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Table of Contents

Papers

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Natural Language Processing for Mapping Exam Questions to the Cognitive Process Dimension

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Abstract—Exam questions as a test instrument to measure educational success must have good quality. This quality can be measured by the level of cognition expected of students. The level of cognition reflects the mastery of learning materials as a form of evaluation of the teaching and learning process outlined in the curriculum. For this reason, the exam questions need to be mapped into the cognitive process dimensions, namely based on the categories in the Revised Bloom's Taxonomy (RBT). The mapping method used is Natural Language Processing (NLP) as one of the fields of Artificial Intelligence development. The stages in this mapping are pre-processing, including tokenization, stemming, stop-word removal, and feature extraction using POS Tagging. The output of this mapping process is in the form of categories of test items into RBT: remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6). The classification results obtained information that the exam questions prepared were still dominated at the C2 cognitive level, which was indicated by the use of operational verbs in the understanding category. The results of testing the method used produce an accuracy of 82.22%. Thus, the NLP method can classify test items into Revised Bloom's Taxonomy to determine the dimensions of students' cognitive processes.

Keywords—Natural Language Processing, exam questions, cognitive process dimension, Revised Bloom's Taxonomy

1 Introduction

Education is a system, while learning is a form of educational activity. As a system, education is a continuous activity. It involves many components, namely: a) raw input (students), b) instrumental input (educators, objectives, materials/programs/curriculum, methods, infrastructure, and facilities), c) environmental input (situation and conditions of the educational environment, social, economic, cultural, security conditions), d) process (implementation of education), and e) product (graduates) [1]. The availability of educational components determines the quality of graduates both in quantity and quality and the functioning of each element according to its role in the implementation of education as a system.

An effective and efficient educational process will help assess the process and assessment of learning outcomes; on the other hand, a good and correct, valid, and reliable learning assessment will reveal the level of achievement and actual learning conditions. The relationship between the elements of the educational process was proposed by [2] which became the basis for other general models. The interpretation of Tyler's model, in practice it is implemented into defining learning goals, organizing learning activities, and evaluating the learning process implemented.

Educational objectives are formulated to describe student behavior reflected through instructional objectives in the perspective of the course. The instructional goals are elaborating educational plans [3]. The formulation of the proper educational purposes will determine a good assessment. According to [4], a good assessment must describe the expected learning outcomes. Assessment as a pedagogic ability [5] must be carried out appropriately to get good feedback on the learning carried out. A good assessment will obtain good feedback on the teaching carried out, which means that the quality of education is also good.

The test is given to students as an assessment instrument in the form of items. Ref [6] conveyed the stages of item development, namely: production, preparation, administration, reporting, documentation, and evaluation. Besides, ref [7] said that assessment activities through written tests are traditional and common methods practiced in most educational institutions today. Hence, questions must be given under the content of the courses studied to meet learning objectives. Writing questions is a very challenging step for questions makers. The situation is daring the teacher or items maker to compile quality items that can be used to know the various cognitive levels. Thus, Bloom's Taxonomy or its revision named Revised Bloom's Taxonomy (RBT), has become general references to guide for preparing test items for the teaching and learning process [8].

Interpretation of test results is conducted by making standard terms indicators of what will be measured. These indicators must be derived from the formulated categories and subcategories, classifying educational objectives and the education taxonomy classification. A goal formulation contains a verb which is a learning objective. This verb describes the expected cognitive process, which includes six categories, namely remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6) which previously consisted of knowledge, comprehension, application, analysis, synthesis, and evaluation [9]. The six categories are known as Revised Bloom Taxonomy, as shown in Figure 1.

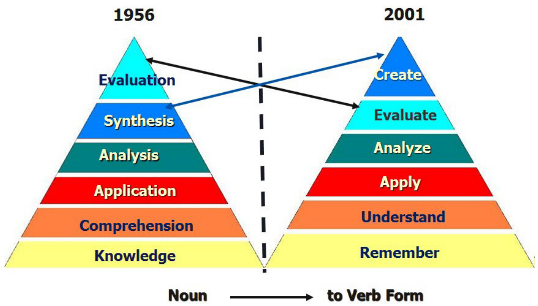

Fig. 1. Bloom's Taxonomy and Revised Bloom's Taxonomy diagram [10]

The cognitive processes dimension in education refers to the RBT for classifying instructional objectives, as shown in Figure 1. There are several other terms for instructional purposes, namely learning objectives, performance goals, or learning objectives. The taxonomy of instructional objectives is a hierarchy that starts from the lowest instructional purposes to the highest level. In other words, goals at a higher level cannot be achieved until the goals at a lower level are achieved.

In the current situation of the COVID-19 pandemic, almost all work is carried out using computer technology [11]. Along with this pandemic period, we are currently in the era of the Industrial Revolution (RI) 4.0 or the Digital Revolution, where the use of computer technology is unavoidable [12]. In this era, large-scale changes in various fields profoundly impact real life [13], not to be separated from the world of education [14]. Applying new methods in the teaching and learning process by integrating information technology is a challenge for an educator/teacher to innovate in the teaching and learning process [15]. The impact of AI developments is also strongly felt in the learning and teaching process [16] and [17], including in conducting assessments in the context of learning evaluation [18] and [19].

Based on the description that has been presented, the problem identified is the relationship between the prepared test questions as a feedback instrument on the achievement of learning objectives and the development of AI technology. The test is carried out to the learning evaluation process through test techniques. The exam questions that are prepared must be able to measure the level of student cognition on the mastery of the lecture material presented. A mapping of exam questions into the dimensions of cognitive processes is needed to determine this level of cognition. Natural Language Processing (NLP) is one of the developments of AI that has proven its impact in various fields of life [20]. NLP can help solve this problem because it can parse a sentence into its parts.

Natural language processing is a research field in computer science, especially AI which focuses on natural or human language. This process translates natural language into data used by computers to learn how to understand the language as outlined in the text [21]. Simultaneously, text processing is a knowledge extraction process in text data [22]. Ref [23] called it a process that typically contains elements of information retrieval, which is one of the methods of text acquisition.

Several studies on computational classifying tests into Bloom's Taxonomy have been carried out. The Inference Engine method was carried out by [24], the artificial neural network method by [25], and the Support Vector Machine (SVM) by [26]. In addition, the use of the rules method with POS tagging was carried out by [27] and in the same year [28] using weighted rules. The SVM method is also carried out by [29] and combines it with Naïve Bayes (NB) and K-Nearest Neighbor (K-NN). Meanwhile, NLP with lexical and syntactic extraction was carried out by [30] for elementary school level questions. Therefore, it is necessary to follow up research on mapping or identify exam questions based on the dimensions of cognitive processes at the tertiary level. Mapping questions into cognitive dimensions are necessary because, based on research [31], there is a significant positive correlation between teaching and cognitive attendance.

2 Method

Items as elements of questions that contain students' thinking abilities after the learning process have a role in the educational process because they determine students' cognitive quality in mastering the lecture material given. Good items must have a level of cognition under the learning design as outlined in the curriculum. We must consider the expected level of student cognition in preparing the items. Before writing the item text, we must do an initial step, namely compiling test specifications in which the test objectives are listed, to measure the level of cognition that can be achieved. However, most of the question makers (lecturers) rarely do it. Based on the performance of NLP, which can extract and map language in the form of text into other formats, this research will map the test questions to the dimensions of cognitive processes, in this case, the category in the Revised Bloom Taxonomy (RBT). This framework is shown in Figure 2. The final result achieved from this process is the type of questions into the cognitive level, namely remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), or creating (C6).

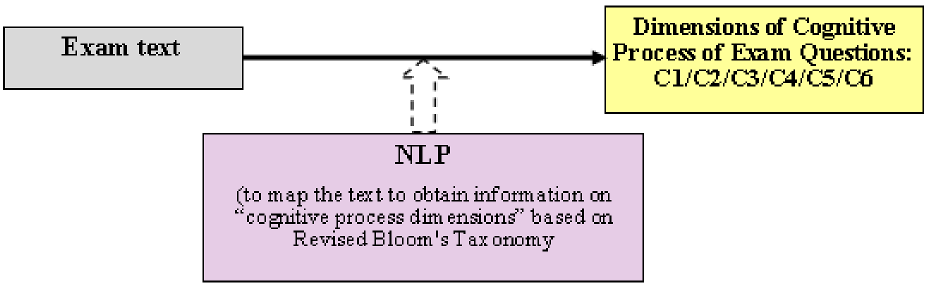

Fig. 2. The framework of the research carried out

2.1 Data acquisition

This research is limited to the written exam questions used as research objects, namely the text of exam questions for various subjects held at the Faculty of Engineering and Science and the Faculty of Teaching and Education. This study needs text data about the end of the 2020-2021 academic year exam. Samples were taken from the questions tested in the study program from both faculties of Universitas Muhammadiyah Purwokerto.

2.2 Research stage

The method used in this study is simpler than the methods that have been used previously, namely applying the basic NLP concept to extract text to find the verb and then looking for the equivalent in the operational verb table (KKO - in Bahasa) [8] and [9]. Based on the framework presented, an outline of the general description of the steps taken in this research is illustrated in Figure 3.

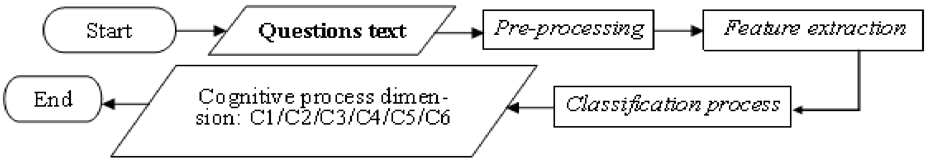

Fig. 3. Research step

The first stage of the model, as in Figure 3, is pre-processing the identification of the test question text under the framework of learning objectives in the RBT. At this stage, we do tokenization, case folding, stemming, and stop-word removal. The tokenization stage splits the input string based on each word that composes it, followed by case folding by reducing all letters to lower case, stemming, to transform the terms contained in a text into its root words, and stop-word removal, which removes non-descriptive words, for example, "*yang* (which)," "*dan* (and)," "*di* (at), "*dari* (from)," "*ke* (to)," and others. This stop-word removal aims to reduce index size and processing time. Furthermore, the feature extraction process is carried out using Part-of-speech (POS) tagging, which assigns POS markers or syntactic classes to each word in the corpus. The verbs resulting from the pre-processing are then matched with the list of operational verbs included in the KKO table. This KKO table contains a list of operational verbs used in RBT which is divided into six cognitive levels.

2.3 Testing design

This NLP-based model was tested for its accuracy in generating information on the level of student cognition based on the RBT using eq. (1). This test compares the number of items that the model can map to the total items [30].

$$AM = \frac{\sum_{i=1}^{n} B_i}{N} x100\% \tag{1}$$

with AM is model accuracy level; B_i is the i-th item that was successfully analyzed by the model and matched the expert's judgment with i = 1, 2, .., n; and N is total items mapped. We used three experts, namely lecturers from three disciplines: exact sciences, social sciences, and education.

3 Results and discussion

3.1 Dataset

The research data is exam questions written in Bahasa from two faculties, namely the Faculty of Engineering and Science and the Faculty of Teaching and Education of Universitas Muhammadiyah Purwokerto, Indonesia. This data is considered sufficiently representative from exact sciences, social sciences, and education. The number of datasets used is 90 items representing 30 items from the three fields of science. Examples of items used in this study are shown in Table 1.

Table 1. List of sample questions in the dataset

No.	Items text
1.	*Jelaskan apa yang dilakukan seorang perekayasa PL setelah kebutuhan-kebutuhan user diakomodasi?* (Explain what a software engineer does after the user's needs are accommodated?)
2.	*Jelaskan perbedaan white box testing dan black box testing!* (Explain the difference between white box testing and black box testing!)
3.	*Informasi apa saja yang dapat diperoleh dari peta RBI? Jelaskan dan berikan contohnya!* (What information can be obtained from the RBI map? Explain and give an example!)
4.	*Apa perbedaan informasi pada peta umum dan peta tematik? Jelaskan dan berikan contohnya!* (What is the difference between information on general maps and thematic maps? Explain and give an example!)
5.	*Jelaskan apa saja komponen pariwisata dan berikan contohnya!* (Explain what the components of tourism are and give an example!)
6.	*Destinasi wisata juga sebaiknya dikembangkan di wilayah saudara tinggal. Bagaimana potensi obyek wisata tersebut? Jelaskan!* (Tourist destinations should also be developed in the area where you live. What is the potential of these tourism objects? Please explain!)
7.	*Apabila Hari Pendidikan Nasional pada tanggal 2 Mei adalah Selasa, HUT Kemerdekaan RI tanggal 17 Agustus pada tahun yang sama adalah ...* (If National Education Day on May 2 is Tuesday, the Independence Day of the Republic of Indonesia on August 17 of the same year is…)
8.	*Apa perbedaan yang mencolok antara struktur data stack dan queue? Jelaskan dengan singkat!!* (What is the main difference between stack and queue in data structures? Explain briefly!)
9.	*Apakah ada perbedaan kecepatan proses dari ketiga jenis prosesor yang ada dengan tingkat alpha = 0,025? Beri penjelasan!* (Is there a difference in the processing speed of the three types of processors with alpha = 0.025 level? Give an explanation!)
10.	*Karena data harus dikelompokkan menjadi 2 kelompok yaitu kelompok atas dan kelompok bawah, maka urutkan data tersebut dari tinggi ke rendah (sortir berdasarkan skor total)!* (Because the data must be grouped into 2 groups, namely the upper group and the lower group, then sort the data from high to low (sort by total score)!)
…	
90.	*Buat pohon pencarian berdasarkan graph berikut ini, dimulai dari S dan berakhir di G. Angka di samping node menunjukkan panjang lintasan dari node tersebut ke goal state (G)!* (Create a search tree based on the following graph, starting at S and ending at G!. The number next to the node indicates the path length from that node to the goal state (G).)

3.2 Data processing

The NLP is a natural language identification process so that humans can communicate with computers using human language [32]. The basic process of natural language identification includes tokenizing to set the input string as a word order [33], case folding, stemming that cleans or removes affixes in a word, and stop-word removal to eliminate the unused terms. Stemming in Bahasa (Indonesian language) is better based on a dictionary so that fewer errors are generated than based on rules [32]. The identification process is according to the type using POS Tagging.

The item text data was extracted to find verbs as the basis for classification into the RBT. Therefore, the first step to take is tokenization. The POS Tagging method is used to obtain verb information. Its results are then calculated using the Bag of Word (BoW) technique to know how many verbs are in each item. Furthermore, a dictionary was built by first doing stemming fromgetting the meaning of the verbs contained in the item text in the operational verb framework (KKO – in Bahasa) in the RBT.

Preprocessing is the initial step in classification that aims to interpret a sentence into a feature vector by converting into words [34]. This step dramatically affects the classification process. The deletion of stop-words is carried out after the stemming process to avoid capitalization/lowercase writing errors. The pre-processing stage is intended to shape the text of the questions into a structured form so that the mapping process to the cognitive dimensions in the RBT can be carried out. This RBT includes six classification categories, namely: remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6). Pre-processing that has been done through the stages tokenization, case folding, stemming, stop-word removal, and POS tagging.

Tokenization is the process of parsing sentences, in this case, the text of the questions, into smaller parts, namely in the form of words. The tokenization stage cuts the input string based on each word that composes it. Before the input string is cut, it is necessary to do case folding to convert the text into a standard form, namely lowercase or lowercase. Tokenization aims to avoid writing errors in letters in the item text. The tokenization stage breaks down strings or sentences in a text item into words, distinguishing certain characters that can be treated as word separators or not. For example, whitespace characters, such as enter, tabulation, space (as word separators) or single quotation characters (‘), period (.), semicolon (;), colon (:) or others that function as non-word separators in general. In this study, the item text as a model input case must have met the correct grammar. Case folding is carried out to avoid errors in writing upper/lower case letters. Case folding is done to change the writing of words into lowercase entirely. It is intended to prevent being case-sensitive to find word similarity.

The stemming process is carried out to produce essential words. This process is used to anticipate ambiguity between nouns and verbs (for example, the basic word "sequence" if it gets an affix can become a sequence, namely a noun, or sort which is a verb). The next step is stop-word removal, which remove unused words. This stage aims to reduce index size and processing time. Words are the syntax in a sentence. Words in Bahasa are not consistently recognized directly because sometimes these words have affixes. To find out the labeling, the affix removal process was carried out. Affixes are additional things attached to words and give rise to new meanings [32]. Affixes are divided into three types: prefixes, suffixes, and confixes.

POS Tagging is the stage of identifying the sentence structure in the item text to determine the verb used. These verbs are the basis for mapping the dimensions of cognitive processes in the RBT. This tagging uses CRFTagger based on Fam-Rashel [35] and [36]. This process is the main key in recognizing the type of word, whether a word is included in the type of noun, verb, adjective, etc.

3.3 Classification process

The first thing to do is feature extraction in the classification process. A feature is a distinguished thing used to classify a question. There are three types features to organize questions, namely lexical, syntactic, and semantic features [37]. This study used only two kinds of feature extraction, namely lexical and syntactic extraction, as shown in Table 2.

Table 2. Types of feature extraction used

Feature	Description	Reason
Lexical	Types of words in the question	as one of the characteristics that can be used to classify questions [37]
	Question length	
Syntactic	Number of verbs	characteristics that can be used to identify the level of Bloom's Taxonomy [27]
	Keywords	keywords can interpret a topic [38]

Lexical features extracted the questions based on the context of the words [39]. One of the text extraction or feature extraction methods used to extract text features based on their appearance in sentences is the Bag of Word (BoW). This process determines how many verbs there are in the item text to indicate the level of cognition needed in working on the questions. As an example of the following computer subject questions:

"Jelaskan apa yang dilakukan seorang perekayasa PL setelah kebutuhan-kebutuhan user diakomodasi?"

After tokenization and case folding is performed, the following results are obtained:

[*'jelaskan', 'apa', 'yang', 'dilakukan', 'seorang', 'perekayasa', 'pl', 'setelah', 'kebutuhan-kebutuhan', 'user', 'diakomodasi', '?'*]

The length of the question or the number of words is 11.

Syntactic features are extracted from the syntax questions. As in the previous example of math problems, the results of extracting the syntactic features from the sample questions using POS Tagging are as follows:

[[('*jelaskan*', 'VB'), ('*apa*', 'WH'), ('*yang*', 'SC'), ('*dilakukan*', 'VB'), ('*seorang*', 'NND'), ('*perekayasa*', 'NN'), ('*pl*', 'NNP'), ('*setelah*', 'SC'), ('*kebutuhan-kebutuhan*', 'NN'), ('*user*', 'NN'), ('*diakomodasi*', 'NN'), ('?', 'Z')]]

The item text contains two verbs.

Defining keywords is essential for the success of item classification. The problem classification process can be carried out if the keywords represent the identified taxonomic level. This study uses keywords that exist [40]. However, some keywords are less specific because they are also at another level of Bloom's taxonomy. If there is one keyword or verb in the question text at a different level in the RBT, it is classified to a higher level [41].

Based on the classification process carried out on the dataset and concerning the operational verb dictionary [8], the results are shown in Figure 4. The level of cognition of C2 occupies the highest percentage, while C6 is the lowest. The highest rate was found in the items tested in social science and education because they used operational verbs included in the "understanding" category. On the other hand, the C6 class is found in exact science items where students are asked to build a structure or program.

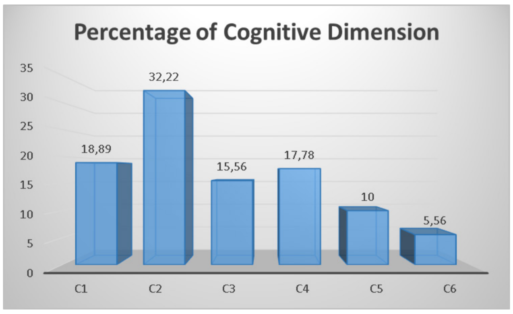

Fig. 4. Results of item feature extraction

This model has been tested by comparing the results of the classification of questions from the model with the NLP method used in this study with expert classification. The testing produces accuracy that can be used as a successfully study benchmark of this method. Based on the test result as in eq. (1), the result obtained from the accuracy of the technique used is:

$$AM = \frac{74}{90} x100\% = 82.22\%$$

This accuracy may be different because the mapping of items into level's taxonomic classification carried out by experts is subjective [42], even though there is already a classification standard or benchmark. This accuracy is relatively higher than [24] at 51%, [25] at 65.9%, and [27], which reached 77% who also used the POS tagging method, even [29] with the K-NN method which reached 81.6%. However, the accuracy achieved in this study is still below the performance of using the SVM method as done by [30], which is 88.6%, [26] at 87.4%, and [29], which achieved 86%. Ref [29] also used the NB method and produces an accuracy of 85%.

4 Conclusion

The testing results show that the model based on the NLP method can classify questions based on the dimensions of cognitive processes in Revised Bloom's Taxonomy. The use of lexical and syntactic features succeeded in classifying questions with accuracy results above 80%. The success of items classification in various fields of science proves that lexical and syntactic features can be used. However, this accuracy may be improved using different methods, such as Naïve Bayes (NB), K-Nearest Neighbor (KNN), or other methods.

5 Acknowledgment

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Gamification: A Motivation Metric Based in a Markov Model

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Abstract—The current situation in the world with the COVID-19 pandemic has reinforced a pre-existing trend based on increasing the use of gamification tools in education to motivate students. In this work, a study based on a Markov model is proposed to assess motivation during the training process in higher education. The evolution of Faculty of Business Administration graduates when using a gamified smartphone application (HEgameApp) has been measured. The behavior of graduates is assessed through collaboration in fora created by HegameApp, and the recognition given by their classmates. A utility function is defined to obtain a statistical estimator used in the assignment of motivational states of the study participants. In addition, a decrement function is assigned to the value of the components of the utility function to estimate the time variation of motivation during the process of knowledge assimilation. The proposed solution shows that when graduates are involved in using the app, they significantly increase their academic outcomes and satisfaction while receiving the lectures. In addition, the positive feedback perceived through the application fora has a measurable effect on their motivation.

Keywords—mobile learning, gamification, Markov model, higher education

1 Introduction

Gamification is generally considered a valuable strategy to increase student performance and satisfaction: (i) improve their tendency to collaborate in the learning process and (ii) intensify their motivation. In addition, gamification contributes to obtaining relevant information that can be exploited in other settings to enrich the educational process, be it face-to-face, remote, or in a hybrid format, ensuring the attention of all students [1].

The search for motivational strategies for the lessons, which encouraged the participation and satisfaction of the university students, has been a continuous task since teaching ceased to be individual. Currently, immersed in implementing digital technologies, it is still a generalized question since it is common to find students who systematically use smartphones with objectives other than those studying during lectures. Besides, banning mobile phones during lectures or applying any punitive measures has proven to be ineffective [2]. Furthermore, information and communication technologies, particularly smartphone-based applications, provide several instruments that can be used to increase students' motivation while they carry out their duties.

Gamification is a motivational strategy that uses components of the structures of games in a non-playful environment. It has been used extensively in recent times to increase the integration of students in their training procedures (especially in higher education), making them pleasant, more attractive, and productive [3]. Motivation, established as the aspiration or inclination to get involved and persevere in a task, can be declared to be the central axis of gamification [4,5]. Studies of educational process researchers have analyzed motivation from a static perspective, assuming it as a photo at a given sampling instant. However, other investigations, more adapted to reality, warn that the contribution models of the students show an important variable component, that is, motivation evolves with time. If these oscillations are not considered, motivation research may conclude erroneously [6]. Therefore, a dynamic perspective makes possible to study incentives or time-dependent variables, which can be intrinsic or extrinsic and affect changes in motivation states. From this perspective, the objective of this analysis is to study the variability of user motivation [7].

This study aims to generate a measuring instrument prepared to forecast the situations of motivation of users in a higher education framework based on incentives from gamification tools. This forecast is made by analyzing an online university class for which a tool is designed based on a gamified application called HEgameApp, built as a program whose objective is to exchange information that serves their learning strategies. This tool makes possible to identify the state of motivation of a student or a group of students during an academic year using a Bayesian Markov Model (from now on MM). HEgameApp tries to get students to acquire helpful study habits from the behaviors caused by gamification. For this, it is necessary to know the dynamics of motivation of the students. In this way, state changes in this process can be identified in real-time. Therefore, while it is observed that the motivation of the students declines, it is possible to incorporate motivators (actions performed by agents) to recover the high states of motivation, which, as it has been verified, coincides with the increase in the scores of the students in subjects.

The proposed tool, based on managing the evolution of motivation over time, classifies the created online community concerning the motivation measures. This segmentation enables the teacher to find the ideal occasion, in a certain period, in which it is necessary to make a decision that increases motivation and changes students' behavior. For this target, a MM has been proposed. Data from an online community feed the model, and through a utility function made up of the attributes from the contributions or evaluations of the students. Moreover, a decay function has been applied, considering that student motivation tends to decline over time [8].

