results do not show that the Mechanical and Electrical Engineering degree is the one with the greatest negative variation in satisfaction of 3.96%. While the Systems Engineering career presents the highest positive variation of 7.54%.

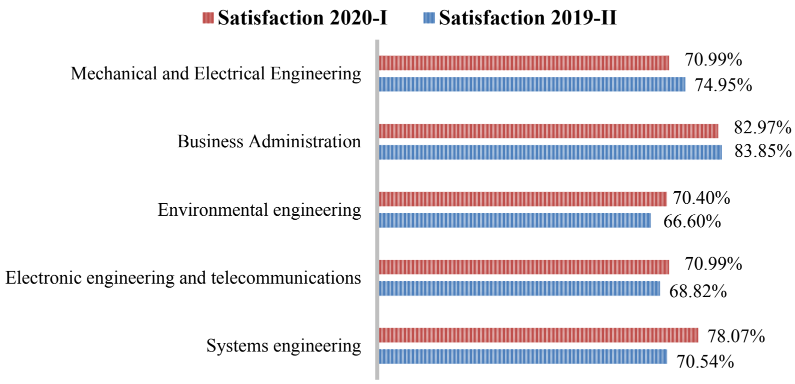

Fig. 2. Satisfaction of teacher performance indicators by professional school

In Figure 3, you can see the comparative analysis of the satisfaction of the 10 indicators belonging to the variable teacher performance, of the 5 professional schools. As can be seen in Figure 3, the indicator that presents a greater positive variation of 9.87%, is the indicator "Teacher's responsibility"; then there is the indicator "His firmness so that students respect university rules", with a positive variation of 5.25%. Likewise, the indicator that presents the greatest negative variation with 5.88%, is the indicator "The quality of the development of classes and activities", followed by the indicator "Treatment of students during class", with a percentage of negative variation 2.49%. From Figure 3 it can be deduced that student satisfaction towards teaching performance presents a slight improvement of 1.73%, when applying the virtual modality.

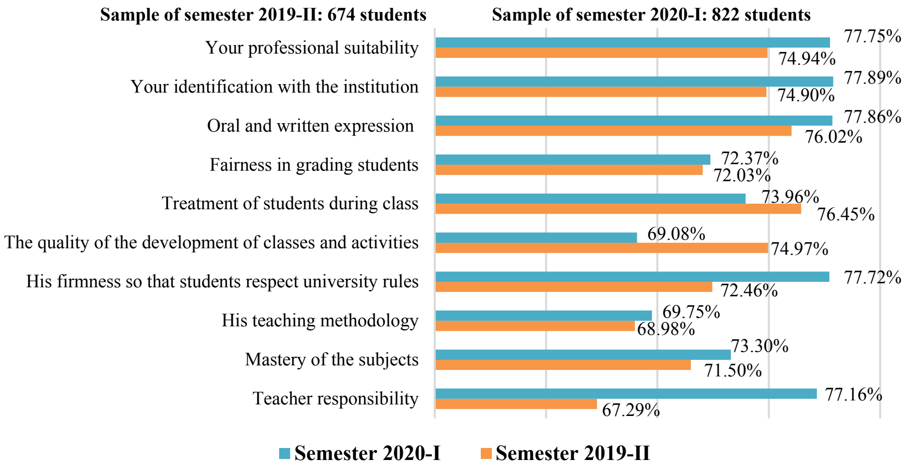

Fig. 3. Satisfaction of the 10 teacher performance indicators

In the following table we will identify the percentage of students who are dissatisfied, with respect to the two indicators that present the greatest negative variation. For this we will take with reference the systems engineering career.

Table 2. Percentage of dissatisfaction of students of the indicators with the greatest negative variation

Results obtained for the Professional School of Systems Engineering				
	Treatment of students during class		**The quality of the development of classes and activities**	
	Frequency	***Percentage***	***Frequency***	***Percentage***
Dissatisfied	45	30.4	50	33.8
Satisfie	101	68.2	96	64.9
Total	146	100.0	146	100.0

Although the systems engineering school is one of those that presents the greatest satisfaction, when implementing the virtual modality, a significant number of students, representing 33.8% and 30.4%, are dissatisfied with the indicators that have presented a greater negative variation.

In Figure 4, the causal or influence diagram obtained using the Vensim software is shown, the same as from the entry of the data collected from each of the indicators under study, referring to the sample analyzed during the academic semester 2020-I, evidence that there are significant levels of association between each of the indicators with respect to the perception of satisfaction of teaching performance in the context of virtual teaching. Thus, it can also be seen that the indicator with the lowest contribution or influence on the perception of student satisfaction is the indicator called "Oral and written expression", with a level of 62.4%, while the indicator with the highest contribution is "Treatment of students during class", whose level is 82.4%.