This work is organized as follows. In this section, the theoretical foundations of the link between gamification and education are presented, besides Markov Chain applied to education and, the last, motivation as a gamification strategy. Section 2 shows how the proposed gamification experimentation was developed and describes in detail the mathematical modeling of the proposed Bayesian approach to mobility management and the basis of its performance for the assessment of motivation. Next, section 3 presents the results of the recommended motivation measurement tool using the database with the gamification behaviors derived from the test. In section 4, there is a discussion and reflection on the results. Finally, section 5 presents the conclusions and future work.

1.1 Education and gamification

Technological advances and their continuous progress have transformed the way educational activities, especially those related to learning, are carried out; educators have the opportunity to introduce and integrate learning activities based on play through technology in learning processes. Incorporating ludic tools in this process has emerged a particular concept of game-based learning [9]. Play-based learning or educational gamification is based on the experimental nature of these tools that allow students to fully participate in the learning cycle. Also, design principles grant greater engagement and fun during the learning process. The engagement and fun factors of game-based learning have been shown to increase student motivation and maintain retention. There is also strong evidence showing a relationship between play and increased motivation, as well as the persistence of learning behaviors [9,10].

Tools like HEgameApp can increase motivation and commitment (which promotes learning), and they are also helpful for evaluating students' understanding of a topic. Most significantly, gamification develops students' metacognitive abilities, fosters empathy and teamwork skills. On the other hand, Wang [11] found that gamification tools can affect concentration, engagement, enjoyment, motivation, and classroom dynamics in a significant and positive way.

In short, gamification supposedly offers many benefits and allows educators to be creative and students to be intrinsically and extrinsically motivated. Game-based learning provides an emotion of the ordinary, an emotion that is absent from traditional education. These apps can make students enjoy and persist in doing tasks that they would not normally do. In his commentary on gamification, McGonigal [12] asserted, quite rightly, that the real world does not offer with the same ease the carefully designed places, the exciting challenges, and the powerful social bond that virtual environments provide. Furthermore, says the researcher, the reality is not motivated as effectively, nor is it designed to maximize people's potential.

Therefore, the study of student motivation and engagement classifiers, such as Markov Chains (from now on MC), seems relevant to know the influence of motivation on learning. In the context of higher education, this study aims to assess whether these tools would be helpful to university students [13].

1.2 Markov chains applied to education

If it considered the studies of recent years, an increase in the use of MC could be found in the analysis of educational processes applied to different elements of the field of education. One of these applications is the use of MCs to analyze academic performance and progress. Students' progression towards completing their higher education degrees has stochastic characteristics and can therefore be modeled as MC. Such an application would have a high practical value for the estimation and continuous monitoring of various indicators of quality and effectiveness of a given higher education study program [14]. In terms of quality, MC have also been used to improve the teaching of graduate physical education in schools using machine learning technology [15].

On the other hand, recent research has influenced the study of tutors' strategies to model their interventions where they present information and define activities, and strategies that promote students' will and motivation. Following the research trend of discovering new ways of evaluating teachers' approaches, physiological sensors are used based on student performance (successful completion of tasks). And, consequently, motivational strategies implemented through serious games are studied to support students' performance and motivation. For this, hidden Markov models based on Keller's ARCS model of motivation (Attention, Relevance, Confidence, and Satisfaction) and together with electrophysiological data (HR heart rate, SC skin conductance, and EEG electrocardiograms) have been used [16]. These analyses have identified physiological patterns correlated with different motivational strategies [17].

In the same way, the categorizations that label university students as full-time or part-time students have been studied with Markov models. Since student enrollment patterns at many colleges can be very complicated, it is not uncommon for students to alternate between full-time and part-time enrollment each semester based on finances, scheduling, or family needs. This effort to categorize is helpful to correlate it with variables such as academic performance [18].

Likewise, quality education is a fundamental element in any country's economic, political, and social development. Therefore, enrollment forecasting is necessary for higher education to assist universities in preparing their educational frameworks and budget, providing all the required facilities, and planning the general objectives in the short and long term. The evaluation pattern of students and their academic performance can be defined based on a Markov chain model (from now on MCM), where students' absorption, retention, and repetition rates in the different academic programs are analyzed [19].

Other research focuses on modeling the flow of students in the educational system with a stochastic process that depends mainly on Markov chains to predict the number of students graduating for the following years [20]. Markov chains have even been used to design more reliable piano teaching methods [21].

Similarly, it has been investigated whether it is possible to classify the time series data from a gamified learning management system in such a way that teacher supervision could be distributed more efficiently among students who are more likely to fail, that motivates the possibility of increasing the retention and completion rate of students [22].

In another vein and starting from the idea that most gamified learning systems were designed without considering the personalities of the different students, other researchers combine gamification, classification, and adaptation techniques to increase the effectiveness of e-learning by classifying students into different types of players based on their interaction with the gamified system [23].

Finally, regarding the measurement of motivation derived from gamification in the university education environment, there is not much research beyond the research team that proposes this study [24]. However, previous research has been conducted applying models based on Markov chains to study the change in the learning capacity of the students, a hidden Markov model is used that analyzes the continuous learning process of the MOOC students where it characterizes the high and low learning capacity of the students [25].

1.3 Motivation: Gamification strategies

Gamification and motivation go hand in hand, and they are intimately linked. Starting from a theoretical basis, the foundations of gamification instruments have their origin in individual reasons since it requires the game's resources to promote behavior change [26,27]. This study uses of the theory of self-determination (SDT) that bases its propositions on the division of motivation into two categories: extrinsic and intrinsic motivation. Extrinsic motivation is made up of agents external to the subject that elicit the behavior through tangible rewards, and the intrinsic one is formed from internal agents such as one's longings, values, self-determination, or the sense of being part of a group [28]. In addition, these two subdivisions are compounded by internalized extrinsic motivation [29], which, although it arises from external influences, such as prestige, achieves self-regulated behavior from the subjects. There is a phenomenon of internalization of these external influences.

It can be observed that performance throughout the students' training and achievements are influenced by factors originating from knowledge and emotions [30,31]. Motivation, therefore, affects performance throughout the training but also the consequences of that training. Researchers in this field have dealt with motivation by considering different points of view, but there seems to be an agreement that intrinsic factors have the most significant impact on motivation. Some of them believe that the particularities of each student are the elements that most influence motivation [32,33], and others deduce from their research that intrinsically motivated students not only progress in their studies but also obtain higher outcomes than those who are extrinsically motivated [34]. However, university students often must study subjects that they do not find suggestive or attractive but essential to their instruction. When this situation occurs, the use of a punishment or reward structure is the only tool left to educators to promote those behaviors that facilitate the educational performance of university students. In this sense, the use of strategies based on the game, in addition to the tactic based on rewards and punishments, offers an added stimulus to teaching that turns training tasks into fun and enjoyable hobbies [12]. In this way, the use of game elements in learning activities favors creating a stimulating environment in a teaching environment, something that gamification strategies such as those used by HEgameApp in this study allow to fulfill and, therefore, facilitate the creating motivating environments. Since it has been shown that motivation influences different learning styles, knowing the student's state of motivation seems essential in teaching processes [35].

2 Materials and methods

2.1 Development of the gamified app

This research addresses the analysis of the evolution of student motivation in a temporary way. An MM-based strategy is developed to identify the impact of motivational processes in a scenario of optional participation. This central archetype establishes the mechanics of student contributions and the jumps between the different categories of motivation. In this study, a MM has been implemented with the information generated during the use of HEgameApp. It refers to a gamification web application that was developed for three purposes: (i) to make students aware of the appropriate use of smartphones in face-to-face teaching, (ii) to exchange information, and (iii) to provide references to the teacher on the student's evolution in the subject.

The goal of integrating HEgameApp into the class is to provide students with the opportunity to be fully engaged in their learning processes. User engagement is achieved by utilizing the benefits of gamification through a combination of points-based rewards. Research by Robson et al. [36] defines a gamified practice as employing the MDA fundamentals (mechanics, dynamics, and aesthetics) based on the peculiarities of the learners involved in the game practice. Thus, the structure of the HEgameApp pursues a game orientation towards a uniform set of undergraduates with a similar degree of education and age. Despite this orientation, the gamified experience of this app favors more those socializing university students who are inclined to exchange the information they have in their possession. This development is adapted to a website (WebApp), which is platform-agnostic. It offers enough flexibility for the user to have at his disposal a wide range of devices on which to use the app.

The development of HEgameApp follows the MDA framework [37,38] with the following layered design: the first layer (the mechanics) involves data representation and programming; the second layer (the dynamics) alludes to the behaviors that manifest themselves as a result of the students' action on the mechanics selected for the development of the application; the third layer (the aesthetic) is linked to the fundamental purpose of the game which is to induce an emotional replica of the student. In the developed experimentation, three essential strategies were used: the self-satisfaction that makes students aware of the importance of exchanging information, the tangible prize measured in points, and, finally, the achievement of prestige before the teacher that materializes as a plus in the grade at the end of the study of the subject.

HEgameApp includes five parallel themed channels (knowledge sharing venues) in which students can neatly insert their contributions: Questions, Resources, Presentations, News, and Others. It should note that contributions with the "Others" theme are not considered for counting points since this channel accepts contributions unrelated to the course's contents. For enrollment, a username and password are required to access the application, which ensures student privacy. The reward structure based on obtaining points includes the following inputs:

1. The number of contributions by thematic channel
2. The number of classmates' evaluations: each student values the contributions of other colleagues
3. The quality of the contributions according to the peers' evaluations (other university students), in an evaluation range from 1 to 5, with five being the highest and one the lowest.

The equation to estimate the total value through the structure of rewards for evaluations is the following (these coefficients were proposed by a panel of motivation experts using the DELPHI method):

$$Score = contributions \times 0.3 + performed\ assessments \times 0.2 + received\ assesements \times 0.1 \tag{1}$$

Additionally, HEgameApp rewards the evolution of students through badges, which are awarded for each thematic channel, scalable in three possible categories according to the value achieved: bronze, silver, and gold. The bronze reward is obtained after five contributions, the silver one after 10, and the golden one after 20. Also, when a student has achieved the awards of all thematic channels, they will obtain a diamond award. The gamification experimentation carried out throughout the 2018-2019 academic year is explained below when the disciplines of "Organizational Behavior" and "Leadership Skills" were taught at the Faculty of Economics and Business Administration of the University of Las Palmas de Gran Canaria, Spain.

2.2 A mathematical model for estimating motivation

The mathematical model that has been developed assesses and classifies motivation, analyzed as a value that changes over time in the students' learning process.

Utility function (UF). A multivariate has been proposed to quantify the variation in student motivation throughout the training process. The purpose was to shape the attributes of this question using the originated data when the community of students used the application.

Let $I_{A_K}^{C}(x)$ be an indicator function such that if x belongs to the set $A_K^{(c)}$, the set comprising all contributions of the learner k in the interaction topic channel c, then $I_{A_K}^{c}(x) = 1$ otherwise $I_{A_K}^{C}(x) = 0$. If it is employed the above relationship, the first attribute of the posed UF can be established as follows:

$$A(t) = \sum_X I_{A_K}^{c}(x) e^{-\lambda t} \tag{2}$$

Where x is set as the input made in the online classroom. When a specific time elapses, gamification incentives need to be reactivated; student motivation decreases during learning procedures. For this reason, it becomes necessary to model the change in motivation originating from an input or assessment when it moves along the timeline.

In this mathematical modeling in (2), a well-known general function was selected with an exponential decay factor λ, a positive constant that sets the decay rate, which can be estimated based on the average duration of an input. If the independent variable (time) is quantified in days, the average duration would therefore be:

$$t = 14 = -(\log 0.5)/\lambda;\ \lambda = 0.05 \tag{3}$$

Similarly, the second UF attribute quantifies the feedback received from other learners on the learner's contributions k in the subject channel c, i.e.:

$$B(t) = \sum_x I^c_{B_K}(x)e^{-\lambda t}, \tag{4}$$

where $B_K^{(C)}$ indicates the set of ratings received by the k-th student in the interaction topic channel c. Finally, a quality attribute is added to quantify the effect of student contributions k, which is represented as:

$$C(t) = \sum_{x_l} I^c_{C_K}(x_l) * l * e^{-\lambda t} \tag{5}$$

where x_l is the rating made on the contribution x with a rating of $l \in$ 1, 2, 3, 4, 5. According to the peer ratings, the quality score of the contribution's ranges from l=1 to 5.

Thus, the multivariate UF for the k-th student in one of the thematic channels of interaction is specified as:

$$U_c t = \alpha * A(t) + \beta * B(t) + \gamma * C(t) \tag{6}$$

Therefore, the overall UF over the four thematic interaction channels for the *k-th* learner can be quantified as follows

$$U(t) = \sum_{C=1}^{4} U_c\, t \tag{7}$$

Markov Model (MM). The evolutionary model used measures and studies the point-based reward combination developed to encourage students' contributions to their training process. Its fundamental particularity is its dynamism. This characteristic entails constituting a model that allows the quantification of the students' contributions and their evaluation over time. For this, a strategy based on a MM is proposed that establishes a transition matrix of motivation levels for each student, and derived from this matrix, a vector state of stationary probability is formed that serves to classify students into three different degrees of motivation.

The proposed strategy is based on a homogeneous evolutionary Markov model, which uses the contributions and ratings of each student to feed the points-based reward system. This information is measurable by the UF of (7). To pin down the evolutionary behavior of the MM, one must determine not only its configuration but also the transition probabilities. The design of the proposed MM is depicted in Figure 1. There, the tree states S_1, S_2, S_3 are contemplated, which correspond to the degrees of motivation (from lower to higher) and which are achievable with a change probability $P_{i,j}$ for i, j=1, 2, 3, assigned to every arc. Those values refer to the conditional probability $P(S_j/S_i)$ of moving to state S_j given that the current one is in state S_i.

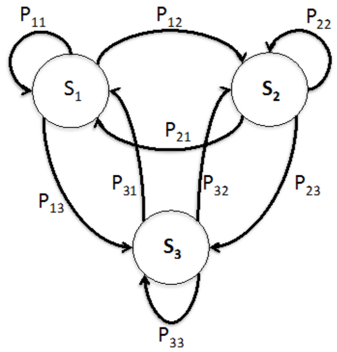

Fig. 1. MC diagram

To determine the transition probabilities, the degree of motivation of all undergraduates must be available daily and for a specific period of time using the UF $U(t)$ (see equation 7). Figure 2 shows an example of this function, in which the values of U are represented for a specific student during a time interval of one semester (120 days). It is possible to appreciate some periods of decay time; this behavior occurs because the values of the UF are given by the period quantified in days from the date on which the contribution occurred. The following procedure was proposed to characterize this model:

1. A normalized histogram was composed with each of the UFs of the university students who participated in the experimentation.
2. Then a soft classification was performed using a Gaussian mixture model (GMM) composed of a trio of distributions (low, medium, and high motivation).
3. Finally, a student's level of motivation was determined by evaluating the utility function $U(t)$ each day and then estimating the maximum likelihood of the three quantities of probabilities provided by the GMM.

A sample of these histograms and Gaussian mixture for four months is observed in Figure 3, where each distribution appears with different coloration.

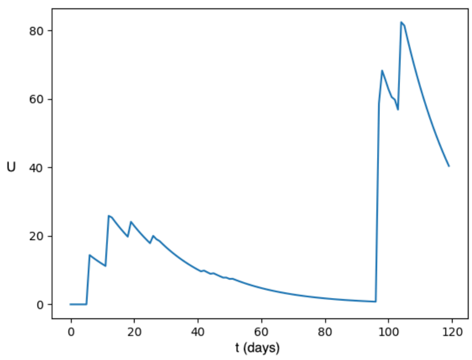

Fig. 2. Sample of changes in a UF for a single student

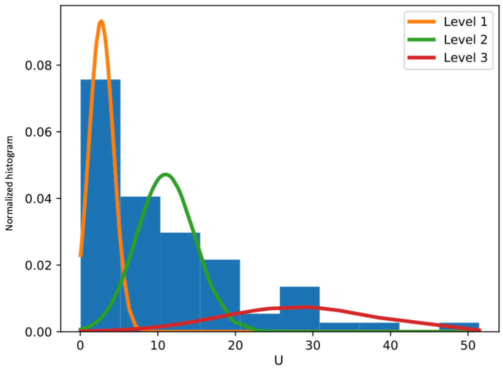

Fig. 3. Histogram and Gaussian mixture model of the UF proposed for the whole set of students studied

It is established a 3×3 change matrix for everyone to define probabilities. This matrix is set as follows: for each day, a state is fixed using the maximum likelihood of the GMM as previously mentioned, and it is analyzed whether there is a variation in the state compared to the preceding day (Markovian process), and one is added to the corresponding marker (remaining or changing) to consider it in the change matrix. The derived matrix is normalized, so the summed total of each row is 1; thus, a 3 × 3 matrix is obtained in which the element (i, j) quantifies the change probability $P_{i,j}$. Then, employing the change matrix, one can determine the likelihood of being in each state of motivation S_i after many days. If a person begins in the state $S1$, its state-vector can be established as $\boldsymbol{p}T = 100$. Then, the probability of being in any of the states on the second day can be calculated with the function

$$\boldsymbol{p}^{(2)} = \boldsymbol{p}^{\boldsymbol{T}}\boldsymbol{M}, \tag{8}$$

where $\boldsymbol{M}$ is the change matrix, and $\boldsymbol{p}^T$ is the vector transposed on the first day ($\boldsymbol{p}^{(1)}$). Then, after n days, it is obtained

$$\boldsymbol{\pi} = \boldsymbol{p}^{(n)} = \boldsymbol{p}^T\boldsymbol{MMM} \cdots \boldsymbol{M} = \boldsymbol{p}^T\boldsymbol{M}^{n\text{-}1}. \tag{9}$$

Equation (9) is convenient since the probability of being in any of the states after a period of n days could be quantified. Thus, in the limit (when $n \to \infty$), it is possible to calculate a stationary matrix of rank one and choose some row as $\boldsymbol{\pi}$, regardless of the initial state $\boldsymbol{p}^{(1)}$. Practically, there are very effective ways to avoid lifting power matrices with these characteristics, such as the eigenvector-eigenvalue decomposition used in this work [39].

A complicated element of the presented methodology was using the vector $\boldsymbol{\pi}$ in $\boldsymbol{R}^3$ of all the students to concentrate them in three global clusters representing the degrees of motivation and, thus, assessing and examining the point-based reward system. To this end, a hard clustering scheme was implemented using k-means with k=3 [40]. It should be noted that each $\boldsymbol{\pi}$ vector is in the x+y+z=1 plane, where the xyz axis refers to the probability of being part of the S_1, S_2, and S_3 states, respectively; furthermore, the centroids the three clusters must lie in this plane. Figure 4 shows an example of this representation in which the blue spheres and pyramidal markers close to coordinate 1,0,0 refer to the individuals that are part of state S_1 (low motivation class), those marked in red, close to 0,1,0, to state S_2 (medium motivation class), and the green ones close to 0,0,1 to state S_3 (high motivation class). This representation is adequate as it presents the predisposition from a probabilistic optic for the three degrees of motivation posed rather than a strict taxonomy. It is necessary to emphasize that this work is strictly modeling, not intervention.

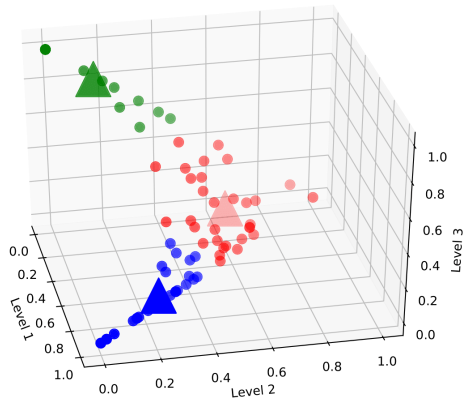

Fig. 4. Clusterization and centroids of the set of students for the three degrees of motivation: (1) Low, blue markers; (2) Medium, red markers; (3) High, green markers

3 Results

The proposed points-based reward structure pattern was tested on a set of 69 students of the Faculty of Business Administration, Economics and Tourism of the University of Las Palmas de Gran Canaria, Spain, in the disciplines of Organizational Behavior and Leadership Skills, when using HEgameApp, a gamified WebApp, throughout four months (during February to May 2019). Then, the method specified in the epigraph on methodology was applied, where the k-means clustering procedure was able to determine three centroids that have been used to label each student's initial motivation state: Low (set 1), Medium (set 2), and High (set 3); it is equivalent to the 3D polytope (plane x+y+z=1) in Figure 4. It is possible to notice that the centroids are also placed in the polytope, indicating that probability density functions appear clustered in the same way as the distributions being classified. At the end of the experiment, the students' final assessments in each classroom were obtained; Figure 5 presents the boxplot of these ratings clustered by the degree of motivation. It is possible to appreciate that the median of set 1 is less than 6, while set 2 is 6.62 and finally that of set 3 is 7.62. Similarly, it is even more interesting to note that the dispersion of set 1 is much higher than that of the other sets, which shows that the taxonomy derived from the proposed methodology appropriately divides the groupings with a high degree of motivation, which is reflected in the final ratings. To corroborate this result, Table 1 presents the quantification of the median shown in the graphs, but in addition, some statistical measures such as the mean, the standard deviation, and the maximum value of the final grades are presented.

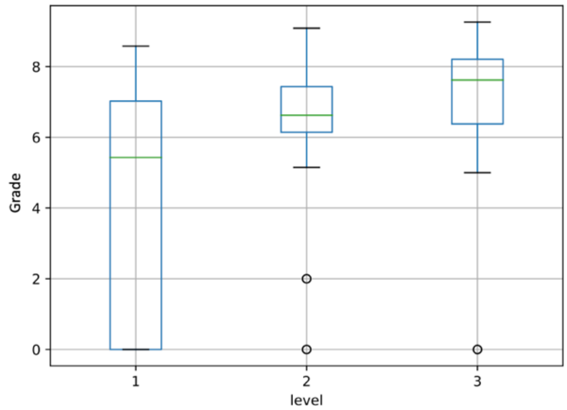

Fig. 5. BoxPlots of the final ratings clustered by the three degrees of motivation

Table 1. Mean and variance for each of the sets

Set	Mean	Standard deviation	Maximum value
1	4,54	3,15	8,58
2	6,57	1,82	9,09
3	6,88	2,28	9,26

4 Discussion

This paper assumes that, apart from the initial surge of community launch, the number of new contributions will be relatively stable over time. Similarly, the trends should be regular about the number of badges and positive votes. This stability suggests that those who contribute to the community should consider the responses' quality and consistency. Likewise, the quality of the answers must be stable, except for a decrease in the initial period.

If it is studied over time, significant heterogeneity in user contributions should be observed. However, the contribution at the individual level should show a different, decreasing pattern, although it seems that some individuals remain active throughout the study period. Understanding the behaviors and motivations of those individuals who contribute the most over the experiment’s lifetime may help create sustainable communities and elucidate what type of gamification tools will be most efficient for student academic success.

In addition, one could drill down to the individual level and plot the contribution of several representative users in the sample. According to [7], even relatively active users should show substantial fluctuation in their contributions during their tenure in the online community. These would contribute actively during some periods, while in other periods, they would be inactive. The objective of this work was to model the fluctuation of user contributions (dynamics) and, in the future, to study the influences of different motivational mechanisms leading to such dynamics of active contribution or lack of them.

User contributions are public goods by nature in online communities since they are voluntary, free, and open. The critical issue in public goods is opportunism, which means that everyone can share the benefits, but only the contributor incurs the cost. The students who were part of this experiment are in those very circumstances. In this sense, lack of provision is a common problem in many models of pure altruism [41]. Consequently, online communities may eventually become exhausted, suffering from "the tragedy of public goods." But these models are not adequate to explain why some groups can attract substantial contributions from users. Such discrepancies between theoretical models and empirical phenomena can be reconciled by models of impure altruism [42,43], where individuals contribute because they derive utilities, not only from pure altruism but also get personal benefits of their own, such as highlighting their skills or the satisfaction of helping others.

The public goods framework and particularly models of impure altruism have been used to model user contributions in an online community. Each user chooses how much to contribute. The utility of a user network is made up of three parts:

1. Their valuation of the accumulated contribution in the community
2. Their valuation of their own contribution
3. Their contribution cost

The first part captures the benefit that the user could obtain from the community as suggested by the pure altruism literature. The second part captures impure altruism corresponding to the internalized extrinsic motivation reviewed in the literature. The third part indicates that making contributions is costly in terms of time and effort. However, this treatment of public goods theory is a convention used by this paper and is open to further contributions by other researchers. On the other hand, the distribution of motivation in three grades, low, medium, and high, also agrees with the findings of other researchers [44].

5 Conclusions

The doctrine implicit in these mathematical analyzes is the habit cycle. This theory exposes the formation of a habit based on behaviors derived from gamification strategies. These strategies convert extrinsic motivations into internalized extrinsic ones. It is also introduced a new concept of gamification. In this case, gamification is defined as a tool that transforms a repetitive behavior into a habit by internalizing extrinsic motivators, using external stimuli derived from gamification, such as the visibility of individual behaviors, the study process, or peer feedback [24]. In this work, gamification strategies are used to foster critical thinking and deep learning skills into successful habits and accentuate behaviors that reflect autonomy capabilities in students. It is intended that students can assimilate such behaviors so that, when the external incentives disappear, the attraction for gamification can also disappear, but maintaining the habits of critical thinking and deep learning.

The research presented here was based on the students' contributions to an online collective and the evaluations of their peers. It is inferred that the motivation categories correspond to the sets of students grouped by their qualification, as evidenced by the grouping of university students in the categories of medium and high motivation with a minimum standard deviation, increasing this standard deviation for the category of low motivation and showing no correspondence with the student's qualification.

Due to the COVID-19 pandemic, many higher education institutions closed their campuses and switched to online education. Some researchers [45] have found that staying at home affects students, especially their motivation. Students, in general, rated online education as less satisfying than on-campus education and defined their motivation as unfavorable. This fact was reflected in lower time investment: lectures and small group meetings were attended less frequently, and students' estimates of hours studied decreased. Lower motivation predicted this drop in effort. In general, students were not satisfied with online education; there was a decrease in motivation that could be due to the lack of means of most universities for this type of education and that they were used to a social interaction that did not occur [46]. Using gamification techniques to increase motivation also entails a point of online socialization through the exchange of knowledge and assessments to other students that can solve this demotivation.

The use of the tool that classifies students by their motivation at any point in the learning process, during the course in which their motivation is evaluated, can be used to prevent sudden decreases in motivation. Moreover, if this decrease is generalized, it is possible to investigate its causes. This tool can indicate both generalized and individual problems in periods such as those during the COVID-19 pandemic. In this way, the teacher can react as quickly as possible before the root problem becomes entrenched or give individual or generalized guidelines to the cause of the drop in motivation. However, it should be noted that the tool must be used frequently, and its results analyzed. This frequency depends on the teacher's criteria, but it is recommended that the data be analyzed weekly [47]. This solution proves the effectiveness of the application since the proposed MM has shown its capacity for future use in decisive situations during the learning process. It has been proven that, based on this classification, the introduction of stimuli from gamification corrects behaviors and optimizes the performance of the online lessons in a specified period. In addition, more efficient study progress is obtained with an immediate consequence on the students' final scores in the course.

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Influences of Online Learning Support Services on Continued Intention to Use MOOC

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Abstract—In this study, an undergraduate course in Wuhan City, China was chosen as the respondent and a questionnaire of influences of online learning support services on continued intention to use MOOC was designed. The influencing degree of four aspects of online learning support services (education teaching, curriculum resources, learning facilities and management services) on continued intention to use MOOC were analyzed. Moreover, differences in continued intention to use under various online learning contact time were discussed. Results demonstrated that the overall Cronbach α of the questionnaire was 0.872, KMO value was 0.833 (>0.8) and the corresponding P value was 0.000, indicating that the designed questionnaire had good reliability and validity. Education teaching, curriculum resources and learning facilities all have significantly positive promotions on the continued intention to use MOOC. According to the Kruskal-Wallis test statistics, online learning contact time presents typical "inverted V-shaped" relations with the learners' continuous intention to use. Research conclusions have important values to maintain a relatively high learning intention of learners by strengthening learning support services and promote learning outcomes of MOOC and adopt specific learning support service strategies.

Keywords—online learning, learning support services, MOOC, continued intention to use

1 Introduction

The COVID-19 pandemic promotes large-scale applications of online education. Emerging technologies such as cloud computing, big data, and artificial intelligence continue to promote education reform. Not only did it propose higher requirements on learning support services to remote education, but it also lays solid foundations for personalized and intelligent education teaching. In the era of "Internet+", learning has not been limited within various campuses at all levels and online learning has been realized by using various advanced mobile Internet technologies and high-quality mobile terminal equipment. As an important type in online courses, MOOC is widely accepted with having considerable potential to overturn existing high-education modes due to its openness and sharing characteristics. Promoting educational equality of MOOC becomes a hotspot of learners. Meanwhile, new high-quality education resources are added into the free and open resource lists continuously. Many of these resources provide valuable opportunities to students who originally cannot contact such high-quality education resources completely. Thus, a common consensus that MOOC has considerable values in promoting educational equality was observed. With the increase in MOOCs, poor-quality courses are increasing continuously and learners are difficult to distinguish accurately. Thus, the learning quality and learning enthusiasm cannot be protected effectively. The primary characteristic of online courses is temporal-spatial separation between teaching and learning, which allows learners to determine their learning pace by themselves and bring them many adverse influences on online learning. The teacher-student dialogue is established through interaction, which provides an optional path to solve online courses. Moreover, MOOC has some unique attributes, such as large-scale applications and openness. It requires more resources to guarantee the good operation of MOOC.

Nevertheless, the low completion rate of MOOC is also an important aspect of doubt. Motivation and attitudes of MOOC learners can be evaluated effectively by improving their continued intention to use, thus preventing learner loss. In the beginning of contacting MOOC, learners have a sense of freshness. However, as time goes on, learners are easily burnt out and they have no stronger continuous intention to use, thus decreasing the learning performance. In the era of big data, data analytical methods such as learning analysis enrich online learning support services contents. Online learning support services can design intelligent and humanized support services based on data analysis technologies like learning analysis to facilitate learners to make more effective learning of MOOC. Centering at online learners, learning support services aim to explore service needs hidden behind the data by collecting, storing and analyzing online learning data of learners. On this basis, it provides learners support services from various dimensions, including schools, teachers, peers, and so on. Perfect learning support services can improve autonomous learning enthusiasm of students, increase online learning outcome and facilitate knowledge system construction of learners. With the popularization of higher education, there may have been remarkable changes and progresses in concepts, teaching process and management of traditional higher education. The scope of learning support services to students is more extensive and there are components of learning support services in all aspects, such as governments, schools, teachers, and peers. Thus, increasing learning support services can make learners maintain a relatively high level of learning duration, increase their learning efforts and learning motivations, strengthen emotional communication of online learning, and improve learning effect, thus enhancing their continuous intention to use MOOC.

2 Theoretical basis and proposition of hypotheses

2.1 Theoretical basis

The theory of learning support services develops early in developed countries and has achieved relatively rich research fruits. Some achievements in teaching practice have been gained. David Sewart [1] proposed the concept of "learning support services" explicitly in his Continuous Attentions of Distance Learning System to Students. This provides a unified expression and research basis for support services to students in the distance education circle. Subsequently, numerous scholars have made positive explorations on learning support services. Theoretical studies on learning support services focus on service system, service mode, and education technology. Theory of learning support services mainly believes that learners do not have an inborn learning ability and they can only finish the learning process under the strong learning support service system, thus building the knowledge system successfully. Deep learning abilities of learners such as the autonomous learning ability and self-management ability can only achieve considerable development under assistances of strong learning support services. Learning support services promote learners to realize the learning process through comprehensive assistance. The essence of learning support services lies in the continuous two-way communication activities between students and schools/teachers. Schools can provide learners with appropriate feedbacks by using the perfect learning support service system or help learners to gain all activities and factors related with cognition, skills and emotional improvement during the teaching process. In view of existing studies, learning support services include teaching and tutoring institutions, advice and consultation institutions, information and monitoring institutions, and other microscopic factors. From the perspective learners' demands, it is believed that all services shall be centered at learners to improve the reflection, emotion and cognitive ability of student individuals and promote their systematic development. Therefore, various schools at all levels in foreign countries pay attention to providing learners with personalized learning services, thus fulfilling the learning demands of each student. Through one-to-one mentor system, many measures are adopted to promote learning of learners at a higher efficiency, such as diversified evaluation services, elastic exam system and trans-school acceptance of credit points. With the continuous development of teaching information technology, the personalized learning services of network education based on big data technology fulfills the personalized learning demands of learners to some extent, while avoiding great investments of capitals and equipment. Moreover, they have the potential for large-scale applications and may lay foundations for online learning support services to personalized learning. In a good school environment, learning support services can collect data to evaluate the learning states of learners by analyzing their behavioral data throughout the process, thus forming a learning database of learners. Learning outcomes are evaluated comprehensively from the learning effort, learning effect, learning style, and individual characteristics perspectives, thus providing learners more scientific and accurate online learning support services. Schools and teachers can adjust management services and resource services timely according to data feedbacks of students in the network learning environment.

2.2 Proposition of hypotheses

Many studies have demonstrated that building a learning support service system not only guarantees the online learning outcome, but also plays an important role in improving talent training quality. Some studies have discussed how the learning support service system may influence teaching and influence the learners' continuous intention to use courses. Ludwig-Hardman, S et al. [2] demonstrated that using effective learning support services can decrease loneliness of some students of distance learning programs and courses, strengthen self-guidance and management, and improve their learning motivation level. MacGillivray, H [3] analyzed the effectiveness of learning support services provided by the Queensland University of Technology. Results found that such learning support services fulfilled the students' need of various abilities. Britto, M et al. [4] demonstrated that online learning support service department builds and implements a whole set of services for online students, which can strengthen experiences of online students, thus increasing retention rate of students directly and indirectly. Russo-Gleicher, R [5] determined that university managers have to educate and encourage online teachers to acquire various learning support services by using the community universities, or insufficient use of learning support services may lead to relatively low retention rates of online courses. Walters-Archie, A et al. [6] analyzed the effects of various academic support services and resources to improve online learning outcomes in the Open University of the West Indies. Results demonstrated that these support services aim to train positive and meaningful online learning experiences, thus assuring students to complete courses and learning plans successfully. Rangara-Omol, T. A et al. [7] investigated the degree of available support services of students and they found that only four of nine indexes to measure learning support services are positive stimuli. They suggested schools to improve their support service ability to solve problems that may occur. Conceição, S. C. O et al. [8] investigated support strategies that are viewed as important by students in the higher education network in the United States. Results showed that learning support services mainly include support services from teachers, family members, and friends. Hunte, S [9] described support services to new students of online learning in the background of developing countries in Caribbean small islands. According to survey results, participants have relatively high overall cognition to support services and school's supports to new students of online learning have positive influences on their performances in online learning environment. Lee, S. J et al. [10] believed that learning support services include teaching support, peer support, and technological support. Results showed that teaching support, peer support, and technological support are significantly correlated with their overall satisfaction to the online course. Tere, T et al. [11] determined that the learners' satisfaction can be promoted by strengthening the construction of the learning support service system. Alzaza, N. S et al. [12] concluded that current higher education environment now is equipped with mobile technological infrastructure for mobile learning and students have sufficient knowledge and good consciousness to use such technologies in their education environment. Tallman, F. D [13] found that the students' satisfaction is significantly correlated with support services that learners perceived. Malanga, A. C. M et al. [14] investigated the behavioral factors that influenced the intention of university students in Brazil to use an e-learning system and found that promotion conditions, social influences, habits, and quality can influence their intention to use the system. Dai, H. M et al. [15] demonstrated that learning habit is the key factor that increases the continuous intention to use MOOC significantly. Wu, B et al. [16] determined that perceived ease of use, task-technology matching degree, reputation, social recognition and social influence are key influencing factors of continued intention to use MOOC. According to results, Hsu, J. Y et al. [17] found that consciousness of community and perceived benefits both may influence behavioral intention of learners from ordinary e-learning platforms and MOOC. Yang, M et al. [18] indicated that system quality, course quality, and service quality are significant decisive factors of continuous intention of individuals to use MOOC. Dai, H. M et al. [19] found that the continued intention to use MOOC can be predicted from individual curiosity, but the attitude plays a considerable dominant role. Relevant factors of online learning support services can improve learning motivations, learning performances, and continuous intention to use significantly. Learning support services include various support services and many factors, including personal support, learning resource support, learning activity support, learning evaluation support, and so on. Strengthening learning support services can help and promote autonomous learning of students, solve difficulties they encounter in the learning process, improve learning quality and effect, and promote innovative talent training.

Based on aforementioned studies, the following hypotheses were proposed.

- H1: In online learning, teaching can significantly improve continuous intention of learners to use MOOC.
- H2: In online learning, curriculum resources can significantly improve continuous intention of learners to use MOOC.
- H3: In online learning, learning facilities can significantly improve continuous intention of learners to use MOOC.
- H4: In online learning, management services can significantly improve continuous intention of learners to use MOOC.

3 Methodology

3.1 Questionnaire design

In this study, a questionnaire of Effects of Online Learning Support Services on Continuous Intention to Use MOOC was designed. It covers three aspects. The first aspect is basic information of respondents, including four questions about gender, subject, grade, and online learning contact time. The second aspect measures the online learning support services. Learning support services use studies that are highly cited in China. Four aspects in evaluation indices of distance learning support services in Zhu Z L et al.[20] were applied, which were teaching, curriculum resources, learning facilities, and management services. These four aspects were measured by 4, 3, 3, and 4 questions. The third aspect was applicable to measure continuous intention to use. In this study, seven questions from Lin, W. S et al. [21] questionnaire were used. The questionnaire was measured by a seven-point Likert scale and all questions were scored from 1 to 7.

3.2 Respondents

A college of civil engineering in an ordinary university in Wuhan was chosen as the respondents. This is a key school of the university and has obvious advantages in faculty. The school has carried out a lot of teaching reforms in recent years and possesses good online teaching resources. The research team conducted a paper questionnaire survey during break time. A total of 254 questionnaires were set and 236 were collected. After invalid questionnaires were excluded, 196 questionnaires remained, showing an effective collection rate of 77.17%. In view of gender, these questionnaires were filled by 107 boys (54.59%) and 89 girls (45.41%). In view of majors, there were 21 respondents from civil engineering (10.71%), 34 from the project management (17.35%), 72 from the engineering cost (Sino-foreign cooperation) (36.73%), 29 from the water supply and drainage science and engineering (14.80%), 28 from environmental engineering (14.29%), and 12 from underground works (6.12%). In view of grades, there were 40 freshmen (20.41%), 71 sophomores (36.22%), 67 juniors (34.18%), and 18 seniors (9.18%). In view of online learning contact time, there were 32 respondents who have contacted with online learning for less than one year (16.33%), while 31 respondents who have contacted with online learning for one to two years (15.82%), 28 respondents who have contacted with online learning for two to three years (14.29%), 27 respondents who have contacted with online learning for three to five years (13.78%), and 78 respondents who have contacted with online learning for more than five years (39.80%). University students have accepted online education modes extensively during middle school or high school. Therefore, most students have more than five years of online learning experiences.

4 Results analysis and discussion

4.1 Reliability and validity

The questionnaire data's consistency and stability were measured by a reliability test. Cronbach's α is a common method. The higher Cronbach's α indicated the higher consistency of the scale. According to data analysis based on SPSS22.0, Cronbach's α is higher than 0.8 for all four independent variables and one dependent variable and the Cronbach's α of the whole questionnaire was 0.872, indicating that the designed questionnaire has good reliability.

Table 1. Reliability results

Variable type	Name of variables	Number of questions	Cronbach α	Cronbach α
Independent variable	Education teaching	4	0.935	0.872
	Curriculum resources	3	0.869	
	Learning facilities	3	0.856	
	Management services	4	0.946	
Dependent variable	Continued intention to use	7	0.939	

A validity test aims to test the effectiveness of the questionnaire, determine whether the designed questions are reasonable, and whether it is corresponding well to the research expectation. In the statistical analysis, it is the most common questionnaire validity test method. Questionnaire validity was tested by the KMO and Bartlett spherical test. Results are shown in Table 2.

Table 2. KMO and Bartlett tests

KMO value		0.833
Bartlett sphericity test	***Approximate chi-square***	3891.295
	df	210
	p value	0

Table 2 shows that the KMO value was 0.833 in this study (>0.8) and the corresponding P value was 0.000 (<0.01), indicating that the proposed questionnaire has good validity.

4.2 Regression analysis

It can be seen from Table 3 that:

H1 is true. In online learning, education teaching can significantly improve continued intention of learners to use MOOC. Reasons are explained as follows. Although online teaching requires independent study of learners in many times, teaching and tutoring of teachers have very important influences on academic performances of learners. Since online learning lacks the sense of immediacy in traditional teaching, learner-teacher interaction has to be completed online in to improve learning outcome comprehensively. Therefore, teachers shall be familiar with use of online teaching platforms, increase interaction frequency with students during live broadcast by establishing various social groups (e.g. WeChat group and QQ group), improve interaction quality and fulfill emotional needs of learners. With respect to use of teaching strategies, teachers shall trust learners completely, give them enough learning space, promote them to make more learning reflections and deep learning reflections, help learners to control learning process effectively, facilitate their high-efficiency integration of curriculum knowledge, and form a more scientific knowledge system. Moreover, only teachers who have corresponding professional knowledge and training background can answer questions of students better during online learning, thus enabling to help students in improving learning performances and guarantee satisfying learning outcomes. Through after-class tutoring, learners can reflect on learning process effectively, control progress in the next learning process, improve initiative in learning, and finally strengthen the continued intention to use MOOC.

H2 is true. In online learning, curriculum resources can significantly improve continued intention of learners to use MOOC. During online learning, curriculum resources are a type of very important learning resources for learners. Quality of curriculum resources determines the independent learning outcome of students directly and influences quality of online learning indirectly. This reflects that great effort has been invested to curriculum development and a perfect curriculum development system is developed to guarantee high quality of curriculum resources. Nowadays, online learning courses have considerable resources in diversified forms, which include teaching videos, document resources, microlectures, Flash cartoons, etc. In particular, learners are easy to be distracted after watching the microlecture videos for a long time. On the one hand, university teachers can help learners to concentrate by embedding tests and forming question popups in videos. On the other hand, students can get feedback timely and determine whether they have mastered knowledge points, thus taking the initiative to build, criticize and understand knowledge. Moreover, curriculum professor teams from the university are good at listening feedback of learners and attach high attentions to iterative optimization of curriculums. The rich curriculum resources can help learners devote themselves into learning and participate in learning process positively, thus increasing their continuous intention to use MOOC. Therefore, universities shall pay attention to the quality of curriculum resources and avoid rejection of learners due to the excessive low quality of curriculum resources when establishing the learning support service system.

H3 is true. In online learning, learning facilities can significantly improve the continuous intention of learners to use MOOC. Reasons are interpreted as follows. Online learning depends more on good use of learning resources. University students basically have good basic conditions (e.g., mobile phones, iPads, and laptop). Nevertheless, online learning is based on network. The Internet speed and coverage degree may influence the student-teacher online interaction and students' learning. Now, most universities have high basic Internet speed and large coverage area. Students can watch video resources and make independent learning at any time and any place, without any obstacles. Good online learning hardware basis can improve the continued intention to use MOOC. To realize personalized and accurate learning of students, learning states of learners are analyzed by using information technologies such as big data, which is convenient for learners to adopt more scientific learning plans and guarantee the final online learning outcome.

H4 is false. In online learning, management services fail to improve the continuous intention of learners to use MOOC significantly. Reasons are introduced as follows. Online learning emphasizes more on teacher-student interaction and student-student interaction. Different from traditional classroom teaching, learners mainly perceive relevant behaviors of teachers and peers, but they have fewer perceptions to management services and they even believe that management services are ineffective. This conclusion also inspires our high efficiency. Setting a special study consultant and provide management service consultation to students is necessary. Therefore, students can seek assistance from the consultant when they encounter problems and difficulties. The consultant can provide specific advices and opinions to students. This not only guarantees answering to the students' confusions and prevents problem accumulation and even outbursts effectively, but is beneficial to maintain the stability in learning enthusiasm, realize management services, and improve continuous intention of users to use MOOC.

Table 3. Regression coefficient

Variables	Standardized coefficient	t	p	VIF	R^2	Adjusted R^2	F
Constant	-	2.469	0.014*	-	0.227	0.211	F (4,191)=14.035, p=0.000
Education teaching	0.328	5.011	0.000**	1.056			
Curriculum resources	0.351	4.789	0.000**	1.328			
Learning facilities	0.159	4.856	0.000**	1.191			
Management services	0.043	0.604	0.547	1.228			

D-W:1.470
* p<0.05 ** p<0.01

4.3 Difference analysis

Kruskal-Wallis test statistics are shown in Table 4. Obviously, online learning contact time is significant on the 0.05 level with respect to the continued intention to use (p=0.036<0.05), indicating that online learners have different continuous intentions to use. In view of specific numerical values, online learning contact time presents a typical "inverted V-shaped" relationship with the continuous intention of learners to use. This reflects that when learners come into contact with online learning in the beginning, they are unfamiliar with online learning resources, failing to realize preview and review. As a result, learners exert fewer efforts to learning and thereby decrease their academic performance. Finally, their continued intention to use is decreased. With the increase of online learning contact time, learners become more familiar with the method of using online learning resources, which stimulates their online learning enthusiasm and increases learning efforts. Accordingly, they are more skilled in interacting with teachers and other students by using the online platform and strengthen emotional communications with others. However, online learners lose their initial learning interests and encounter barriers in learning after online learning contact time reaches its peak. Therefore, they are easily burnt out and cannot keep learning anymore. Their enthusiasm in interaction with teachers and peers declines and their learning motivations are weakened, thus decreasing continuous intention to use accordingly.

Table 4. Non-parameter test results

	Online learning contact time (median)					Kruskal-Wallis test statistical H value	P value
	1.0 (n=32)	*2.0 (n=31)*	*3.0 (n=28)*	*4.0 (n=27)*	*5.0 (n=78)*		
Continued intention to use	4.125	4.151	4.423	4.256	4.175	10.248	0.036*

* p<0.05 ** p<0.01

Table 5 shows that students from different majors and at different grades show similar continued intention to use MOOC. This proves that online learning in universities brought relatively equal benefits to students from different majors and at different grades, without obvious differences.

Table 5. Difference analysis of continued intention to use among different majors and grades

Major (mean ± standard deviation)						F	P
1.0(n=21)	***2.0(n=34)***	***3.0(n=72)***	***4.0(n=29)***	***5.0(n=28)***	***6.0(n=12)***	0.752	0.586
4.25±1.27	4.15±1.15	4.52±1.15	4.27±0.86	4.23±0.97	4.25±0.57		
Grade (mean ± standard deviation)						**F**	**P**
1.0(n=40)	***2.0(n=71)***	***3.0(n=67)***	***4.0(n=18)***			1.311	0.272
4.11±1.00	4.35±1.09	4.50±1.00	4.14±1.38				

5 Conclusions

With the popularization of online learning, many universities in China have begun to build MOOC in accordance with their situations. Online courses do not supplement traditional teaching, but it becomes the mainstream teaching mode. However, learners of MOOC are easily tired of learning and decrease learning enthusiasm because MOOC emphasizes on knowledge transfer and has spatial separation between teaching and learning. Strengthening online learning support services can increase learning efforts of students and maintain a relatively high continuous intention to use MOOC. This study conducts a case study based on an undergraduate university in Wuhan, China. Influencing degrees of four aspects (education teaching, curriculum resources, learning facilities and management services) of online learning support services on continued intention to use MOOC are analyzed. Meanwhile, differences in continued intention to use with online learning contact time are discussed. Research results demonstrated that the overall Cronbach's α of the questionnaire is 0.872 and the KMO value is 0.833, indicating that the designed questionnaire has good reliability and validity. Education teaching, curriculum resources and learning facilities all have significantly positive promotions on the continued intention to use MOOC. According to the Kruskal-Wallis test statistics, online learning contact time is significant on the 0.05 level with respect to continuous intention to use ($p=0.036<0.05$). It is suggested to expanding questionnaire respondent samples in building the learning support service system from the mixed perspective and conducting deep studies on the relationship between individual characteristics of learners and their continued intention to use MOOC.

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AR-Supported Mind Palace for L2 Vocabulary Recall

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Abstract—MnemoRoom4U is an AR (Augmented Reality) tool that uses a memory-palace strategy for foreign-language training. A memory palace helps information recall with the aid of object association in visualisations of familiar spatial surroundings. In MnemoRoom4U, paper or digital flashcards are replaced with virtual notes containing L1 words and their L2 translations that are placed on top of real physical objects inside a familiar environment, such as one's room, home, office space, etc. The AR-supported notes aid associative memory by establishing a relationship between the physical objects in the user's mind and the virtual lexis to be retained in L2. Learners first set up a path through their familiar environment, attaching virtual sticky notes—each containing a target word to be memorised together with its corresponding source-language translation—to real-life objects (e.g. furniture in their homes or offices). They then take the same path again, reviewing all the words, and finally carry out a retention test. MnemoRoom4U is a technological artefact designed for specific didactic purposes in the Unity game engine with the ARCore augmented-reality plug-in for Android. This work takes a Design-Science approach with phenomenological, exploratory underpinnings tracking back to the efficiency of spatial mnemonics previously reported quantitatively and combines it with AR technology to effect L2 vocabulary recall.