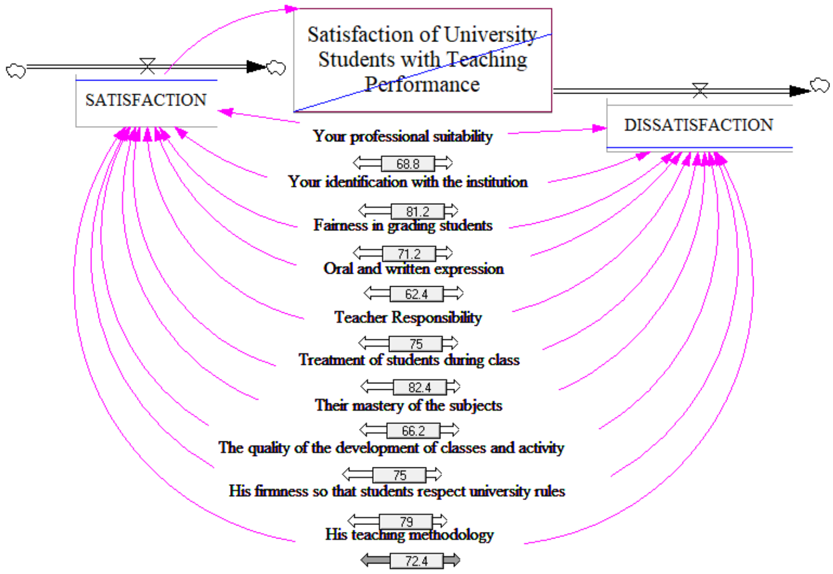

Fig. 4. Variation of the behavior of the variable student satisfaction towards teaching performance

3.2 Discussion

The business administration career and the systems engineering career present the highest percentage of satisfaction while the Mechanical and Electrical Engineering career is the one that presents the greatest negative variation in satisfaction from the perspective of teaching performance.

This can be supported by the nature of the systems engineering career, which implies that the teacher, as part of their methodology, uses simulation software for the delivery of their classes, thus complying with the curricular requirements; As indicated in [14], student satisfaction in teaching-learning is highly related to the fact that the teacher fully complies with what is established in the curricular plan, since this allows the student to feel that he is developing professionally.

Another different scenario occurs, in the Mechanical and Electrical Engineering career, because this career does not have the appropriate tools to carry out its subjects, which mostly involve carrying out mathematical calculations and practical electrical and mechanical activities; As indicated in [15], the satisfaction of students in engineering careers is related to the efficient fulfillment of their practical training during the teaching-learning process.

As it was determined, the indicators that present a greater positive variation are: "Teacher's responsibility" and "His firmness so that students respect university norms". Likewise, the indicators that show the greatest negative variation are: "The quality of the development of classes and activities" and "Treatment of students during class".

Regarding the quality of the classes, in the study of [16], it is pointed out that the causes of dissatisfaction of the students are related to the lack of preparation or updating of the teacher in the use of technological tools that allow the professional development of the student. This arises from the abrupt change from the face-to-face to the virtual modality, since many state universities lack optimal tools for the development of various subjects and this abrupt change has not allowed the correct training, education and adaptation of the teacher. In addition, there is the poor internet connectivity that both teachers and students present, since this new teaching-learning normality often saturates the internet signal, making classes not continuous. As indicated in [17], student satisfaction with teaching performance is related to the quality of the explanation and to understanding efficiently by the student.

An important aspect is the results that show that the percentage of student satisfaction was found to increase slightly during virtual learning in all indicators; This is due to the fact that although it was abruptly to move from the face-to-face to the virtual, the response of the university institution allowed to guarantee the continuity of the educational service, through the implementation of a virtual platform, whose functionality and operation, turned out to satisfy the expected demand for the students. In this regard, in [12], the author points out that the declaration of the state of emergency did not allow the development of aspects associated with the virtual teaching-learning process in a planned and structured way, however the universities made necessary efforts, which led to the implementation of learning environments virtual.

Finally, two indicators of the systems engineering study program (see Table 2) show a decrease in the level of satisfaction, and this result allows the identification of certain deficiencies focused on the performance of the teacher with respect to the interaction with virtual tools, since the lack of training and adequacy of the teacher in the management of this type of environment, are reflected in these two indicators; In this regard, in [13], it is specified that in the systems engineering school the teacher's challenge is greater with respect to the domain and management of virtual environments, since the use of software or computer programs is in itself necessary and essential, which at the same time involve competencies related to the management of information and communication technologies.

4 Conclusions

During the research, it was determined that the business administration career presents the highest percentage of satisfaction, with 82.97% in the 2020-I semester, followed by the systems engineering career with 78.07%. Likewise, the indicators that present a greater negative variation are "The quality of the development of classes and activities" with 5.88% and "Treatment of students during class", with 2.49%. With these results it can be indicated that the satisfaction of the students has presented a slight positive variation of 1.73% towards the teaching performance when applying the virtual modality.

To continue improving the satisfaction percentage, it is suggested the implementation of didactic strategies through digital resources, feedback programs, follow-up and monitoring of the integral commitment of the students and the teacher with the teaching-learning process; this process must be associated with the support of the authorities of the public university and of the state itself.