Keywords—augmented reality, mnemonics, visuospatial bootstrapping, second-language learning, vocabulary retention

1 Introduction

1.1 Background

Vocabulary learning difficulties, although considered to be a norm in second-language (L2) acquisition, have always caused worries among learners, motivating researchers, teachers, and application designers to look for new ways to stimulate memory. To be able to communicate in a new language, it is recommended a learner obtain at least 2,000 items of high-frequency vocabulary [1]. This means that efficient visualisation techniques are crucial to retaining any meaningful amount of vocabulary. Vocabulary memorisation can be defined as the ability to "remember things after an interval of time. In language teaching, retention of what has been taught may depend on the quality of teaching, the interest of the learners, or the meaningfulness of the materials” [2]. The most common techniques implemented in classroom vocabulary instruction until now rely on verbal (learning through context, definition, keywords, synonyms, antonyms, scales, word grouping) and visual aids (drawings, photos, common objects, physical response, schemes, semantic mapping). Flashcard-supported memorisation through repetition is easy to use in daily life [3], which influenced the method´s popularity. A word card (flashcard) was identified by Nation [4] as writing a word in a target language on the front part of a card (form) and providing its definition in the language of origin (meaning) on the back side. Modern flashcards can be translation-, image-, sound-, or animation-supported, among other options.

Traditional vocabulary instruction gave way to the contextual learning and application of mnemonics in L2 acquisition proposed by Schmitt and McCarthy [5], which was in turn followed by a search for new methods and experimental approaches to word memorisation. Technological and methodological progress also had an impact in this field through computer-assisted language learning (CALL) and its later subset of mobile-assisted language learning (MALL), which during the latter half of the 20th century and the start of the 21st century significantly transformed the way languages were taught [6], [7]. Since the advent of the Internet and mobile applications, self-study language-learning proprietary, freemium (i.e. freely available but with in-app purchases that grant certain advantages), and freeware applications have been developed and made available to the public, with Babbel [8], Busuu [9], and Duolingo [10] among the highest-ranking ones. Such self-instruction possibilities have made learning a new language more accessible and casual [11], [12].

The success of the Pokémon Go [13] mobile game—released in 2016 by Niantic, the developers of another augmented-reality mobile game called Ingress [14]—drew researchers’ attention to the use of augmented reality in education [15] - [18]. Ingress’ innovative use of game design relied on displaying virtual game characters among real-world objects by tracking the camera’s position and orientation in relation to the environment. Augmented reality overlays a virtual environment on top of a projection of the real world, unlike virtual reality (VR), which projects a fully virtual environment that follows the movements of the observer [19]. Practical applications of AR can be found as early as 1957 in the cinema industry, and later during computer-graphics research and experiments with head-mounted displays. By 1980 a photographically overlaid reality was achieved on a portable-computer prototype [20] - [23]. The United States Air Force tested the system in the 1990s, obtaining positive results [24]. The educational possibilities of this technology have since been observed and explored for pre-school use in such applications as AR Flashcards [25] for alphabet and animal learning, Quiver Education [26] for colouring, and Narrator AR [27] for writing. Primary- and secondary-school applications include Amazing Space Journey [28] for astronomy use, Experience Real History [29] for history, Anatomy 3D Atlas [30] for natural science, biology and anatomy, and AR Critic [31] for foreign-language study and translations. Research has also been conducted on how AR can be used for 3D visual aids for books [32], as well as for teaching geometry [33] and science vocabulary [34]. A variety of sources describe the educational possibilities of AR, but there is still a lack of research in this field, and more study is required to obtain enough evidence of its practical benefits [35].

Augmented reality is less immersive than virtual reality as it combines both real-world and virtual-world elements, but it also provides possibilities for integration into any familiar environment. Linking geographical locations to items which need to be remembered is called the method of loci. First applied by the ancient Greeks and Romans, it entails associating a word or image to an attribute on a layout of the environment so that one can recall this word or image through the association of the two. The mental map of the surroundings that is thus created supposedly aids recall, and research attests to the efficacy of the technique [36], [37]. There are parallels between the method of loci and AR technology: they both rely on visualisation, and since L2 acquisition requires large amounts of memorisation, the three could potentially be combined to create an AR language-learning application applying the method of loci to a flash card-like map of the user's familiar environment. Previous research shows that separately flashcards, the method of loci, and AR show positive results in the domain of education, so it is logical to assume that combining them can produce an effective tool. The MnemoRoom4U prototype was designed for mobile devices with the Android operation system (optionally iOS), thus providing a technologically accessible alternative to commercially available software such as Loci Memory Palace [38], developed by In Formation, Inc. for mixed-reality immersive head-sets. The experimental app is meant to be used for second-language vocabulary recall, but its use could be extended to other, educational and non-educational sectors that require the efficient memorisation of non-related items.

The research question of the study was: how can the implementation of MnemoRoom4U (the experimental technique) improve second-language vocabulary retention in comparison with conventional alternatives? The hypothesis of the study was that MnemoRoom4U offers a more motivating and immersive environment for L2 non-related vocabulary recall than traditional techniques. The aim was to provide a holistic picture of the use of the application and its alternatives based on users' experiences. Related research in psychology conducted by Darling, Allen, and Havelka [39] under the name of visuospatial bootstrapping revealed that it was more productive for recalling numbers to map them out on a keypad-like grid than to display them one by one in sequence or mapped out linearly. In other words, there is an advantage in memory retention when items are visually linked with spatial locations. A recent quantitative study in applied linguistics conducted by Larchen Costuchen et al. [40] showed that augmented-reality cards under visuospatial bootstrapping and taking a real and an imaginary route through various objects in participants' households helped to retain formulaic language (idioms) more efficiently than the conventional method of digital flashcards on devices. The AR-VSB method was significantly more efficient for second-language vocabulary learning than digital flashcards supported by image and translation after both 15 min and 1 week, despite a higher forgetting rate, which is promising for this research paper's hypothesis.

A number of sources [41] - [44] attest to the efficiency of a similar mnemonic technique, the method of loci, applied to different fields. This work proposed replacing imaginary elements with augmented-reality technology (virtual sticky notes) in foreign-language vocabulary training and to bring to the foreground the holistic user-experience approach when dealing with the technological artefact MnemoRoom4U.

2 Method and application development

This proposal focuses on Design-Science Research (DSR), whose goal is pragmatic, aiming to design solutions to a problem [45], [46]. Specifically, this work follows a DSR subtype, Design-Inclusive Research (DIR), proposed by Horváth [47], which consists of three phases: (1) exploration of the problem, the context, and the activities; (2) design and testing of the solutions; (3) validation of the research. The application was developed in the Unity [48] game engine (Figure 1) with the ARCore [49] augmented-reality plug-in for Android. The necessary scripts were written in C# using Visual Studio (Figure 2), [50], which handled the creation of sticky notes in the app and the words that should appear on them using the existing Google sample scenes found in the ARCore Extensions package. Google Cloud [51] was used to create an API key that allowed cloud anchors to be hosted from the target device for up to one day. The application was built into an APK file for downloading and installing on any Android device that supports ARCore, or Google Play Services for AR [52] as it is known on Google Play (only a limited number do [53]).

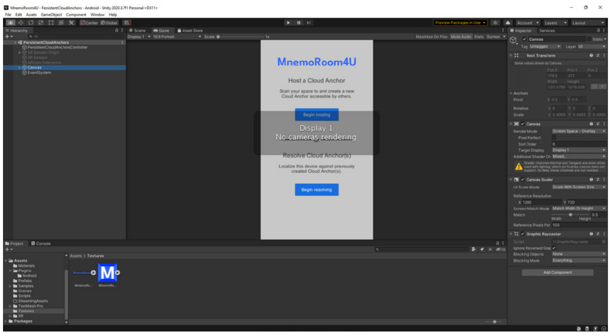

Fig. 1. Development environment – Unity

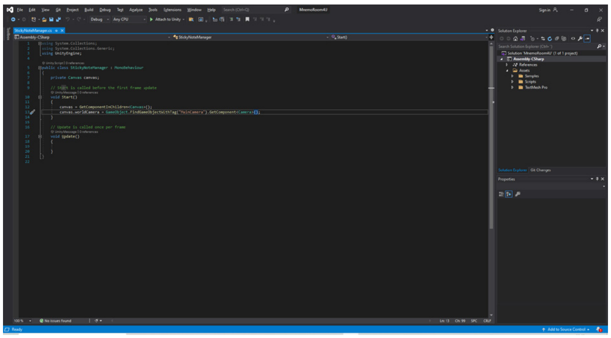

Fig. 2. Development environment – Visual studio

The conceptual design of the app consists of 5 steps: (1) the user distributes the L2-L1 words on the virtual sticky notes around the familiar environment (e.g. the user's home or office) close to the selected objects (e.g. entrance door, television, window, painting, etc.); (2) the user observes the spelling and translation of each item; (3) the user repeats the route as many times as necessary (moving always in the same direction and keeping in mind the order of the objects on the route); (4) the user does the post-test. The research population (N = 12) consisted of Spanish native or bilingual speakers who had no previous knowledge of Swedish. All the participants consented to participate in the study and were subsequently randomly distributed into three groups (one experimental and two control) with 4 participants in each (n = 4). One group was asked to use translation-based cards presented one by one, another group was instructed to use paper sticky notes combined with a route or routes around some familiar environment, and the experimental group used the application combined with a route or routes around some familiar space. The post-tests (immediate delay) were used to collect the scores; however, this study took a phenomenological perspective of lived experiences, relying for its analysis on field notes and semi-structured interviews. In all the groups, learners were not time-restricted during acquisition, but they were asked to check how long it took them to feel ready to do the post-tests. The current prototype did not use any deep-learning API, which is why the list of 15 non-related vocabulary items in Swedish (Table 1) had to be included into the programming stage.

Table 1. A list of words selected as L2

L2 (Swedish)	L1 (Spanish)	English (Translation)
Tangentbord	Teclado	keyboard
Penna	lapiz	pencil
handel	comercio	commerce
Högtalare	Altavoz	speaker
Dom	Juicio	trial
Ansluta	conectar	connect
Skön	Bonito	beautiful
Förstöra	Destruir	destroy
Svår	Dificil	difficult
Tak	Techo	roof
Väska	Bolso	bag
kunskap	conocimiento	knowledge
Väg	carretera	road
Tvivel	Duda	doubt
flygplan	Avion	airplane

The post-test design for immediate delay used an orthographic structure. The post-tests (Table 2 and Table 3) were presented sequentially, not simultaneously.

Table 2. Post-test 1

Post-test 1: choose the correct letter among the three options		
tan*entbord (k, j, g)	kuns*ap (h, j, k)	hand*l (e, a, i)
hög*alare (t, d, i)	t*ivel (w, v, y)	do* (n, m, r)
*nsluta (e, a, u)	väs*a (c, h, k)	sk*n (o, ö, n)
för*töra (s, z, c)	*enna (r, p, t)	*vår (z, f, s)
*ak (l, t, i)	v*g (ö, u, ä)	fl*gplan (o, y, a)

Table 3. Post-test 2

Post-test 2: choose the L2 equivalent among the three options				
Lapis a. penna b. tena c. henna	Bolso a. wäska b. väska c. väkka	Altavoz a. högtalare b. högtalere c. gögtalare	Conectar a. ansluta b. alzluta c. anslata	Techo a. taf b. tuk c. tak
Bonito a. sfön b. skön c. sken	Teclado a. tangentbort b. tangentbord c. fangenbord	Juicio a. tom b. dom c. don	Duda a. dvivel b. tvivel c. tviwel	Avion a. flugplan b. flygplan c. fligplan
Comercio a. handell b. jandel c. handel	Carretera a. wäg b. väh c. väg	Destruir a. törstöra b. förstöra c. förstöry	Conocimiento a. kunskap b. hunskap c. kunzkap	Dificil a. svår b. svus c. sver

The pedagogical approach for method evaluation used a 3W3H model integrated with the DIR. It was guided by the following questions: (1) Who are the method users? (2) What vocabulary items are used for recall? (3) How is the method used? (4) Why is the method efficient? (5) How did the participants feel? (6) How can the method be improved?

3 Results

The 3W3H model was applied to collect data on the participants' experiences and opinions in relation with the experimental and the control techniques.

3.1 Participants and input

The participants were all Spanish C2 speakers (native or bilingual); graduates of the Polytechnic University of Valencia (UPV) or University of Valencia (UV); holders of a Master´s, Postgraduate, or PhD degree; and active users of mobile phones and computers, with 91.6% belonging to the "digital native" category as defined by Prensky [53], according to whom "children raised with the computer think differently from the rest of us. They develop hypertext minds". The participants´ ages ranged from 26 to 48, with all but one of them having been born in the digital era. None had any prior knowledge of Swedish, but all spoke other L2s at different levels. The L2 lexis was composed of non-related items in Swedish selected randomly and checked for possible similarities with the participants' L1 (Spanish) to avoid interference.

3.2 Experimental group

In the experimental group, MnemoRoom4U was combined with one or several routes around a familiar environment (Figure 3). L2 and L1 were presented on the same side of the virtual cards. The system required the use of a compatible mobile phone [54]. The task consisted of carefully looking at the L2-L1 virtual notes distributed on or beside the objects in the household or office while walking through the route or routes (time-limited: no; time-controlled: yes; post-tests: immediate delay). Innovative elements presented in this work include the use of AR instead of imagery elements and the use of AR instead of paper-based or digitally presented notes with textual information. This study collected information on the motivational factors related to this method, on how the participants felt, and on how this method/application can be improved according to users' opinions.

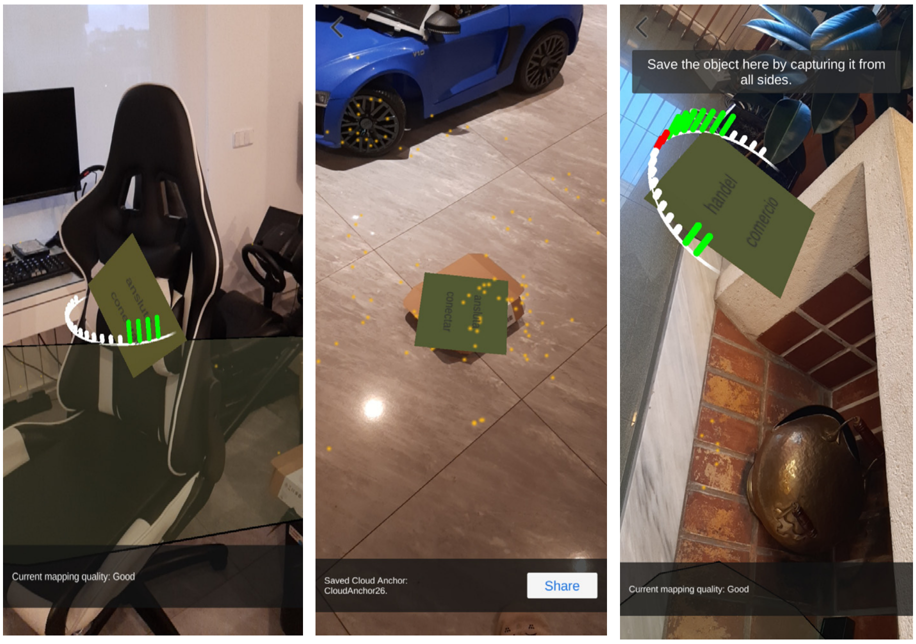

Fig. 3. Virtual sticky notes placed beside an object in a household

Table 4 summarises the post-test scores (maximum score = 29), the time required (in minutes) to set up the environment and to recall the items, the Likert scale on motivation (1 = very boring, 7 = very entertaining), and the Likert scale on the application's design (1 = very difficult to use, 7 = very easy to use).

Table 4. Experimental group

	Participant EG-1	Participant EG-2	Participant EG-3	Participant EG-4
Post-test score	28	29	28	27
Time	32	28	23	40
Motivation	7	7	7	6
Design	7	7	7	6

Participant EG-1. "The easiest words to memorise were *tvivel* (I remembered that the first letter was *t*) and *tak* (probably because it's short). I thought about Taco Bell at that moment. The most difficult words for me were those that contained *ä* and *ö*. In one part of the test, I had to choose between *sfön*, *skön* and *sken*. I was sure that it was not the last one, but I had a doubt between the previous two. There was a curious thing with the word *förstöra*. When I saw it, I thought that it was the most difficult of all because it contained two *ö*. In the end, it was the word that I best remembered." "I used it in my house, it worked best with medium-size furniture pieces or objects (preferably on the floor or walls). I am sure I would use it faster next time. The objects that are a bit far (on the ceiling) generated a smaller card. It should be kept in mind." Improvement tips: "Some cards looked reverse, but it was ok. The text was clear to read."

Participant EG-2. "The words would not be too difficult to remember. I had to use them for speaking, but I tried hard to recall the spelling and that was pretty challenging." "I would call it some fairy-tale-like experience. It was great fun. Never tried such a system before. I would be happy to use this or a similar app to improve my French. The easiest word to memorise for me was *skön*. I associated it with a name of a small cute white dog. It still sounds like a name to me. Probably another association was with the word *guapo – cute*." Improvement tips: "I would appreciate some video on how to use the application. The ReadMe document was clear and well written, but I am a very visual learner. I prefer videos and pictures."

Participant EG-3. "Associating foreign words with the objects was a curious thing. It was weird, but it worked." "The easiest word to memorise was dom. I memorised it as mod read backwards. The object to host was a VRAM box. I associate the word *väg* with *vago* in Spanish and vague in English. I imagined somebody who was lying on the sofa and did not want to go on a business trip. He did not feel like driving that day. The object that I used to host that anchor was my backpack on the floor, not far from the sofa." "I liked the colour of the cards (green) and the system of lights that appeared when you scanned the objects. It was also quite intuitive to observe red, yellow, and green indicators of the correct scanning of an object." "I think such an app would be useful to memorise passwords (e.g. strong bitcoin wallet password)." Improvement tips: "Probably I would enjoy it even more if the application had a pronunciation option and an image option too. However, I understand that not all the words can be presented as an image, especially when it comes to some abstract terms."

Participant EG-4. "The easiest words to memorise were *tak* (association with a word in Ukrainian that sounds the same and means *yes*, *so*) and *dom* (association with a Russian word that sounds the same and means *home*). I associated the word *ansluta* with connect not only because of the translation but also because the reference object in the household was an electric water boiler with a cable." "The objects around the house helped me to recall the words in the following order (e.g.: the frog – *kunskap*, the ball – *tvivel*, the painting of a house – the word *destruir* in Spanish, the plant – *lapiz* - *penna*). First I recall the object, then the word in Spanish and only then the word in Swedish." "Sometimes I couldn´t remember the last element, the word in Swedish." Improvement tips: "It takes some time to get accustomed to the application and to scanning the objects. The application provides a beautiful blend between real and virtual elements, but you should keep in mind the safety measures when you move around your household scanning the objects."

3.3 Control Method 1

Translation-based, L2-L1 word cards were presented to the participants one by one in random order (Figure 4). L2 and L1 were introduced on the same side of the cards, which could be either printed out or presented virtually on a mobile-phone device. The task consisted of carefully looking at the L2-L1 notes (time-limited: no; time-controlled: yes; post-tests: immediate delay).

Fig. 4. L2-L1 word card on a digital device

Table 5 summarises the post-test scores (out of 29) and the time required (in minutes) to train recall. Seven-point Likert scales were used to measure user's motivation (1 = very boring, 7 = very entertaining) and their evaluation of the application's design (1 = very difficult to use, 7 = very easy to use). The cards were prepared by a peer—a friend or family member who needed from 5 to 10 minutes to prepare the activity (not included in the table).

Table 5. Control method 1

	Participant CG1-1	Participant CG1-2	Participant CG1-3	Participant CG1-4
Post-test score	26	26	29	29
Time	15	10	10	12
Motivation	1	3	1	4
Design	7	7	2	6

Participant CG1-1. "The easiest words to remember for me were *penna* (association with *pen* in English), *dom* (association with *doomed* which means *ill-fated* or *condemned* in English), *tak* (association with *tall* in English and with a word combination *tall/high roof*). *Skön* (association with Ikea furniture). The technique that I sometimes use to memorise unrelated information, or a list of new vocabulary is writing that list down a lot of times (by hand). Another option is writing short notes or making some scheme or a drawing. Such things work quite all right for me. The second part of the test was easier for me than the first one. I thought I remembered the word, but then I could not remember what the missing letter was." Improvement tips: "Probably the same card system could be used on mobile phones with the option of note writing, drawing making, and pronunciation recognition." "For note writing, mobile phones like Samsung Note are really handy."

Participant CG1-2. "Easiest words to memorise were *handel* (association with *hand* in English and *del* in Spanish; I thought about a person with coins in his hand). I associated the word *dvivel* with the Spanish imperative *vive – live* in English and *doubt*, like *live with a doubt, dvivel*." "I used paper flashcards in the past. The great thing is to pass them from one pocket to another (one pocket for those words that you have already learnt, and the rest go to another pocket). I also know that there are apps for mobile phones which use the same system with sound / pronunciation." Improvement tips: "A visually attractive app would be better than just looking at white paper with some text."

Participant CG1-3. "The easiest words to memorise were *penna* (association with *pencil* in English), *tangentbord* (association with *board* in English), *flygplan* (association with *fly* and *airplane* in English). Two words looked a bit similar, *skön* and *svår*, which made it difficult for me." "I don't like this method for vocabulary memorisation." Improvement tips: "Well, I guess that the foreign-language words could be linked to images. The learner would need to listen to pronunciation several times and look at the image at the same time." "Probably some contextual use of a new work would be a necessary element, something similar to a dictionary text but on a separate card."

Participant CG1-4. "All the words were easy to memorise except for *dom*, *kunskap*, and *väska* because they are not similar to their equivalents in the languages I know." "The associations that I had were the following: *Tangentbord – teclado*, *keyboard* and *board* in English. *Skön – bonito – schoon* in Flemish. *Väg – carretera – weg* in Flemish, *way* in English, *Weg* in German. *Penna – lapis* – You write with a pen. *Förstöra – destruir* – sufficiently similar in meaning to *verstoren* in Flemish. *Tvivel – duda* – this one confused me a bit at first because it made me think of *duivel* in Flemish, which means *devil*. But then I saw *twijfel* in Flemish, which is *duda*, *doubt*. *Handel – comercio* – Exactly the same in Flemish, *handel*. *Svår – difícil* – Schwer in German, *zwaar* in Flemish. *Flygplan* – avion – *Flyg* is very transparent, but I was confused because I thought of *flight plan*. Then I associated plan with airplane. Improvement tips: "When the participants have to choose between three options, make it easy on them to indicate their choice."

3.4 Control method 2

Paper sticky notes were combined with one or more routes around a familiar environment. Materials could be printed or hand-written. When hand-written, the sticky notes had to be prepared by a peer, i.e. a friend or family member with clear handwriting

(Figure 5). L2 and L1 were introduced on the same side of the cards. The task consisted of carefully looking at the L2-L1 notes distributed on or beside the objects in the household or office during the route or routes (time-limited: no; time-controlled: yes; post-tests: immediate delay).

Fig. 5. A paper sticky note placed beside an object in a household

Table 6 summarises the post-test scores (out of 29), time required (in minutes) to train recall, the Likert scale on motivation (1 = very boring, 7 = very entertaining) and the Liker scale on application design (1 = very difficult to use, 7 = very easy to use). This activity was peer-assisted, which required from 5 to 7 minutes of additional time to prepare the environment (not included in the table).

Table 6. Control method 2

	Participant CG2-1	**Participant CG2-2**	**Participant CG2-3**	**Participant CG2-4**
Post-test score	28	24	28	29
Time	20	5	17	18
Motivation	4	6	4	5
Design	6	6	5	7

Participant CG2-1. "The easiest words to recall were *penna* (association with pen in English), *svår* – association with *schwer* in German and *flygplan* - association with *Flughafen* in German." "The system of distributing sticky notes around my house was unusual and I had to understand how and why it worked. It did. It was neither very entertaining nor uninteresting, it was all right." Improvement tips: "Probably in the near future gadgets will provide much more data to us about anything in the physical world (scanning for information about anything around you)."

Participant CG2-2. "I was guided by the root of words like: *penna*, *flygplan*, *tangentbord*, one letter substitution like: *skön (schön), väg (weg),* multiple letter substitution: *tak, ansluta* and some faraway relation (e.g.: *dom* in German is *cathedral* but in Swedish - *juicio*)." "Associations: *penna* - *pen* (English), *skön – schön* (German), *ansluta* - *anschliessen* (German), *tangentbord* - *keyboard* (English), *wäg* - *weg* (German), *tvivel* - *zweifel* (or something similar) *förstöra* - *zerstören* (German), *kunskap* - *kenntnis* (German), *tak* - *dach* (German), *flygplan* - *flugzeug* (German), *sver* - *schwer* (German)." Improvement tips: "Learning a new language is always tough at the beginning, so different techniques can help people and motivate them." "To memorise unrelated vocabulary items I normally use flashcards, write down words that I heard during the day together with the situation."

Participant CG2-3. "A difficult word was *väg*. In a test I chose *wag*. I had an association with a Volkswagen car, and I was not sure if it was correct to write *Wolksvagen* or *Volkswagen*. It was very confusing. The sticky note with a word was placed on my aircon." "At first I thought that such a system would be great if you used the sticker to indicate what the real object meant (for example, let's take the gas stove and translate this word into a couple of other languages. Then I thought that we cannot put a sticker on everything, and there are more complex concepts that require specific translation." "It was my first experience with the mind-palace system. I could try to use it to remember speeches that I have to prepare in English). One of the easiest words to remember was *väska* (I remembered the part *ska* and I imagined a black handbag with a big golden *V* letter). The word *kunskap* was also relatively easy. I associated it with *kunst*, which means *art*. I never studied German, but somehow I know the word." Improvement tips: "This system could be more interesting if we could use some technology (probably some voice assistant and a writing assistant; all - on an electronic device)."

Participant CG2-4. "The shortest words with no special symbols were the easiest." "I just used the instructions and was trying hard to memorise. What helped me to learn was the order of the words and the objects. It was really helpful. This system made me feel more relaxed than when you try to memorise for example a shopping list not in a given order." Improvement tips: "I just thought of a room with empty walls that could be filled with any learning content (by projections, for example)."

4 Discussion

The Likert-scale findings demonstrate that the use of the experimental technique was significantly more appealing and motivating to participants than the control methods. However, it took the learners more time to set up the environment and to do the training. The application produced a positive effect on the users, with all of them finding it intuitive and quite easy to deal with. The important general takeaway from this study is that the majority of the participants used associations based on the similarities between the unknown words and the languages they had some knowledge of. Moreover, some participants in the experimental groups in Control Method Two linked objects with the chains of associations, which is another interesting issue for further research and updates of MnemoRoom4U. The control groups' participants mentioned the possibility of adding personalised images and pronunciation options, which will be included in new MnemoRoom4U versions. All the participants performed quite well in the post-tests, although due to the nature of the qualitative study we cannot make any conclusions based on numerical information and comparison between the groups. More research (qualitative and quantitative) will be required to test the updated MnemoRoom4U versions that may contain a wider range of possibilities (API for Indo-European languages, personalised images or doodles, hearing and reproducing pronunciation). All these elements provide additional technology-related challenges at the programming and testing stages.

5 Conclusion

Combining AR technology with mnemonics and language didactics was an exciting goal, however developing the current application was not an easy task for the author and the developer, as it required interfacing with Google Cloud's very unwieldy API. Creating an API key that supported cloud anchors that could be hosted for up to one day was feasible but hosting them for a longer period of time (up to 365 days) required maintaining the locations of all the loci, and an OAuth 2.0 client ID was needed [55]. After trying to get it working for several weeks, the effort was abandoned in favour of the simpler API-key method. Due to the aforementioned issues, the rest of the application was developed for experiments to be conducted within a 24-hour time period. Future versions of the application will foreseeably feature other AR frameworks as well as more and richer data. Since context-based learning in AR is another highly promising emerging pedagogy, its elements are planned to be added to MnemoRoom4U as an alternative to mnemonics. We hope to expand this research with more analysis of digital and non-digital generations in second-language vocabulary recall (applied to a variety of latin-based languages), and to consequently verify if there may be any statistically significant differences in performance between genders. We hope to contribute to innovations in education, in teaching languages, and in lexis memorisation, and finally to make vocabulary recall more fun.

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Design and Implementation of a Blended Learning System for Higher Education in the Democratic Republic of Congo as a Response to Covid-19 Pandemic

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Abstract—Until now, the higher education system in the Democratic Republic of Congo has relied on the traditional face-to-face teaching method, which consists in the real physical presence of students and teachers during classes and lectures. Thus, the United Nations Educational, Scientific and Cultural Organization (UNESCO) is currently advocating e-learning as the only alternative for education in the COVID-19 era. It goes without saying that this requires specific frameworks and appropriate resources, including access to a good quality internet connection. Several countries around the world have implemented this recommendation since the first quarter of 2020 to protect their populations from the significant risks of Covid-19 contamination. In educational environment however, given the disadvantageous realities of the Democratic Republic of Congo, including the cost and quality of internet, the low rate of electrification, and the lack of experience of the educational stakeholders involved, the shift to e- learning remains a challenge. Thus, we propose in this paper a blended learning model that can smoothly introduce e-learning through a platform specially designed to integrate the traditional way of delivering courses in Congolese higher education with e-learning based on ICT.

Keywords—Covid-19, e-learning, blended learning, blended didactic model, face to face teaching, ICT

1 Introduction

The Coronavirus (COVID-19) pandemic, that has hit the world since 2020, has brought significant changes and transformations to the world. By the end of 2019, COVID-19 began to spread rapidly around the world, causing the death of thousands of people. The COVID'19 epidemic tested the readiness of educational institutions to offer distance education [1]. In terms of teaching and learning methodology, the COVID-19 epidemic has had an impact on many educational institutions. Face-to-face instruction has been phased out of many schools, colleges, and institutions [2]. As a result, several countries initiated relevant strategies to contain this virus. Subsequently, all spheres of life have been affected and all sectors of governance have been impacted, including the education sector. In the Democratic Republic of Congo (DRC), in March 2020, the President of the Republic announced the closure, until further notice, of schools, colleges and universities throughout the country to stop the spread of COVID-19, ordering millions of students to stay home. While many countries around the world have been able to quickly develop alternative distance learning strategies, the education system in the Democratic Republic of Congo has not been able to meet the challenge of adapting to this new learning mode.

It is true that the Ministry of Primary, Secondary and Technical Education (STE) has successively proposed solutions to save education in the DRC, but the courses have been broadcast two hours a day on several national radios and continuously on the television channel of the Ministry In addition, a massive distribution of exercise books throughout the country was announced. The vodacom telecommunication company application, VODA EDUC, which is supposed to be accessible via the Internet to teach students at home, was also tested. However, all these initiatives were limited to the primary and secondary education sector and not to higher education. This is easily explained by the fact that all primary and secondary schools in the country follow the same school calendar, with the course content for each option being the same, being well defined, documented and scheduled throughout the year by the STE. This uniformity of content facilitated continuity, as all students were expected to be at the same level and could therefore relate to the instruction provided through these different alternative tools.

However, at the level of higher education in DRC, it can be observed that there is more flexibility in the approach to teaching. Although the basis is the same, each university has its own way of delivering courses. In addition, the professor is known to be the master of the course, having the ability to adapt the course schedule to his or her own schedule, to decide on the best approach, content, materials, and documentation for the course. In this view, tools such as radio or television would not work in a liberal and independent context. It goes without saying that popular learning management systems (LMS) such as Moodle and blackboard could have been deployed and applied. Unfortunately, there has been no initiative to integrate them and facilitate distance learning in universities and colleges. A few universities such as Catholic University of Congo (CUC) have tried to use the Zoom videoconferencing platform to continue delivering live courses. But overall, all teaching activities stopped during this period. This has led us to ask many questions, as several studies and surveys have suggested that higher education in Africa is in a much better position to face the challenges of the pandemic, as higher education students are adults and are much more likely than others to have access to the internet and online learning. So, without underestimating the challenges, provided universities are proactive and thoughtful, they can probably reduce the educational impact of Covid-19 on their students more easily than other sectors [3].

However, we note a willingness on the part of the Congolese government to change things, notably through the initiative to install free WIFI in all public universities to facilitate access to knowledge. In addition, in 2021, the Minister of Higher Education and University (HEU) prohibited the sale of handouts or syllabus stating that every teacher has the obligation of making available to the faculty the electronic version of each course assigned to him. The initiative is commendable, but many professors deplore the lack of an adapted platform that will allow them to exchange electronic pedagogical and didactic resources with their students. All these realities reveal the major vulnerabilities of the current system to adapt to changes. The level of efficacy and preparedness for teachers, students and the entire education system is now being checked [4]. The need to develop our own digital learning solution for a flexible and resilient education model is therefore a major concern.

Until now, the Congolese higher education system has been based on the traditional approaches of teaching consisting in the actual physical presence of students and professors during classes and lectures, as well as paper evaluations. However, the recent health crisis has shown the limits of this system. Today, international education is promoting e-learning as the only alternative in the context of COVID-19 education, which requires special settings and appropriate resources. Many universities have successfully shifted to distance learning. For example, New York University, Shanghai, and Duke Kunshan University offer examples of successful adaptation and rapid deployment of educational technology products, such as the Zoom video conferencing platform and Moodle [5]. An important point to consider is that these universities had previous or existing experience with these technologies that they were able to scale; they were not starting from scratch with new and untested technological solutions. This is not the case for the Congolese educational institutions, which lack such preparation and planning. Moreover, in a country where the internet penetration rate is one of the lowest on the continent with nearly 19% for a population of 88.18 million people, or 16.35 million internet users [6], it would be illusory to believe that we could move to distance learning without significant adaptation difficulties. The other serious problem is the energy challenge facing the Democratic Republic of Congo. The country has one of the lowest rates of electrification in the world. Less than 10% of the Congolese population has access to electricity, 35% in urban areas (50% in Kinshasa) and less than 1% in rural areas [7] and without electricity, there can be no digital development.

2 Related works

The attention given to blended learning, a model of education where students combine classroom instruction with online training and resources is growing in reformist circles. Blended learning is also defined as a type of online and offline learning that combines the benefits of online and traditional learning [8].This new approach is now presented as a new way to individualize learning within competency-based education systems [9]. A lot of research has been done on e-learning and especially on blended learning systems.

In a Malaysian higher education institution, Farahiza Zaihan Azizan conducted an exploratory study on blended learning. The focus was on understanding what blended learning means, the implementation of blended learning in higher education institutions in Malaysia and the benefits that can be identified. He finally proposed a framework for blended learning to work best in higher education institutions in Malaysia [10].

Based on a survey of 400 higher education teachers, Jintavee Khlaisang and Maneerat Likhitdamrongkiat developed an online learning system in a blended learning environment to improve the cognitive skills of higher education learners. They used 120 students to test the system in three major disciplines established by Office of the Higher Education Commission Thailand. Data analysis indicated that there was a statistical difference between the pre-test and post-test scores at the .05 level of significance [11].

Kadek Suartama et al developed a mobile blended learning design to systematically guide the lecturer through the teaching processes. They created a mobile blended learning design by combining mobile learning and blended learning. Their instructional design is adaptable to learning and effectively promotes mobile blended learning [12].

Tubagus, M., et al. developed blended learning with Claroline as a learning tool to help students learn more effectively. They used a quantitative strategy to collect data utilizing pre and post tests, as well as questionnaires, to achieve their study's goal. Students studying Islamic economics were separated into two classes, with a total of 50 students participating in the study [13].

Because there are so many platforms that can be used for blended learning, it can be difficult for teachers and students to choose the most appropriate one, especially when learning mathematics and ICT. Ardana et al developed a decision support system to help teachers and students choose a blended learning platform that is suitable for learning a variety of subjects such as mathematics and ICT at SMK TI Uda-yana. [14].

3 Design context

According to research objective, we present and analyze the current learning system in higher education in the Democratic Republic of Congo to show how it functions, secondly at the end of analysis of the existing system, we propose solutions considering criticisms made on the existing system. Finally, we model and implement the new system.

3.1 Presentation of the current higher education system in DRC

About the course

- **Location**: Classes are generally held in an auditorium according to a set schedule that may vary depending on the availability of teachers.
- **Delivery of course**: Normally, the teacher teaches the theoretical parts of the course and is supported by assistants or work leaders who take care of the practical parts. But it often happens that the teacher is not available, he/she just introduces the course, and the assistants take care of the course from the beginning to the end. Assistants therefore play a significant role in higher education in the DRC. Teachers often dictate so that students can note down and the teacher often notes on a list the students who have a good application or grants them bonuses.
- **Teaching materials**: Students usually take notes, and if the teacher wishes, he/she provides syllabi or electronical documents that students can also photocopy, or less

often video or audio content in the form of CDs or DVDs. Sometimes written materials are not enough. In computer science field, for example, there is often a need to share project codes between students and teachers on a USB stick. This method often promotes the transmission of viruses between computers. Some teachers prefer to use a projector for better student interaction. They often project slides, videos, or whatever they are doing on their screens so that the students can do the same.

About the exchanges. In the past, students exchanged with each other or with their teachers mainly in the auditorium or on campus, but thanks to social networks such as WhatsApp, more and more exchanges are taking place online. A group is often created for the class in which all students are added and sometimes even professors and assistants. It is in this group that information, announcements, and sharing of files related to courses, practical work, evaluation results... Similarly for group or team evaluations, a WhatsApp group is often created with the different members and group leader to share ideas and resources. Teachers and assistants often share their phone numbers and email addresses so that students can reach them. Face-to-face exchanges are often done in the office.

About student assessment. To ensure that the students understand the courses, evaluations are used. The teacher may dictate the questions orally, or write them on the board, give each student a sheet of paper containing the questions, or give the Head of the class a file containing the questions in the case of a practical assignment. Assessments are often submitted in written form on paper and are corrected manually by the teacher or his assistants. These evaluations can be done in the auditorium or at home within a specific time frame. In the case of practical work, students often submit their resolutions to their head of class who will pass them on to the teacher. However, it is also possible to hand in the work directly to the teacher. The results are known either by handing in the corrected papers or often by publishing lists of the grades of each student, which are often stuck on the wall of the auditorium so that everyone can see their grade. However, these lists are increasingly shared in electronic format (pdf or word) in the class WhatsApp group. When a student challenges his grade on a practical work or a test, he talks to the teacher who, depending on his conviction, may or may not change the grade. There is also group work, students form groups according to a defined number, choose a leader and a subject. The subject can be given to them or can be the result of their personal choice if they agree with the teacher. The work is often a project to be defended or submitted in written form.

About the class attendance. Attendance is a major factor that shows the student's involvement in the course and can affect the student's deliberation and results. Attendance is managed as follows: Paper sheets called attendance lists are circulated in the auditorium for each student present to write his/her name. However, students often add the names of their absent classmates. This leads the teacher to call the roll at the end of the class to weed out the cheaters. After this step, the teacher will have to add the result of the attendance list to an electronic file containing the attendance of all the sessions of the course on his machine in Excel or Word. At the end of the course, the teacher calculates the total attendance of each student. There are however some rare teachers who bring their machines to the course, take the call, and transcribe the result directly on their machines.

Final term paper and dissertations. To complete their undergraduate or graduate final Term paper or thesis, students choose advisors and co-advisors who will supervise them throughout the writing process. Often, the student proposes a topic to the advisor and discusses it with him/her. The director may also suggest a more relevant topic. Each time a chapter evolves, the student presents the work to the advisors, who corrects it and gives it back to the student. For their research, students are inspired by scientific works, articles, publications, and books that are available in libraries, but also online.

3.2 Review of the current system

For the management of the attendance, we observe that there is a triple task, students write their names at each session of the course, the teacher makes the call, the teacher transcribes the result of the call on his machine.

Students without course materials or syllabus take notes and try to understand at the same time, and often teachers who want to keep up with students start dictating the course, which slows the pace of the course, and the assimilation performance is not optimal.

Grading assessments and assignments manually is a tedious task, especially in a context where electricity is often lacking. Moreover, it is difficult for teachers to detect plagiarism online, as more and more students copy their resolutions online. Also, there is a lack of media diversity in teaching.

In analyzing that way, the results of the evaluations are published, we must note a lack of confidentiality. In addition, the fact that students hand in their assignments through class leaders can also have negative effects. Indeed, some less serious class leaders like to offer or even sell the homework or assignment resolutions of students considered bright to weaker or lazy students, to the detriment of their authors.

Sharing course resources in class WhatsApp groups is a good initiative. However, the problem with this system is that everything is mixed up, so that students are overwhelmed by messages from discussions, forums, audio messages and files related to the course, and it is difficult to keep track of them when they are not connected to the internet for several days.

It is sometimes difficult for students to meet with their thesis advisors to follow up on the progress of thesis at each stage due to their busy schedules.

The various scientific works carried out by students are most often piled up in libraries where it is not easy to find works relating to a subject on which one would carry out research.

3.3 The proposed system

Considering the criticisms made previously, we have proposed a blended educational system that we have called CISNET (Campus Information system Network) for the Congolese higher education which considers the following proposals.

- The class materials and all the media of the course are published by the teachers on an online platform so that students already know about it and that in the classroom, they will have further explanations, exchanges, discussion, and interactions.
- The call for attendance list is made in the classroom through the platform.
- The homework, assignments and tutorials are done on the platform, they can be done synchronously (in the auditorium the teacher publishes an assignment, and the students answer it on the platform) or asynchronously (the students submit the assignment later).
- Quizzes may or may not be done on the platform. It depends on the teacher's discretion.
- The publication of the results will be done on the platform. The platform will allow teachers to publish even the results of evaluations that did not take place on it, to allow them to calculate the overall average of the course for each student.
- Requests for thesis advising will have to be made online, as will the sharing of these progress files.
- Student theses and papers will be published on the platform to make them more accessible.

3.4 Design of the proposed system

The actors of the system. The analysis of the existing system of university education in the Democratic Republic of Congo gives us the following actors:

- Student theses and papers will be published on the platform to make them more accessible.
- The teacher or professor: This is the educator who owns a space on the system, creates courses in the system, manages its content, and invites his or her students to enroll.
- Student: A person who receives or follows instruction or training from a teacher or professor who also uses the system.
- Teaching assistant: This is a secondary teacher associated with the course by the tenured teacher and whose actions are limited by the rights and privileges granted to him.
- The administrator: This is the person who manages the system daily. The administrator can be a staff member of a university.
- The visitor: The visitor is anyone who does not have an account on the platform, but he can see the teachers registered on the platform, the publications and scientific works published.

Use cases of the system. Considering the roles that each actor must play, we have listed the following use cases:

Use case for the Teacher

- Authentication: this case allows the teacher to log in to their account.
- Course Management: Allows teachers to manage their courses and add course content, media, archive courses, close courses, and start a new academic year.

- Management of teaching assistants: Allows the teacher to add a teaching assistant for each course, give them rights and privileges.
- Attendance Management: Allows the teacher to schedule class sessions, take roll calls and view individual and general class attendance reports and statistics.
- Students' assessments management: Allows the teacher to add assessments of individual or group assignments, as well as quizzes, with the possibility of self-correction, and then publish the results with comments, and respond to student complaints about the results obtained.
- Students' management: Allows the teacher to manage his students, block them from the course, unblock them, add annotations on each one according to their individual application.
- Management of teacher's space: Allows the teacher to manage his information presented on the platform, his profile, his presentation, his research, etc.
- Management of requests for thesis advising: Allows the professor to accept or refuse students' requests for thesis advising and, in the case of acceptance, to exchange with them and send needed resources concerning the work at each stage.
- Management of supervised thesis: Allows the teachers to manage the student's thesis they have supervised.
- Scientific publications management: Allows teachers or professor to manage his/her scientific publications such as books, articles, etc.
- Management of notifications: Allows the teacher to be notified of events that occur such as each new course registration, when a student sends his or her resolution of assignment, thesis advising requests and new messages.

According to the above use cases of the participating teacher, we have the following use case diagram.

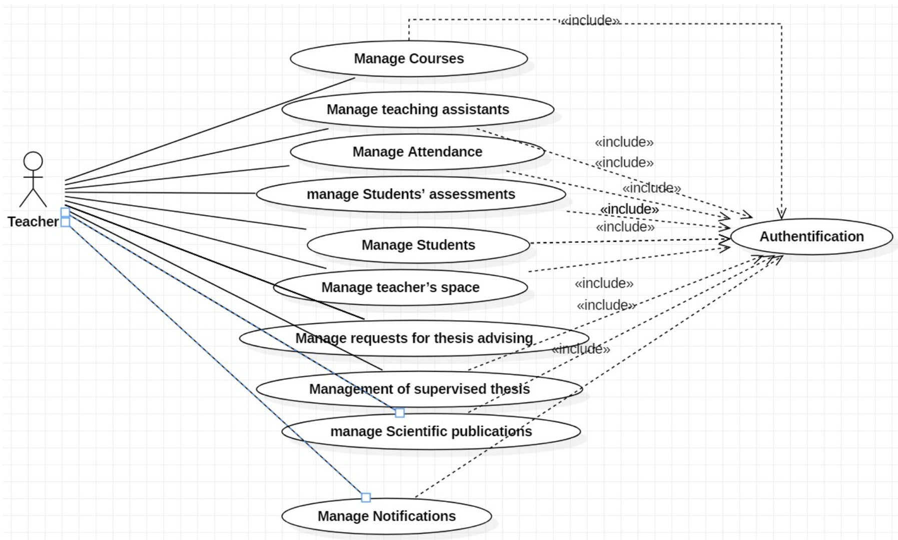

Fig. 1. Use case diagram for the teacher

Use case for the Student

- Authentication: This case allows the student to log in to their account.
- Enroll in the course: This use case allows the student to enroll in a course with the code that the teacher will give, to have access to all the content of the course.
- Access to course content: Students who have registered for a course must be able to access all course content and media, as well as the observations from teachers and their attendance records.
- Taking part in evaluations: The student enrolled in the course must be able to see the evaluations, send in their resolutions, see their results and corrections, send claims, and create an assignment group.
- Thesis advising request: The student can send a coaching request to the professor of his choice on the platform and be notified of the acceptance or refusal. If accepted, the student must be able to exchange with the professor and share files related to the progress of the work.
- Access to publications and scientific works: The student must be able to access all scientific works and publications shared on the platform.
- Profile management: Allows the student to manage their information presented on their profile.
- Receive Notifications: Allows the student to be notified of events that occur such as each addition of content to the course, each new assignment published as well as corrections, and the acceptance or not of his request for thesis advising, new messages received

According to the above use cases of the student actor, we have the following use case diagram:

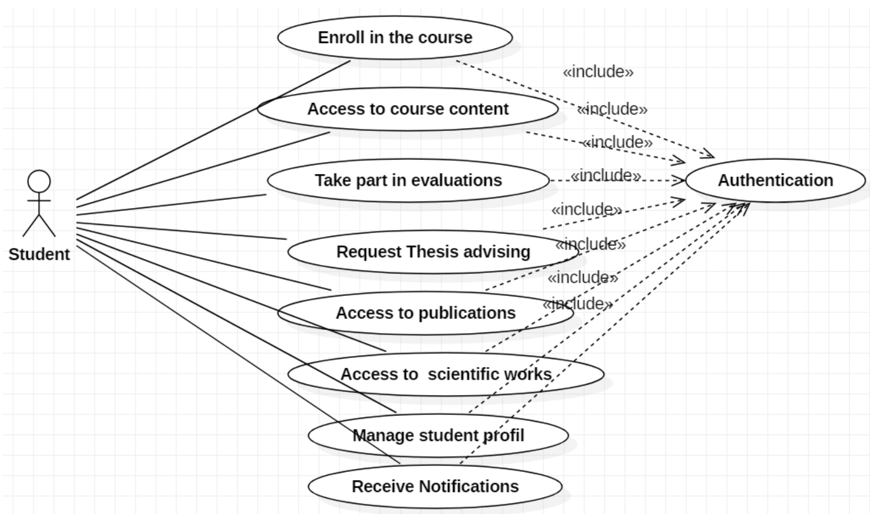

Fig. 2. Use cases for the student

Use case for the teaching assistant

- Authentication: this allows the teaching assistant to log in to the system.
- Course management: Allows the teaching assistant to manage the courses in which he has been appointed as an assistant. He can add content and media.
- Attendance management: Allows the assistant to schedule class sessions, take roll calls and view individual and general reports and statistics.
- assignments management: Allows the teaching assistant to add grades to individual or group assignments, as well as to quizzes, with the possibility of self-correction, and afterwards publish the results with comments, and respond to students' appeals on the results obtained.
- Manage students: Allows the assistant to manage his students, block them from the course, unblock them, add annotations on each.
- Manage Notifications: Allows the teaching assistant to be notified of events that occur.

According to the above use cases of the teaching assistant actor, we have the following use case diagram:

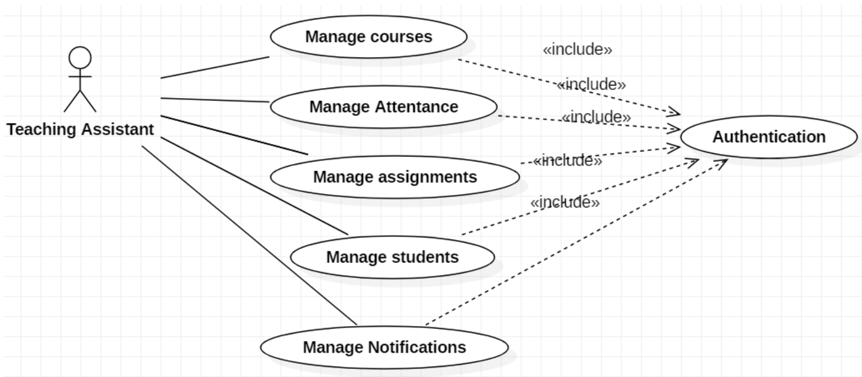

Fig. 3. Use case diagram for the teaching assistant

Use case for the administrator

- Management of notifications: Allows the teacher to be notified of events that occur such as each new course registration, when a student sends his or her resolution of assignment, thesis advising requests and new messages.
- Authentication: this allows the administrator to log in.
- Teachers' management: The administrator is the one who registers the teachers on the platform.
- Users' management: The administrator manages all the users of the system and can see all their information.
- Management of scientific works: The administrator can upload the scientific works of the students to publish them on the platform.