Another important conclusion is that the results are limited to a population made up of students from the seventh to the tenth cycle, in the context of virtual teaching; Under this precision, it is necessary to complement, through further research, the analysis of results for the other population group (students from the first to the sixth cycle), and evaluate how significant the contribution in the results of the perception of satisfaction is of this population not studied with respect to the results shown in this investigation.

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6 References

[1] E. Surdez-Perez, M. Sandoval-Caraveo and C. Lamoyi-Bocanegra, “Student satisfaction in the assessment of university educational quality,” *Education and Educators*, vol. 21, no.1, pp. 9-26, 2018. https://doi.org/10.5294/edu.2018.21.1.1

[2] M. Tobón, M. Durán and A.Äñez, “Academic and Professional Satisfaction of University Students,” Electronic Journal of Humanities, *Education and Social Communication*, vol. 22, no. 11, pp. 110-129, 2017.

[3] E. Escribano, “Teacher performance as a factor associated with educational quality in Latin America,” *Education Journal*, vol. 42, no. 2, pp. 49-58, 2018.

[4] G. Alvarez, D. Tchimnhama and M. Morales, “Performance evaluation of university teachers: an approach to educational realities,” *University and Society Journal*, vol. 9, no. 2, pp. 237-241, 2017.

[5] J. Cabero, J. Morales, “Evaluation of teacher performance in virtual training: ideas for the configuration of a model,” *Ibero-American Journal of Distance Education*, vol. 21, no. 1, pp 261-279, 2018. https://doi.org/10.5944/ried.21.1.17206

[6] G. Martinez-Chairez, A. Guevara-Araiza and M. Valles-Ornelas, “Teaching performance and educational quality,” *Ra Ximhai Journal*, Vol. 12, no. 6, pp. 123-134, 2016. https://doi.org/10.35197/rx.12.01.e3.2016.06.gm

[7] J. Cabero-Almera and C. Llorente-Cejudo, "COVID-19: radical transformation of digitization in university institutions," *Virtual Campus Journal*, vol. 9, no. 2, pp. 25-34, 2020.
[8] A. Baladrón, B. Correyro and B. Manchado, "The digital transformation of university teaching in communication during the COVID-19 crisis in Spain: an approach from the student's perspective," *Latin Journal of Social Communication*, vol. 18, no. 1, pp. 265-287, 2020.
[9] A. Lozano-Diáz, J. Frenandez-Prados and V. Figueredo, "Impacts of confinance by COVID-19 among university students: life satisfaction, resilience and social capital," *Rise Journal*, vol. 10, no. 2, pp. 79-104, 2020. https://doi.org/10.17583/rise.2020.5925
[10] N. Almusharraf and S. Khahro, "Students' Satisfaction with Online Learning Experiences During the COVID-19 Pandemic," *International Journal of Emerging Technologies in Learning*, vol. 15, no. 21, pp. 246-267, 2020. https://doi.org/10.3991/ijet.v15i21.15647
[11] N. Suárez, "University teacher training and the COVID-19 health crisis," *CienciAmerica Journal*, vol. 9, no. 2, pp. 254-268, 2020.
[12] N. Alvarado-Bravo, et al., "The Context of the Covid-19 Pandemic and its Effect on the Self-Perception of Professional Competences by University Students of Business Administration," *Advances in Science, Technology and Engineering Systems Journal*, vol. 6, no. 2, pp. 665-670, 2021. https://doi.org/10.25046/aj060277
[13] T. Diaz-Leyva, et al., "Variation in Self-Perception of Professional Competencies in Systems Engineering Students, due to the Covid-19 Pandemic," *Advances in Science, Technology and Engineering Systems Journal*, vol. 6, no. 1, pp. 1024-1029, 2021. https://doi.org/10.25046/aj0601113
[14] A. Abulrub, A. Attridge and M. Williams, "Virtual Reality in Engineering Education: The Future of Creative Learning," *International Journal of Emerging Technologies in Learning*, vol. 6, no. 4, pp. 4–11, 2010. https://doi.org/10.3991/ijet.v6i4.1766
[15] A. Ojeda-Beltran, D. Ortega-Alvarez and E. Boom-Carcamo, "Analysis of the perception of face-to-face students about virtual classes in response to the COVID-19 crisis," *Espacios Journal*, vol. 41, no. 42, 81-86, 2020. https://doi.org/10.48082/espacios-a20v41n42p07
[16] B. Bahati, U. Fors, P. Hansen, J. Nouri and E. Mukama, "Measuring Learner Satisfaction with Formative e-Assessment Strategies," *International Journal of Emerging Technologies in Learning*, vol. 14, no. 7, pp. 246-247, 2019. https://doi.org/10.3991/ijet.v14i07.9120
[17] D. Reyero, "University teaching excellence: Analysis and proposals for a better evaluation of university teaching staff," *Education Journal*, vol. 17, no. 2, pp. 125-143, 2016.

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