- Consult the statistics of the platform: The administrator must be able to see the number of users, students, teachers, assistants, courses.

According to the above use cases of the administrator actor, we have the following use case diagram:

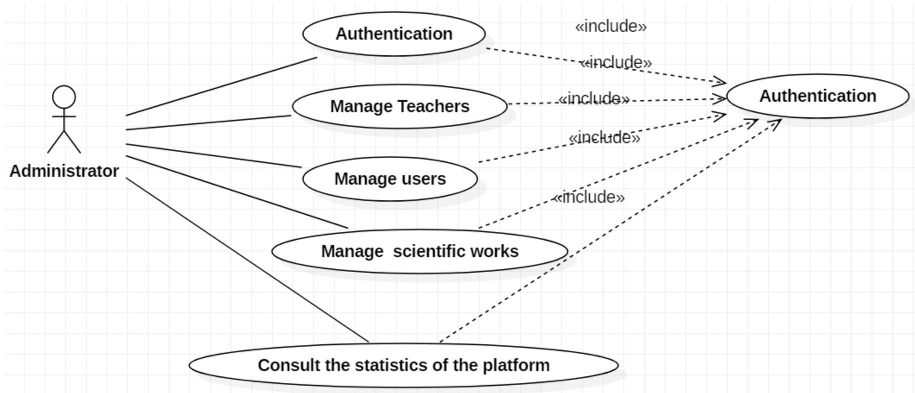

Fig. 4. Use case diagram for the administrator

3.5 Technologies used

To develop the application, we used HTML, CSS, JavaScript, Ajax, and jQuery. To make the application responsive, we used Bootstrap, which is the most widely used HTML framework, CSS, and JavaScript framework for creating responsive and mobile-oriented websites. On the backend, we used PHP, a server-side scripting language and a powerful tool for creating dynamic and interactive websites. For the database, we used MySQL database which is a fully managed database service that can be used to run native cloud services.

4 Result

Our platform is called CISNET (Campus Information System Network). It is a platform independent of universities or institutions. It includes professors, supervisors, teachers, and researchers who want to manage their courses and their students from different institutions. So, they create courses and give them codes through which they can register. It is also a platform for researchers who are looking for or want to share their research results, publications, scientific works. Our application is a dynamic website, it is accessible from a web browser and its code is hosted on a server. The application can be accessed via the URL https://cisnet.online.

Until now, 5 teachers and more than 500 students use the system regularly in 3 universities namely the University of Kinshasa, the Protestant university in Congo (UPC) and the Pan-African University of Governance and Innovation (UPGI).

4.1 Home page

This is the first page that any visitor will see when they first use the site. There is a presentation of what the platform does, as well as the different menus, and the connect button.

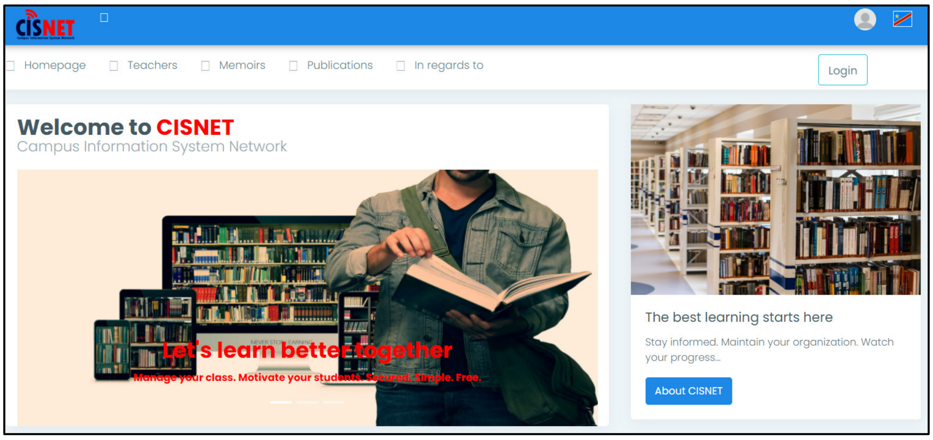

Fig. 5. Home page of the proposed system

4.2 Login page

To connect to the system, users must provide their password and login.

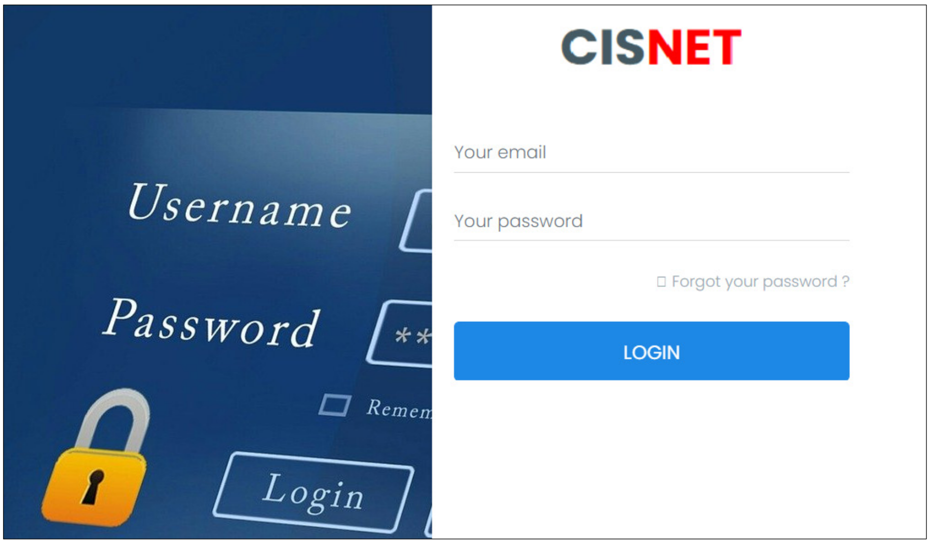

Fig. 6. Login form of the proposed system

4.3 Teachers or Professors list

This interface shows us the different teachers who use our platform and a small summary presenting them. You can see that there are not only teachers but also supervisors or assistants who may prefer.

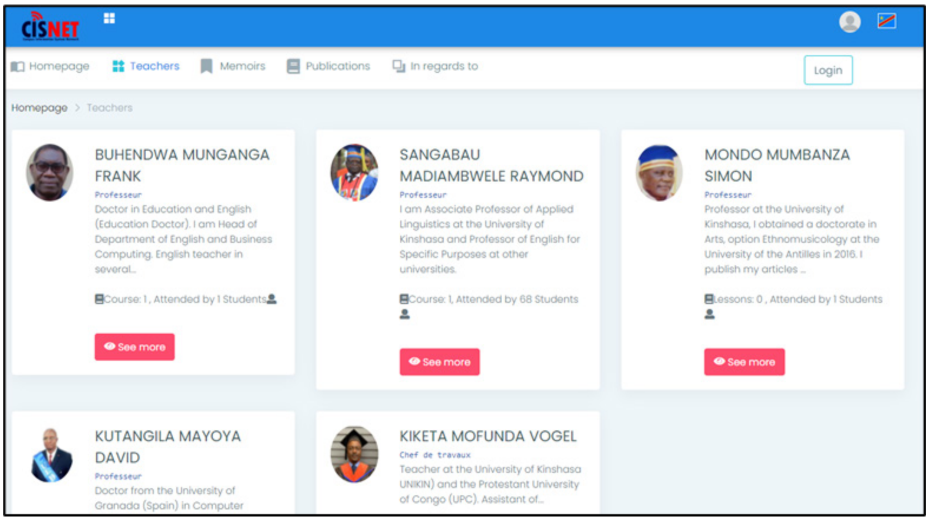

Fig. 7. Teachers or Professors list

4.4 Teacher or Professors presentation page

By clicking on a teacher in the list, you will see his/her presentation, research field, publications, scientific works he/she has supervised and the possibility to register to his/her courses.

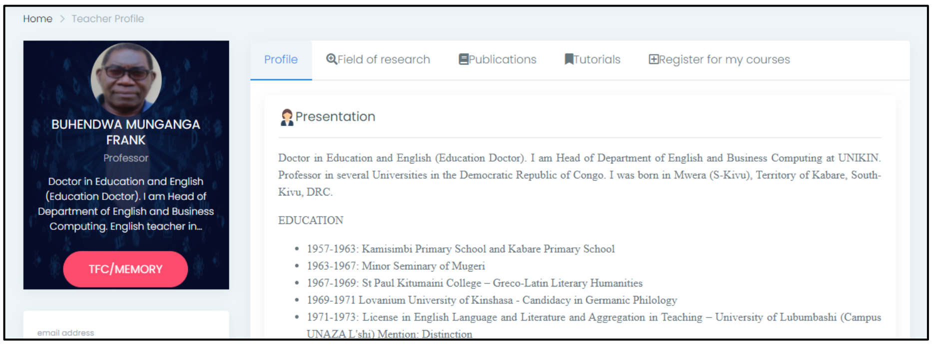

Fig. 8. Professors presentation page

The red button thesis displays the following form that allows you to send a request for thesis advising.

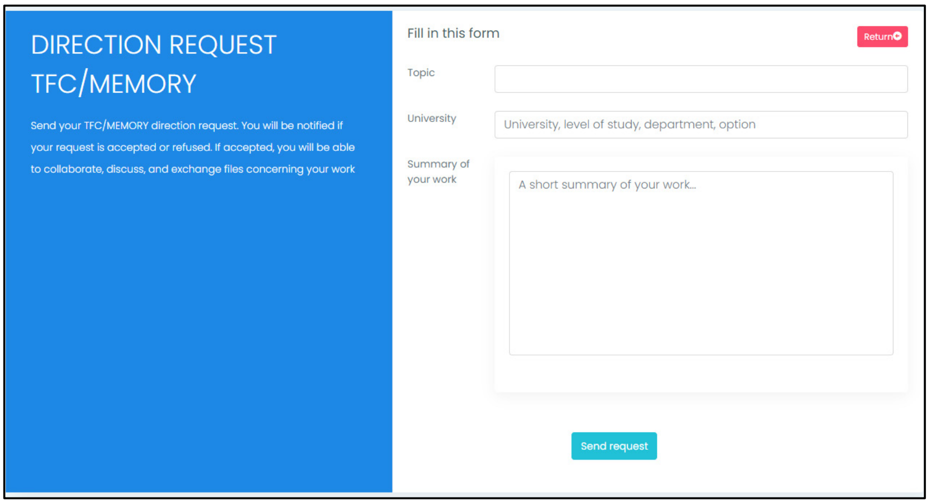

Fig. 9. Request for thesis advising

4.5 Registration to a professor's course

Lorsque l'étudiant clique sur le bouton d'inscription à mes cours pour un instructeur, vous verrez apparaître ce formulaire pour l'étudiant qui n'a pas encore de compte. Il comprend à la fois le formulaire de création de compte et le formulaire d'inscription. Pour ceux qui sont déjà connectés à leur compte, il n'y a que les trois premiers champs. Ils choisissent leur université, et tous les cours de cette université apparaissent, de là ils choisissent les cours auxquels ils veulent s'inscrire et pour éviter les non-étudiants, ils doivent donner le code que le professeur leur aura donné au préalable.

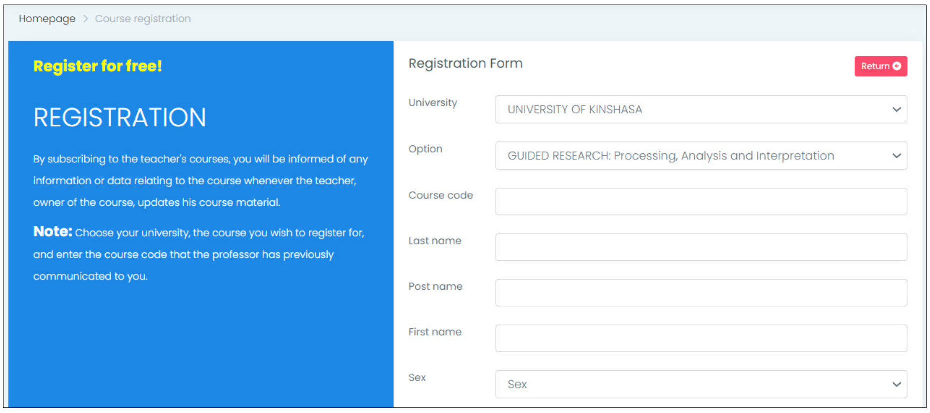

Fig. 10. Registration to a professor's course

4.6 Student dashboard

In the dashboard of a student registered on the platform, there is:- The presentation of his teacher;- The schedule of the scheduled courses;- The list of the active courses in which he is registered;- The current assignments, that is to say those whose deadline has not yet passed. The list of active courses in which the student is enrolled;- Current assignments, i.e., those whose deadline has not yet expired; here, the mention ; - "Not sent" reminds us that the student has not yet handed in his work;- The direction menu of the final work, because if it is supervised by a teacher.

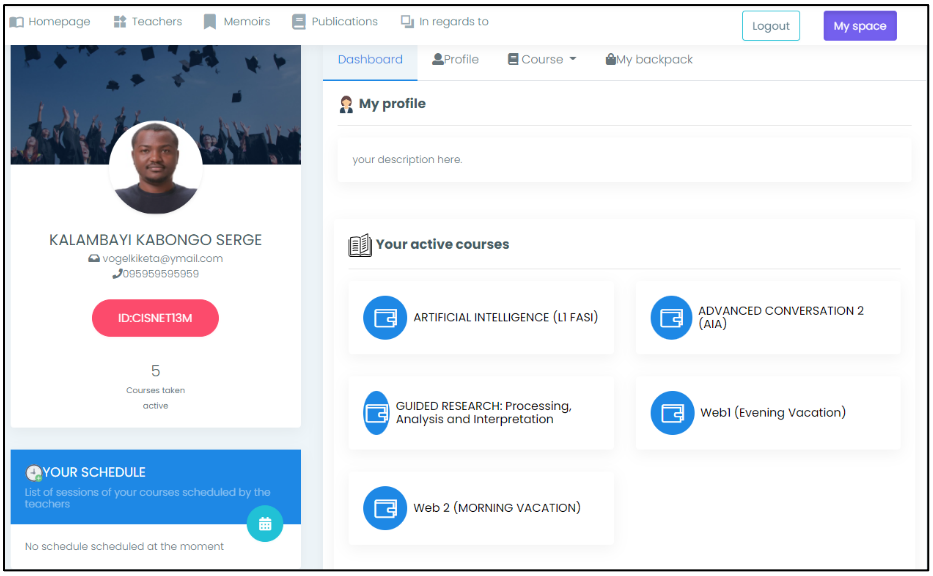

Fig. 11. Student dashboard

4.7 Student dashboard

In the dashboard of the teacher registered in the platform, we find the number of his active courses, his publications, the number of students he teaches and supervises, the total number of assignments in progress. Further down, you will find the course sessions he/she has scheduled, the details of the work in progress, as well as the list of active courses.

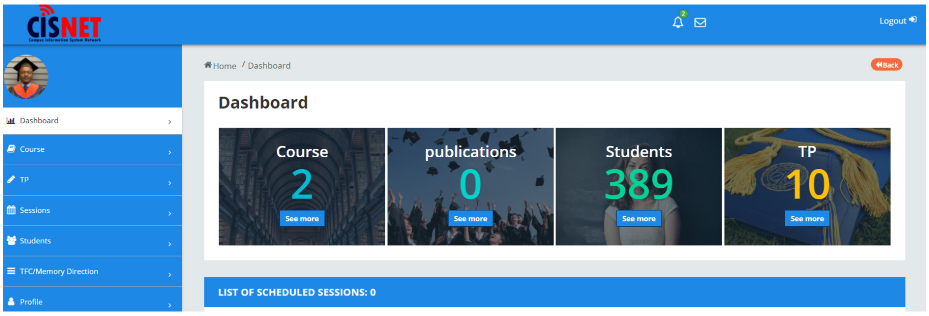

Fig. 12. Teacher dashboard

For more information on the features of the application, you must create your teacher and student account via the link https://cisnet.online.

5 Discussion

This work is a great contribution and innovative dimension on the implementation of an ICT-based system adapted to higher education in the Democratic Republic of Congo.

5.1 Implementation of a custom designed system

The proposed system is not copied from another pre-existing or even foreign system. On the contrary, starting from scratch, from a detailed analysis, we have replicated and digitized the current operating model of teaching in higher education in the DRC. Thus, the functionalities that we had to implement such as the supervision of the final term paper or thesis online, quizzes with different series, introduction of claims after publication of results, and many others are specific to our system, and are rare to find in popular LMS like Moodle, Google School.

5.2 The implementation of the flipped classroom concept in Congolese higher education

One of the solutions we had to mention was that the materials and all the media of the course are published by the teachers on the online platform so that the students already know about them, so that in the in the classroom it is either for further explanations, exchanges, discussion, and interactions.

This is a simple inversion of the traditional pedagogical approach where class time (group learning) is followed by homework or assignments (individual learning). In the flipped classroom, students are first introduced to a new topic individually at home through online videos and supporting content and media, and then they are invited to apply their knowledge in class and to go deeper into the topic through discussion, problem solving and group work under the guidance of the teacher.

The benefits of this approach are multiple: -Teachers spend less time introducing new topics; -Students develop independent learning skills; -Students will avoid absences because the attendance list is done on the platform; -Teachers can reuse the content they create; -Students find the time spent in class more interesting.

5.3 Flexibility

The system we propose is extremely flexible. Indeed, although we offer several features as mentioned above, each teacher is free to use or select those to which he can easily adapt himself and his students and integrate it into his operating model without much adjustment. Let us illustrate this with some examples: We have proposed that the evaluations or grading be done on the platform as well as the final calculation of the average and publication of the results. However, we still give teachers the possibility to print the results in pdf or Excel format in case they prefer to calculate the average themselves, edit, or publish outside the platform. Similarly, if a teacher finds that the internet connection is not reliable enough for online testing, he or she can do it out of the system and publish the results online. They can then add the results of this test to the overall average calculation offered by the system. Teachers who do not wish to redesign their courses into modules can simply upload their syllabus in one file. Our main goal is to allow the different actors to integrate technology into teaching at their own pace and to become familiar with it.

5.4 Better management of evaluations

We have proposed that practical assessments be done on the platform, they can be done synchronously (in the classroom the teacher publishes an assignment, and the students answer it on the platform) or asynchronously (the students submit the assignment later).

The advantages of this system are as follows: -No more problems with deciphering students handwriting; -Possibility of using plagiarism detection software; -Benefit of auto-correction for single choice, multiple choice, fill in the blank, etc.; -Elimination of printing costs and paper purchases; -Possibility of incorporating technological tools, and media.

5.5 Better student engagement and interaction with teachers

In the current higher education system, students are not very close to their teachers. Their class leaders serve as a bridge. With our system, the student can see the teacher's observations of them, their attendance statistics, and be notified directly of all course events. This increases engagement.

In addition, there is often a sloppiness in the submission of assignments because it is known that the head of the class will wait until the majority has submitted. With this system, the student knows that at the deadline, the system blocks and there will be no way to submit his work. He will therefore face his responsibilities. To submit their work, students no longer must go to the office and ask if their work has been properly introduced by their class president, they do it directly.

6 Conclusion

In approaching this research, our concern focused mainly on the issue of the best strategy for integrating e-learning in the Democratic Republic of Congo, given the limitations and inability of the current system to function in a context where the face-to-face learning system is no longer a fact, because of the many confinements and social distancing due to the emergence of the Covid-19. In view of the realities inherent to our country, low rate of electrification, poor quality internet connection and the low experience of the concerned actors with Information and Communication Technologies, we have proposed the implementation of blended learning integrating the efficiency and the possibilities of socialization of the traditional classroom with the digitally enhanced learning possibilities of the online mode. To do this we have in this paper proceeded to the analysis of the current mode of operation of higher education and we have proceeded to the design and implementation of a platform specially designed to adapt to the current model of learning of the higher level of education of the Democratic Republic of Congo. This system has for contribution to familiarize the various actors with the ICT, to increase the engagement and the interaction between students and teachers, to digitize a good number of the manual tasks such as the management of students' attendance, evaluations.

7 Acknowledgment

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Interaction Mechanism for the Entrepreneurship of College Students with Diversified Values

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Abstract—The negative phenomena in the society have subtle influences on the values of college students. Studying the interaction mechanism for the entrepreneurship of college students in the new era will help them establish a healthy entrepreneurial mentality. The current research focuses mainly on the development connotation and mode of the interaction mechanism for the entrepreneurship of college students, which is highly subjective and lacks empirical quantitative analysis of the interactions between multiple participants in the interaction mechanism for entrepreneurship. This paper studies the interaction mechanism for entrepreneurship of college students with diversified values. First an asymmetric game payoff matrix was established for the multiple participants including colleges, college students and cooperative enterprises in the interaction mechanism for entrepreneurship of college students, and then a replicator dynamic equation for the evolutionary game of multiple participants was solved, so as to objectively analyze the optimal behavior decisions of the multiple participants under the condition of bounded rationality. The experimental results verified the effectiveness of the constructed model.

Keywords—values, entrepreneurship of college students, interaction mechanism for entrepreneurship

1 Introduction

With the increasing diversification of the national economic structure, industry types, employment and entrepreneurial forms, and marketing and profit distribution, the values of college students who have just been employed or are in the initial stage of startups are also diversifying [1-5]. In this context, establishing correct values has become the prerequisite to the successful realization of personal values by college students through entrepreneurship [6-13]. In the new era, however diversified the college students' values might be, they should generally be positive, and those who are resilient, innovative, passionate, efficient and honest have the highest chances of success in business startups [14-18]. However, affected by the diversification of lifestyles, ideologies and cultures, there have been negative phenomena in social interpersonal interactions. For example, some people are unable to tell right from wrong or distinguish honor and disgrace, or forget honor at the sight of money or make power-for-money deals [19-24]. These negative phenomena have subtle influences over the values of college students. Therefore, it is necessary to study the interaction mechanism for the entrepreneurship of college students in the new era to help them establish a healthy entrepreneurial mentality.

Based on the mean-end chain model, Lin and Tu [23] conducted in-depth interviews with students who have experience in using BSG with the soft laddering method, and used the concept of “attribute-result-value” chain to understand students’ value cognition structure. The results show that the ultimate value that communication and continuous thinking between teams brings to users is interpersonal relationships and a sense of accomplishment. Bao [25] discussed the effect mechanism of Chinese traditional values in the career orientation of college students, and considered achievement motive and analyzed the relationships among the three variables - traditional values, occupational orientation and achievement motive using the structural equation model. The university-industry-government triple helix constitutes a sustainable innovation ecosystem and promotes regional development. Based on the lessons learned from project-based entrepreneurship programs with industry partners in different contexts, Stolze et al. [26] attempted to develop a novel educational concept that deeply explores the topics entrepreneurship and digital transformation to answer the questions raised. The preliminary findings suggest that the triple-helix interactions need to co-create programs that produce value for all stakeholders, allowing the conceptualization of new approaches for entrepreneurial project development, which will enable technology transfer, emergence of start-ups/spin-offs and foster an entrepreneurial mindset. Bøllingtoft [27] reported the results of an exploratory study on the entrepreneurial environment of two bottom-up business incubators, identified the networking and cooperative activities among entrepreneurs, and investigated the role of the bottom-up business incubators in the promotion and creation of entrepreneurs’ internal network and cooperation conditions, thus exploring how business incubators can become a formal mechanism that embeds enterprises in entrepreneurial networks. Chen et al. [28] studied the education theories, the college education mechanism and the relationship between the talent training model and the education mechanism from the perspective of school-enterprise cooperative education mechanism. With the cooperative training cases of three Chinese universities as the data sources, it proposed a cooperative innovative and entrepreneurial talent training mechanism, which clarifies the educational goals, improves course teaching methods, adds a feedback mechanism between enterprises and universities, redefines educational evaluation methods and ensures good communications between schools, enterprises and students, thus guaranteeing its normal operation.

Based on the existing research results, there is no doubt about the promoting role of innovation and entrepreneurship education in improving college students’ entrepreneurial abilities, and coordinating and involving multiple participants in the interaction mechanism for entrepreneurship of college students is the key to their success of entrepreneurship. The discussions about the connotation of values and the consistency with other participants in relevant research at home and abroad have promoted the maturity and improvement of the the interaction mechanism for entrepreneurship of college students. However, the existing research is still insufficient. At the current stage, the research mainly focuses on the development connotation and mode of the interaction mechanism for entrepreneurship of college students, which is highly subjective and lacks empirical quantitative analysis of the interactions between multiple participants in the interaction mechanism for entrepreneurship. This paper studies the interaction mechanism for entrepreneurship of college students with diversified values. First an asymmetric game payoff matrix was established for the multiple participants including colleges, college students and cooperative enterprises in the interaction mechanism for entrepreneurship of college students, and then a replicator dynamic equation for the evolutionary game of multiple participants was solved, so as to objectively analyze the optimal behavior decisions of the multiple participants under the condition of bounded rationality. The experimental results verified the effectiveness of the constructed model.

2 Construction of the evolutionary game model for behaviors of colleges

The dynamic evolutionary game model can be applied to the analysis of the interactions between multiple participants in the interaction mechanism for entrepreneurship of college students, as it can provide some reference for the scientific analysis of various problems in the interaction process of college students' entrepreneurship, like unclear responsibilities, lack of entrepreneurial resources, capital risks and lack of core competitiveness. First, assumptions were put forward for the choices of the three participants involved in the interaction mechanism for entrepreneurship of college students – colleges, college students and cooperative enterprises, and an asymmetric game payoff matrix was established for the multiple participants, and then a replicator dynamic equation for the evolutionary game of multiple participants was solved, so as to objectively analyze the optimal behavior decisions of the multiple participants under the condition of bounded rationality.

Figure 1 shows a three-party game tree of the interactions in the entrepreneurship of college students, showing 8 combinations of the three parties involved, namely the college, college students and cooperative enterprises.

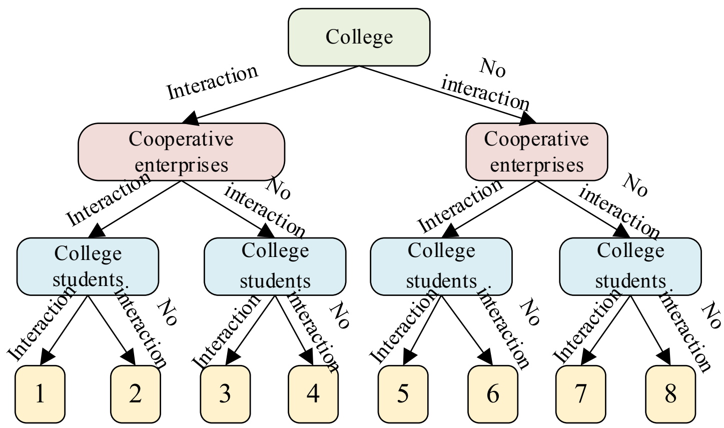

Fig. 1. Three-party game tree of the interactions in the entrepreneurship of college students

The evolutionary game payoff matrix was used to calculate the expected and average payoffs of colleges, college students and cooperative enterprises in the interaction mechanism for entrepreneurship of college students. With the evolutionary game payoff matrix about whether a college chooses to provide support for college students' entrepreneurial interactions, the expected payoffs of the college under different support decisions can be obtained, and the dynamic equation of evolutionary game for the college can be further constructed. When the college chooses to participate in college students' entrepreneurial interactions and provide support for these entrepreneurial interactions, the expected payoff V_{a1} of the college can be calculated by Equation (1):

$$\begin{aligned} V_{a1} &= bc\left(P_a - O_{a1}\right) + \left(1-b\right)c\left(P_a - O_{a1} + O_{b5}\right) + \left(1-c\right)b\left(P_a - O_{a1}\right) \\ &+ \left(1-c\right)\left(1-b\right)\left(P_a - O_{a1} + O_{b5}\right) \end{aligned} \tag{1}$$

When the college chooses not to participate in college students' entrepreneurial interaction, their expected payoff V_{a2} can be calculated by Equation (2):

$$V_{a2} = bc\left(-O_{a2}\right) + \left(1-b\right)c\left(-O_{a2}\right) + \left(1-c\right)b\left(-O_{a2}\right) + \left(1-c\right)\left(1-b\right)\left(-O_{x2}\right) \tag{2}$$

From the above analysis, it can be seen that the expected payoff V_a of the college can be calculated as follows when a mixed behavior decision is made:

$$V_a = V_{a1} + V_{a2} \tag{3}$$

Based on the theory of the evolutionary game model, the following calculation can be done for the frequency of changes in the degree of participation decided by the college:

$$G\left(a\right) = \frac{da}{d\phi} = a\left(V_{a1} - V_a\right) = a\left(1-a\right)\left[P_a - O_{a1} + O_{a2} + \left(1-b\right)O_{b5}\right] \tag{4}$$

When the condition represented by Equation (5) is satisfied, $G(a)=0$.

$$b=\frac{P_a-O_{a1}+O_{a2}+O_{b5}}{O_{b5}} \tag{5}$$

In this case, whether the college chooses to participate or not in the entrepreneurial interactions of college students, their game behavior is stable and balanced, and the decisions of the college will not change easily. When the condition represented by Equation (6) is satisfied, let $G(a)=0$, and two stable equilibrium points can be obtained, namely $a=0$ and $a=1$.

$$b\neq\frac{P_a-O_{a1}+O_{a2}+O_{b5}}{O_{b5}} \tag{6}$$

In this case, when the college has already made a choice to participate or not to participate in the entrepreneurial interactions of college students, if there is no unexpected situation, the college will insist on its choice. Take the derivative of $F(x)G(a)$, and there is:

$$\frac{dG(a)}{da}=(1-2a)\left[P_a-O_{a1}+O_{a2}+(1-b)O_{b5}\right] \tag{7}$$

When the inequalities in (8) and (9) are satisfied, there is a stable equilibrium point $a=1$.

$$b>\frac{P_a-O_{a1}+O_{a2}+O_{b5}}{O_{b5}} \tag{8}$$

$$\frac{dG(a)}{da}|_{a=1}<0,\frac{dG(a)}{da}|_{a=0}>0 \tag{9}$$

In this case, the college finally decides to participate in and provide support for the entrepreneurial interactions of college students, and will resist the unexpected situation that may lead to the decision not to participate. When the inequalities in (10) and (11) are satisfied, there is a stable equilibrium point $a=0$.

$$b<\frac{P_a-O_{a1}+O_{a2}+O_{b5}}{O_{b5}} \tag{10}$$

$$\frac{dG(a)}{da}|_{a=1}>0,\frac{dG(a)}{da}|_{a=0}<0 \tag{11}$$

In this case, the college finally decides to remain silent, that is, not to participate in the entrepreneurial interactions of college students, and to resist the unexpected situation that may lead to the decision to participate. Based on the above analysis, the replicator dynamic phase diagram of the evolutionary game process for the college can be drawn.

3 Construction of the evolutionary game model for behaviors of cooperative enterprises

With the evolutionary game payoff matrix about whether a prospective cooperative enterprise chooses to participate in college students' entrepreneurial interactions and achieve cooperation, the expected payoff of the enterprise under different decisions can be obtained, and the dynamic equation of evolutionary game for the enterprise can be further constructed. When the prospective cooperative enterprise chooses to participate in college students' entrepreneurial interactions and provide cooperation, the expected payoff V_{b1} of the enterprise can be calculated by Equation (1):

$$\begin{aligned} V_{b1} &= ac\left(S_{b1}+S_{b2}-O_{b1}\right)+a\left(1-c\right)\left(S_{b2}-O_{b1}\right) \\ &+\left(1-a\right)b\left(S_{b1}+S_{b2}-O_{b1}\right)+\left(1-a\right)\left(1-c\right)\left(S_{b2}-O_{b1}\right) \end{aligned} \tag{12}$$

When the prospective cooperative enterprise chooses not to participate in college students' entrepreneurial interaction, their expected payoff V_{b2} can be calculated as follows:

$$\begin{aligned} & V_{b2}=ac\left(S_{b1}-O_{b2}-O_{b3}-O_{b4}-O_{b5}\right)+ \\ & \left(1-c\right)a\left(-O_{b2}-O_{b3}-O_{b5}\right)+\left(1-a\right)c\left(S_{b1}-O_{b2}-O_{b3}-O_{b4}\right) \\ & +\left(1-a\right)\left(1-c\right)\left(O_{b2}-O_{b3}\right) \end{aligned} \tag{13}$$

Based on Equations (12) and (13), Equation (14) shows the calculation formula of the expected payoff V_b of the prospective cooperative enterprise when it adopts a mixed decision:

$$V_b=V_{b1}+V_{b2} \tag{14}$$

Based on the principle of evolutionary game, Equation (15) gives the calculation formula of the frequency of changes in whether the enterprise decides to participate in college students' entrepreneurial interactions:

$$G\left(b\right)=\frac{dc}{d\phi}=b\left(V_{b1}-V_b\right)=b\left(1-b\right)\left[S_{b2}-O_{b1}+O_{b2}+O_{b3}+aO_{b5}+cO_{b4}\right] \tag{15}$$

Take the derivative of $G(b)$, and there is:

$$\frac{dG\left(b\right)}{db}=\left(1-2b\right)\left[S_{b2}-O_{b1}+O_{b2}+O_{b3}+aO_{b5}+cO_{b4}\right] \tag{16}$$

When the inequalities in (17) and (18) are satisfied, there is a stable equilibrium point a=1.

$$a > \frac{O_{b1} - O_{b2} - O_{b3} - S_{b2} - cO_{b4}}{O_{b5}} \tag{17}$$

$$\frac{dG(b)}{db}\Big|_{b=1} < 0, \frac{dG(b)}{db}\Big|_{b=0} > 0 \tag{18}$$

In this case, the prospective cooperative enterprise decides to participate in college students' entrepreneurial interactions and provide cooperation, and it will resist any unexpected situation that may lead to its non-participation. When the inequalities in (19) and (20) are satisfied, there is a stable equilibrium point a=0.

$$a < \frac{O_{b1} - O_{b2} - O_{b3} - S_{b2} - cO_{b4}}{O_{b5}} \tag{19}$$

$$\frac{dG(b)}{db}\Big|_{b=1} > 0, \frac{dG(b)}{db}\Big|_{b=0} < 0 \tag{20}$$

In this case, the prospective cooperative enterprise finally decides not to participate in college students' entrepreneurial interactions and will resist any unexpected situation that may lead to its decision to participate.

4 Construction of the evolutionary game model for behaviors of college students considering the influences of values

Under the negative effects of multicultural influence, Internet finance, and fast-paced market economy, the existing innovation and entrepreneurship education is insufficient to exert positive influences on college students' entrepreneurial values, and some ideological problems of college students like utilitarianism, selfishness and hedonism in their entrepreneurship are not effectively corrected. Figure 2 builds a model of the influencing factors to college students' diversified values. This paper conducted relevant analysis from three perspectives - environment, education and college students' values. Environmental factors include entrepreneurship policy environment, industry and market environment, legal environment, cultural environment and financial environment; educational factors include penetrating entrepreneurship education, universal entrepreneurship education, focused entrepreneurship education, and specialized entrepreneurship education; and values of college students include professional values, personal values and entrepreneurial goals.

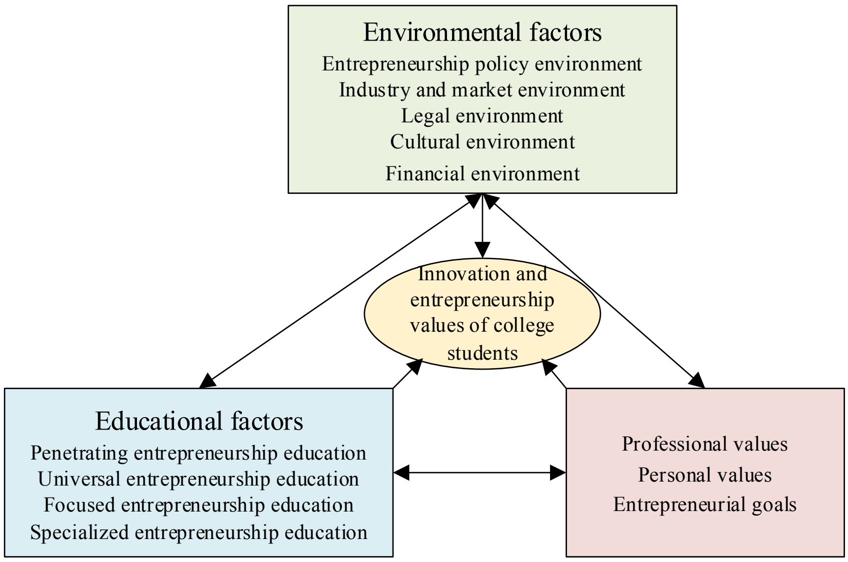

Fig. 2. Model of influencing factors to college students' diversified values

College students' entrepreneurial values represent the goals pursued by college students in the process of their entrepreneurial practice and interactions with other participants. The goal of improving innovation and entrepreneurship values should be to achieve consistency between personal values of college students and social values. Therefore, the positive influences of college students' entrepreneurial values on their entrepreneurial interactions can be analyzed from three perspectives - entrepreneurial value goals, entrepreneurial value evaluation and entrepreneurial value choices. Entrepreneurial value goals are the social and personal value goals of college students in their entrepreneurship; evaluation of entrepreneurial values includes evaluation of entrepreneurial success factors, self-recognition and evaluation of entrepreneurial competence, evaluation of entrepreneurial education satisfaction, and evaluation of entrepreneurial intentions; and the choices of entrepreneurial values includes career choice and choice of justice and benefit.

When a college student under the positive influence of values chooses to participate in entrepreneurial interactions to seek resources and opportunities, his expected payoff V_{c1} can be calculated by Equation (21):

$$\begin{aligned} V_{c1} &= ba\left(T_{c1}+S_{b1}\right)+\left(1-b\right)a\left(T_{c2}-S_{b1}+O_{b4}\right) \\ &+\left(1-a\right)b\left(T_{c1}+S_{b1}\right)+\left(1-a\right)\left(1-b\right)\left(T_{c2}-S_{b1}+O_{b4}\right) \end{aligned} \tag{21}$$

When a college student under the negative influence of values chooses not to participate in entrepreneurial interactions, his expected payoff V_{c2} can be calculated by Equation (22):

$$V_{c2} = 0 \tag{22}$$

Based on Equations (21) and (22), the expected payoff V_c of the college student can be calculated by Equation (23) when he adopts a mixed decision:

$$V_c = V_{c1} + V_{c2} \tag{23}$$

Based on the principle of evolutionary game, the frequency of changes in the college student's decision to participate or not to participate in entrepreneurial interactions under the influence of diversified values can be calculated based on the following equation:

$$G(b) = \frac{dc}{d\phi} = c(V_{c1} - V_c) = c(1-c)\left[b(T_{c1} - T_{c2} - O_{b4}) + T_{c2} - S_{b1} + O_{b4}\right] \tag{24}$$

When the inequalities in (25) and (26) are satisfied, there is a stable equilibrium point c=1.

$$b > \frac{S_{b1} - T_{c2} - O_{b4}}{T_{c1} - T_{c2} - O_{b4}} \tag{25}$$

$$\frac{dG(c)}{dc}|_{c=1} < 0, \frac{dG(c)}{dc}|_{c=0} > 0 \tag{26}$$

In this case, the college student finally decides to participate in entrepreneurial interactions to seek resources and opportunities, and will resist any unexpected situation that may lead to its decision not to participate. When the inequalities in (27) and (28) are satisfied, there is a stable equilibrium point c=0.

$$b < \frac{S_{b1} - T_{c2} - O_{b4}}{T_{c1} - T_{c2} - O_{b4}} \tag{27}$$

$$\frac{dG(c)}{dc}|_{c=1} > 0, \frac{dG(c)}{dc}|_{c=0} < 0 \tag{28}$$

In this case, the college students finally decide not to participate in entrepreneurial interactions, that is, he will not accept the resources and opportunities offered by other participants in the interaction mechanism for his entrepreneurship, and will resist any unexpected situation that may lead to its decision to participate. Based on the above analysis, the replicator dynamic equation for the evolutionary game of multiple participants in the interaction mechanism for entrepreneurship of college students under the influence of diversified values is expressed as follows:

$$\begin{cases} G(a)=\dfrac{da}{d\phi}=a\left(V_{a1}-V_a\right)=a\left(1-a\right)\left[P_a-O_{a1}+O_{a2}+\left(1-b\right)O_{b5}\right] \\ G(b)=\dfrac{db}{d\phi}=b\left(V_{b1}-V_b\right)=b\left(1-b\right)\left[S_{b2}-O_{b1}+O_{b2}+O_{b3}+aO_{b5}+cO_{b4}\right] \\ G(c)=\dfrac{dc}{d\phi}=c\left(V_{c1}-V_c\right)=c\left(1-c\right)\left[b\left(T_{c1}-T_{c2}-O_{b4}\right)+T_{c2}-S_{b1}+O_{b4}\right] \end{cases} \tag{29}$$

5 Experimental results and analysis

This paper analyzed the reasons why college students participate in entrepreneurial interactions, with the statistical results shown in Figure 3. It can be seen that the top three reasons are "obtaining more interpersonal resources" (68%), "seeking more development opportunities" (55%) and "improving market sensitivity" (53%)", followed by "learning social skills" (48%) and "improving the entrepreneurial organizational structure" (38%). Through the survey of the value goals of college students participating in entrepreneurial interactions shown in Figure 4, it was found that the top three value goals chosen by college students were "realizing personal values" (45.24%), "making career achievements" (28.93%), and "obtaining pecuniary interest" (14.21%), and that the remaining two were "fighting for freedom in work" (8.1%) and "fulfilling social responsibilities" (3.52%).

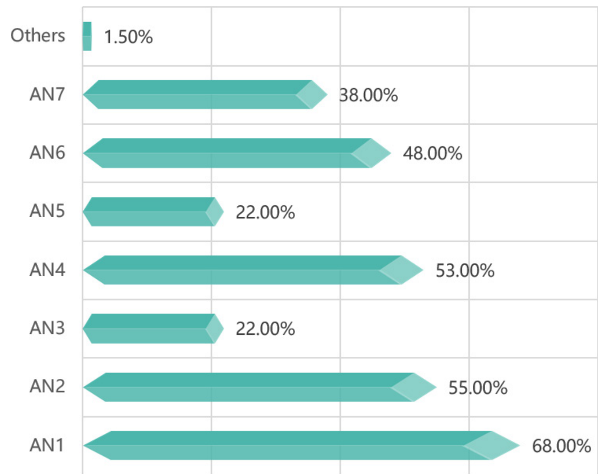

Fig. 3. Reasons for college students' participation in entrepreneurship Interactions

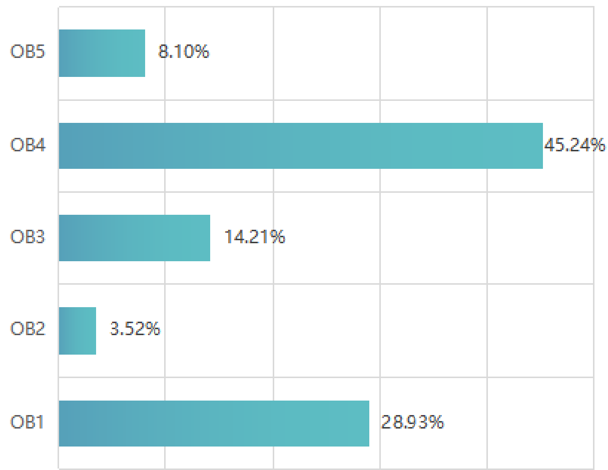

Fig. 4. Value goals of college students in participation in entrepreneurial interactions

Table 1 shows the differences between male and female students in the value goals of "innovation and entrepreneurship". It can be seen that for college students of both genders, "realization of personal value" and "fighting for freedom in work" are the top two. The only difference is that male students pay more attention to "realizing personal values", while female ones, "fighting for freedom in work".

Table 1. Differences between male and female students in the value goals of innovation and entrepreneurship

		Realizing personal values	**Making career achievements**	**Obtaining pecuniary interest**	**Fighting for freedom in work**	**Fulfilling social responsibilities**
Male	Persons	582	83	261	584	139
	Proportion	35.8%	5.2%	16.7%	39.1%	7.4%
Female	Persons	728	85	314	1328	185
	Proportion	26.3%	3.8%	13.7%	48.6%	7.5%

Figure 5 shows the evolutionary trends of the three parties' willingness to participate in the interactions. It can be seen that under the conditional probability of 0.5 in decision making, the results of all the three parties eventually converged to 1. It can also be seen that within one cycle, the evolution path of college students' willingness to participate in entrepreneurial interactions showed a downward trend, which means, the college students' willingness to participate in entrepreneurial interactions tended to be low at this time. After more than one cycle, the evolution path showed a significant upward trend and converged to 1, indicating that when college students truly perceived the benefits of entrepreneurial interactions, their traditional values and entrepreneurial ideas changed and they were more willing to try to participate in the entrepreneurial interaction process, and finally the path reached a stable equilibrium state after 6 cycles. Similarly, the evolutionary paths of the college and the cooperative enterprise rose rapidly at first, and then gradually converged to 1 after more than 2 cycle, approaching a stable equilibrium state. However, the difference between the two is that the growth of the path of the cooperative enterprise in the early stage was slightly faster than that of the college, indicating that with the entrepreneurial time of college students going, the cooperative enterprise contributed more to the entrepreneurial success of college students. As the leading role in college students' entrepreneurial interactions and coordination, the college was ultimately in a stable and balanced state with its active participation and support.

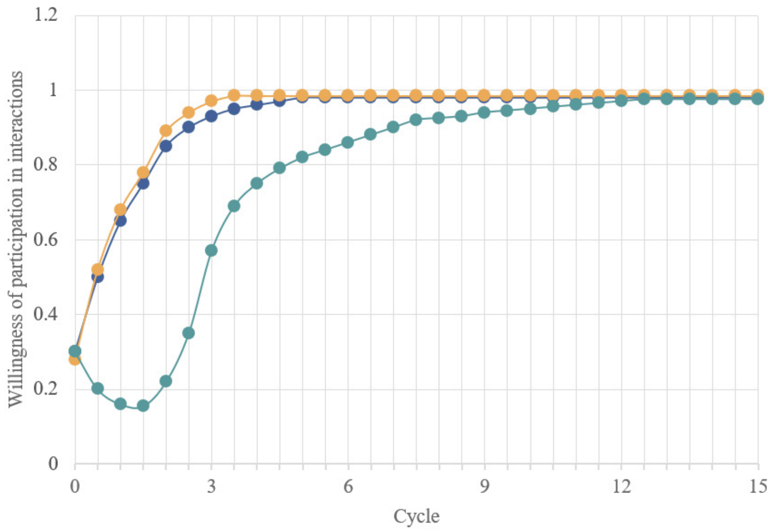

Fig. 5. Evolutionary trends of the three parties' willingness of participation in interactions

Figure 6 shows the evolutionary paths of the cooperative enterprise's willingness to participate in interactions under the influence of the willingness of participation of college students with diversified values, if the probability is fixed for the cooperative enterprise's willingness to participate in students' entrepreneurial interactions, while the probabilities for the willingness of the college and students change. It can be seen that in the initial stage of the evolution cycles, as students are not influenced by the subjective values and the objective environment and also educational factors, they do not quite recognize the importance of participation in entrepreneurial interactions, and their willingness to participate in entrepreneurial interactions tends to decline. Under this circumstance, if the cooperative enterprise shows a good cooperative prospect to the college students with a positive attitude, the college students will gradually change their willingness to participate in the interactions, and at the same time, the relevant college organizations will be much more active.

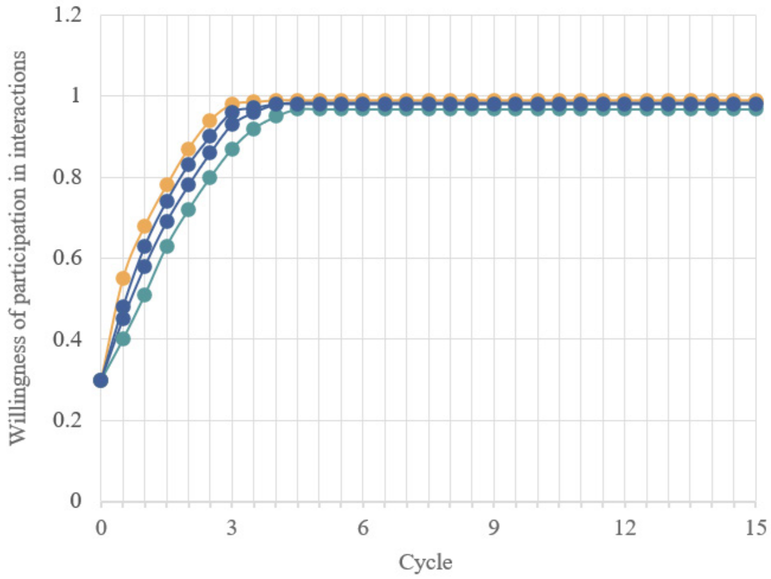

Fig. 6. Evolutionary paths of the cooperative enterprise's willingness of participation in interactions

Figure 7 shows the evolutionary paths of college students' willingness to participate in interactions under the influence of different values if the probability is fixed for college students' willingness to participate in entrepreneurial interactions while those change for the willingness of the college and the cooperative enterprise. It can be seen that in the initial stage of the evolution cycles, college students' willingness to participate in entrepreneurial interactions shows a steady upward trend, and that after more than 10 cycles, it reaches the regional stable equilibrium state. Any initial probability of willingness of the college and the cooperative enterprise to participate will make the final decision of college students to participate converge to a steady state. It shows that the positive attitudes of the college and the cooperative enterprise will change the entrepreneurial attitude of college students. The clear positioning of cooperative enterprises has a great impact on the evolutionary strategy for college students' decision on participation in interactions, and can effectively promote the expansion of entrepreneurial resources for college students.

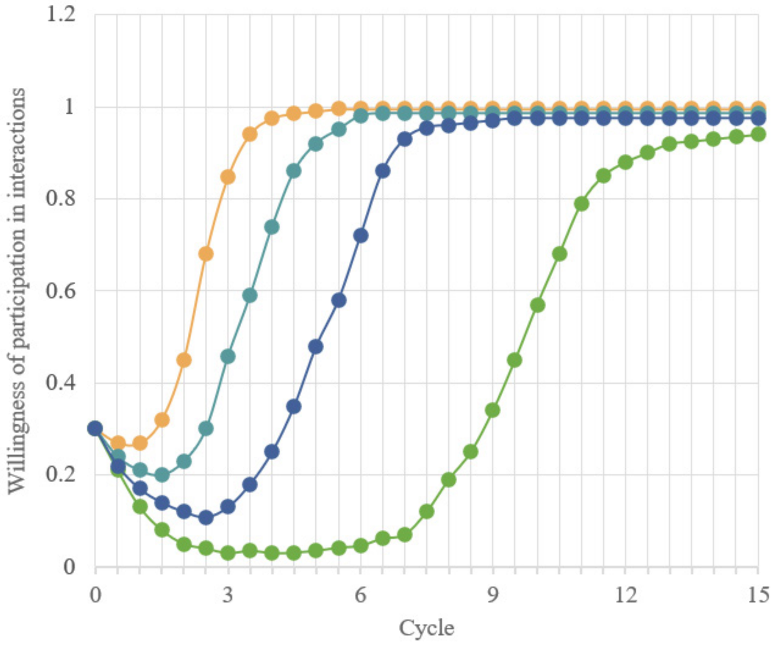

Fig. 7. Evolutionary paths of the college students' willingness of participation in interactions

6 Conclusions

This paper studied the interaction mechanism for entrepreneurship of college students with diversified values. First, an asymmetric game payoff matrix was established for the multiple participants including colleges, college students and cooperative enterprises in the interaction mechanism for entrepreneurship of college students, and then a replicator dynamic equation for the evolutionary game of multiple participants was solved, so as to objectively analyze the optimal behavior decisions of the multiple participants under the condition of bounded rationality. Per the analysis on the reasons for college students' participation in entrepreneurial interactions, the top three reasons were "obtaining more interpersonal resources" (68%), "seeking more development opportunities" (55%) and "improving market sensitivity" (53%)". Per the survey on the value goals of college students participating in entrepreneurial interactions, the top three value goals chosen by college students were "realizing personal values" (45.24%), "making career achievements" (28.93%), and "obtaining pecuniary interest" (14.21%). After that, the evolutionary paths of the three parties' willingness to participate in interactions were drawn, and the relevant analysis results were given.

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SMAC-Based Programming Tool: Validating a Novel System Architecture

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Abstract—Although SMAC (Social, Mobile, Analytics, Cloud) allows pedagogical innovation due to its ability in expanding communication during the learning process, its exploitation for programming learning has yet to occur. Therefore, this study proposes a novel system architecture for a SMAC-based programming learning tool designed to enhance programming students' problem-solving and collaborative skills. In evaluating the effectiveness of this architecture, this study conducted multiple two-week controlled experiments involving 71 introductory programming students. The experiment involves administering pre-and post-study surveys and tests to measure the enhancement in the two skills. The overall findings of this study indicated a statistically significant improvement in both the student's problem-solving ability and collaborative skills. Most importantly, these findings suggest that the synergy of all four SMAC elements in a single programming learning tool has substantial benefits to programming learning.

Keywords—SMAC (Social Mobile Analytics Cloud), programming, collaboration, problem-solving, distant learning

1 Introduction

Studies have proven that students have difficulties learning computer programming [1], often argued due to the lack of problem-solving ability among the students. Such a lack makes them unable to think algorithmically [2], especially in solving programming problems. However, this problem remains unresolved despite being researched in many studies, suggesting its research immaturity. It is vital to handle this problem as it carries several unintended negative impacts on students, such as losing motivation after repeatedly making mistakes in their programming activities [3]. Consequently, this problem might increase the failure rate in programming courses.

Additionally, the current approach to teaching computer programming focuses too much on teaching programming syntaxes and semantics rather than allowing the students to develop their problem-solving skills [4]. Students have no trouble memorising programming syntaxes and understanding their semantics [5]. However, they are often unable to use their programming skills to plan and structure a solution to a programming problem. Hence, developing students' problem-solving abilities is essential before teaching them programming vocabulary [6].

Therefore, this study foresees the importance of the current teaching and learning approach to innovating. For years, the programming learning domain has seen many innovative learning tools to mitigate this problem. However, still, there is no silver bullet learning tool that could solve all issues related to problem-solving skills. A systematic literature review (SLR) by [7] provided an exciting discovery when no study tried to adopt SMAC (Social, Mobile, Analytics, Cloud) into the programming domain, although this concept is not new anymore. SMAC arose from the proliferation and advancement of four disruptive technologies: social media, analytical technologies, mobile computing, and cloud computing [8]. This concept is often seen as a new pedagogical innovation enabler due to its ability in expanding communication across class boundaries [9], [10].

This study was conducted to extend the work of [7] by investigating the synergic impacts of all four SMAC technologies on the programming learning domain. This article reports a novel system architecture for a SMAC-based programming learning tool (SPLT) that combines features from varieties of provenly-effective state-of-the-art learning tools related to SMAC. Most importantly, this study aims to evaluate the extent to which SPLT enhances the problem-solving ability and collaborative skills of programming students. To this end, a controlled experiment involving 71 participants was conducted to answer the following research questions:

1. Does SPLT impact the problem-solving abilities of the participants?
2. Does SPLT impact the collaborative skills of the participants?

2 Literature reviews

2.1 SMAC elements in programming learning tools

SMAC technology is a key enabler for more innovative learning pedagogies [9], [10] that extend learning and student-educator interactions beyond the class boundaries. However, existing studies have yet to exploit the synergy of all four SMAC technologies (elements) for programming learning, as reported in [7]. Besides, [11] also urges the need for more development of theories and models of SMAC-based pedagogy.

Moreover, [7] reported multiple roles of SMAC technologies in aiding programming learning. For example, [7] discovered that social technologies are often used to enhance in-class collaboration, and mobile technologies were often used to enable a mobile-learning environment and for a development host. Additionally, analytical techniques are increasingly applied in programming learning by analysing students' behaviour during programming activities or making early predictions through machine learning. Meanwhile, existing studies used cloud technologies to establish a cloud-based programming environment that allows students to perform programming activities on the cloud.

Although meta-analysis is not possible in [7] due to the heterogeneity of the included papers, the study identified the benefits of using a programming learning tool that combines SMAC technologies to enhance students' performance. For instance, [12] combined social and analytical technologies to develop a new collaborative programming learning environment and effectively group students. Their study concluded that students improved their motivation to learn, programming understanding and communication skills after using their system.

Meanwhile, [13], [14] examined the effects of using mobile devices and social networking sites in aiding programming learning and discovered positive enhancements in students' abstract thinking and students' interactions.

The studies above demonstrate the benefits of combining SMAC technologies in programming learning. Therefore, this study postulates that the synergy of all four SMAC technologies would provide better outcomes for programming students. However, to the best of our knowledge and the findings in [7], there is no framework or pedagogical model for exploiting such synergy.

2.2 Problem-solving skills

Problem-solving is a technique requiring the transfer, adaption, and application of the knowledge they have learned to a new, unfamiliar situation [15]. Problem-solving or critical thinking is essential regardless of whether education is online or physical [16]. Problem-solving skills are an integral part of programming learning [18] and a factor in excelling in the course [6]. A good problem-solver possesses two abilities: first, they possess background programming knowledge learned through programming exercises. Second, they can apply their background knowledge to a new programming exercise. However, recent investigations have demonstrated that programming students put less effort into developing their problem-solving skills [6].

Mhashi and Alakeel [5] claimed that students are often unable to use their programming skills to plan and structure a solution to a programming problem. Researchers concluded that mastering the syntaxes alone is insufficient without possessing good problem-solving skills [2], [14], [17]–[20]. According to [22], developing problem-solving skills is more important than learning multiple programming languages because students' inability to think algorithmically would restrict their knowledge transfer. Hence, educators must cultivate the students' problem-solving skills by focusing more on improving their algorithmic thinking skills.

2.3 Collaborative skills

Collaboration is essential for ensuring impactful programming learning [22], [23]. Chorfi et al. [23] argued that learning programming collaboratively requires students to work together, share skills, and learn from one another. These activities help them learn programming better as they help build a stronger problem-solving ability [22]. However, students will not collaborate naturally in a group [24]. Hence, many studies have provided various guidelines to foster student collaboration [25]. For example, [26] discovered 19 collaborative resources from existing studies to foster student collaboration during programming learning. [7], [26] discovered the two most frequently used collaborative formats in programming learning: 1) pair programming and 2) group programming (more than two students).

Pair programming pairs two students together while solving a programming problem using one computer, and each student takes one role at a time, either as a driver or a navigator [27]. Studies documented its effectiveness in improving students' collaborative skills [27]–[30]. However, existing studies usually focused on investigating the impacts of in-class pair programming and lesser on distributed one [7].

Furthermore, communication is an essential aspect of successful collaborative learning [26]. A chatting tool is the most frequently used communication medium, as reported in [26], making collaboration possible even with geographically distributed students. For example, [23], [30] used a chatting tool to support synchronous collaboration between programming students and reported a positive result. Additionally, using chat tools in class encouraged students to communicate their thoughts and problems [12], demonstrating the effectiveness of the chat system to increase collaboration regardless of the students' location.

3 SMAC-based programming learning tool architecture

Figure 1 shows the system architecture for SPLT, which serves as a blueprint for elaborating the adoption of the four SMAC elements into the programming learning environment. It specifies the functions of each SMAC element and how they should work together to establish a functional SMAC-based learning environment. Besides, the architecture describes the data generated by each SMAC element and how other elements can use the data to benefit from the four SMAC elements' synergy.

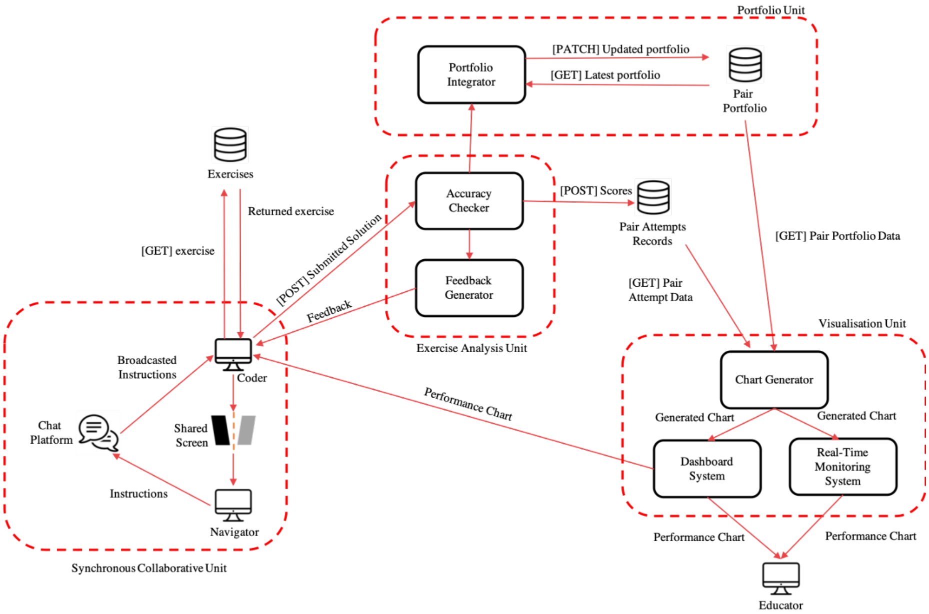

Fig. 1. The header image of online-journals.org

The architecture holds four functional units, namely (1) *Synchronous Collaborative Unit*, (2) *Exercise Analysis Unit*, (3) *Portfolio Unit*, and (4) *Visualisation Unit*. These four functional units work together with twofold aims. Firstly, they aim to establish a cloud-based, collaborative, and analytical-powered learning platform that allows geographically distributed programming students to learn computer programming together. Secondly, they aim to enhance the students' collaborative skills and problem-solving ability by collaborating to solve programming exercises.

3.1 Synchronous collaborative unit

This functional unit combines three SMAC elements (social, mobile, analytics and cloud elements) to create an online programming learning platform with synchronous collaboration capabilities. This unit acts as a social media in this architecture to provide a learning environment where programming students can exchange information [31] and partner with other students in the system. In addition, this unit interacts the most with the students because it provides all the features that help develop their problem-solving ability and collaborative skills.

Studies indicate that pair programming is the most commonly used and provenly-effective collaboration method [27], [30]. Thus, this study proposes the adoption of distributed pair programming into the architecture so that the collaboration can go beyond the geographical boundary.

The architecture proposes combining the benefits of social and cloud elements to enable an online-based synchronous collaboration. One way is by establishing a synchronous code playground (editor), shared in real-time and cloud-based. This social platform allows distant students to collaborate and solve programming exercises while developing their problem-solving skills. Students must be able to view the same editor on their screens. Thus, its interface should be updated synchronously with each student's action.

Furthermore, students who communicate more during a collaborative activity produce better problem-solving outcomes. Besides, an interactive eLearning system could motivate students to learn more [32]. An existing study showed that textual communication increases dialogue, interaction and is helpful for students in an online environment [33]. Thus, this study proposes embedding a synchronous chat tool in the architecture.

Meanwhile, a mobile learning environment is adapted to incorporate SMAC's mobile element. According to [34], ubiquitous and portability are two of the seven core characteristics of a thriving mobile learning environment. Thus, SPLT must be a mobile learning tool that adapts to various screen sizes. Such capability will expand the accessibility of SPLT's content to mobile devices, making learning ubiquitous.

3.2 Exercise analysis unit

This functional unit incorporates only the analytics element into the architecture by holding two main components: (1) Accuracy Checker (AC) and (2) Feedback Generator (FG). These two components perform the system's analytical tasks, aiming to measure students' performance based on their activities in the system. This study proposes using two outcome measures proposed by [35], namely *"success on task"* and *"time on task"*.

There are three factors to determine success in performing a task [33]. The first factor is determining the goal state (GS) that students must achieve to succeed in solving a task. The GS in this study is students' ability to submit a solution that satisfies a model solution. Thus, SPLT must include a platform where educators can submit model solutions for grading.

The second factor is defining a method to determine whether a student reaches a GS. For example, a system could be programmed to automatically detect an event where a student reaches a GS [33]. One method is to use an algorithm that compares a student's solution to a model solution and grades it accordingly.

The third factor is defining a method that unambiguously defines the GS and tells students how to achieve the goal. For this factor, SPLT must clearly explain every programming exercise. For instance, [6] provided textual instructions on their exercises page telling students what they must do to succeed.

Meanwhile, measuring the *"time on task"* requires defining the starting and ending points [33]. A timer can be embedded at the system backend to automatically detect how long students take to solve an exercise and submit their solution.

The AC can perform the first two factors discussed above in the architecture. Following student submissions, the AC will send the calculated score and solving time to the server for database storage. Then, sequentially, the AC will send the calculated score to the FG to generate feedback informing the students of their performance. This study also suggests adopting the *"formative assessment feedback"* technique discussed in [36] to generate the feedback. Formative assessment is a technique that provides feedback to the students instantly as they complete a task to make appropriate adjustments to their learning [37]. Instilling formative feedback in students' daily learning would entice them to learn more, manage it better, and overcome problems in learning better [37].

3.3 Portfolio unit

This functional unit also incorporates only the analytics element into the architecture, but it is responsible for classifying the students based on their performance over time. All the data generated by the students in the system can be used to create a portfolio system (PS). The PS would help educators identify at-risk students quickly and effectively for responsive assistance. Studies have shown the importance of providing immediate assistance [38]–[40].

Rahim et al. [7] identified ways to develop a PS. For instance, [41] used the data collected after students used their online judge's system in the first two weeks of the course and concluded that predictive modelling was helpful for this purpose. However, developing a significant prediction model depends on the quality and volume of the data used. Besides, developing a good prediction model requires mastering different skillsets [41].

Alternatively, the student-generated data in the Synchronous Collaborative Unit (SCU) can be used to generate the PS. Thus, the Portfolio Unit can use students' solution scores to calculate the average scores and use them to classify the students. This study suggests using the classification strategy proposed in [43], as shown in Table 1.

Table 1. Malik and Coldwell-Neilson's [43] classification of programming students based on their average score

Average Score Range	Classification Group
≤ 50	Fail
$50 \leq 64$	Low-performing
$65 \leq 84$	Medium-performing
$85 \leq 100$	High-performing

3.4 Visualisation unit

This functional unit incorporates only the analytics element and holds three main components: *Dashboard System, Real-Monitoring System,* and *Chart Generator*. These components receive data from the Portfolio Unit (PU) and the Exercise Analysis Unit (EAU) and visualise their analytical processes outputs into charts.

The *Dashboard System* possesses two main functions. First, the dashboard must inform students' current performance by instilling formative assessment feedback techniques [36]. Seanosky et al. [34] argued that learning progression charts help students improve their grades. Second, it must provide students with quick access to suitable learning materials based on weak programming topics [44]. Also, future developers could design the dashboard to show the learning progression charts as soon as students log into SPLT.

Meanwhile, the *Real-Time Monitoring System* must support educators to identify at-risk students instantly. One method involves displaying all students' learning progression on a single dedicated page. Additionally, the system must also allow educators to monitor students' progress. These features will help educators keep track of students' progression and provide necessary assistance quickly [45].

Finally, the *Chart Generator* is responsible for generating the analytical charts. This component interacts with the PU to obtain the learning progress data and the EAU for the students' activities data. Most importantly, this study does not restrict the attributes of each chart. For example, the chart can display the calculated score against the number of attempts (score vs attempts) or display solving time against the number of attempts (solving time vs attempts). We postulate that these two attributes will effectively provide formative assessment knowledge to the students.

4 Evaluation methodology

4.1 Participants

This study used convenience sampling to recruit 71 fundamental programming students majoring in computing courses from five institutions in Brunei Darussalam. All institutions provided their ethical clearance to experiment, and all participants provided their consent. The participants' average age was 21.6 years old, of which 42 (59.2%) were males, and 29 (40.8%) were females. Regarding their programming background, the participants have an average of 3.09 years of programming, enrolled in at least four programming modules, and were involved in at least three programming projects in groups. Furthermore, the programming modules in Brunei's institutions include similar programming topics in their fundamental programming modules, including arrays, iterations, and conditions. Hence, the participants had covered similar programming topics regardless of their institutions.

4.2 Procedures

In this experiment, all participants were required to use SPLT and apply conventional learning (CL) to avoid benefiting only one group of the participants. Therefore, this study adopted an AB/BA crossover design with two periods and two sequences. The first group used SPLT in the first period and CL in the second period, whereas the second group used CL in the first period and SPLT in the second period. The experiment was conducted online to simulate a true online learning environment. Each session lasted three and a half hours, so the second period was conducted three days apart. A priori, the carryover factor was considered in this study design as the participants might carry over something from the first period.

Before starting the experiment, the participants were briefed on the purpose, activities, and expected outcomes. Then, all participants signed a consent form and completed a pre-study survey online before being randomly allocated into two groups. The pre-study survey aimed to gather participants' programming backgrounds and perceived collaborative skills. Meanwhile, the pre-study test measured the participants' prior problem-solving skills.

All programming exercises used in this experiment was designed to develop the participants' problem-solving skill, especially in code debugging, tracing, logical thinking, conditional, and iterations. During the experiment, those who used SPLT were given access to the system so they could solve the exercises through the system. Additionally, every two participants who used SPLT were paired based on their pre-study test scores to see the impacts of homogenous pairing. Finally, all pairs used a chat tool to communicate during the experiment. In contrast, those who used CL were not allowed to use SPLT to solve the programming problems, and they had to solve them individually.

In each period, participants from both groups were instructed to solve four programming exercises using their respective techniques within the allotted time. A post-study-test was administered at the end of each period. After the experiment ended, a post-study survey was also administered to gather the participants' perceptions of SPLT.

4.3 Instruments

SPLT proof-of-concept system. For evaluating the architecture, this study developed a proof-of-concept system of SPLT that simulates a cloud-based, analytically-driven, and collaborative programming learning environment. This system supported distributed pair programming by allowing two distant learners to view the same code playground via a web browser (see Figure 2). A chat tool was also embedded to support synchronous communication between the pairs. Furthermore, this study adopted a problem-solving development strategy proposed by [6], which allowed students to solve programming exercises in three ways: (1) rearranging pseudocode in their correct sequence, (2) rearranging programming codes in their correct se1quence, and (3) translating the pseudocode algorithm into programming codes of their preferred language. We believe these three ways of programming learning will induce students' motivation and interest to learn programming, especially when [46] found a relation between task attractiveness and the system's perceived usefulness.

The system also logged students' scores on every programming exercise they attempted. These scores were coupled with exercise ID, time taken to solve the exercise, and the number of actions done to solve the exercise. The data coupling helped the system analyse students' performance on specific programming topics and recommended relevant exercises.

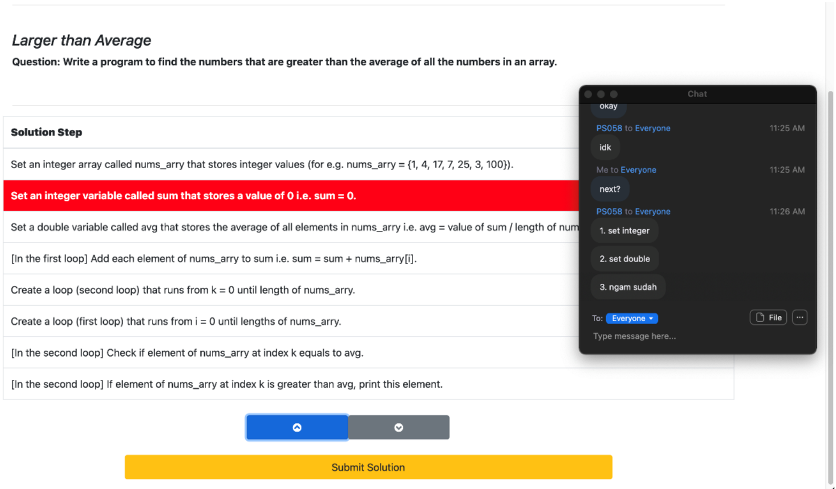

Fig. 2. Synchronous and collaborative code playground (adopted from [6])

The system also displayed relevant analytical outputs through multiple line charts for allowing the students to grasp their learning progression. These charts utilised three data generated by the students in the system: (1) score obtained, (2) time taken to solve an exercise, and (3) the number of attempts the students made on a particular exercise.

Pair Performance Details

Pair ID	23
Partner	EP027
Paired Since	2021-06-15 06:10:52
Avg. Score	Pseudo: 49.62 Code: 0.00
Attempted Exercises	Pseudo: 11 Code: 0

Performance Chart

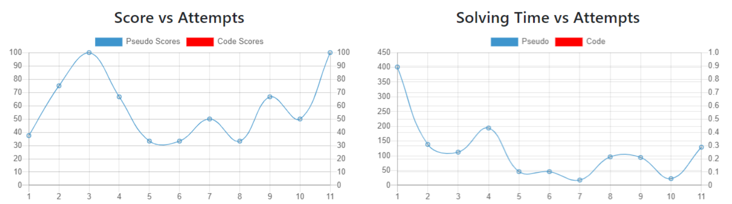

Fig. 3. Learning progression chart of paired partners

Collaborative skills measurement. This study adopted a 37-item collaborative skills measurement survey by Tibi [47] to measure participants' collaborative skills enhancement. The survey used a five-point Likert scale with one indicating "strongly disagree", and five indicating "strongly agree". The survey measured five essential elements of effective group collaboration: *positive interdependence, individual accountability, promotive interaction, social skills,* and *group processing*. The survey was administered twice before and after the experiment to measure changes in the perceived collaborative skills.

Problem-solving skills measurement. Participants' problem-solving skills were measured through pre-and post-study tests. The pre-study test was administered before the experiment started, whereas the post-study test was administered after they completed all the exercises given during the experiment. Both tests consisted of five questions that the participants must solve in the allotted time. Additionally, a senior lecturer from Universiti Teknologi Brunei validated the questions and the marking rubric for the tests. Following the first grading, this study appointed a postgraduate student to assess the scores again to avoid biased grading.

Participants SPLT perception measurement. The post-study survey included three open-ended questions that gathered the participants' perspectives on SPLT's ability to develop their problem-solving and collaborative skills and its potential to be used in programming lectures.

5 Results and discussions

This study used IBM SPSS to statistically analyse the differences in the problem-solving and collaborative skills of the participants before and after the experiment. This section discusses the results from all the statistical analyses conducted in this study.

5.1 Differences in problem-solving skills

A linear mixed model test was first conducted to detect any interaction between period and sequence. The result demonstrated that the interaction between period (p = 0.537) and sequence (p = 0.933) were insignificant. Thus, we could safely conclude that the difference in the effectiveness was not due to other variables than the techniques used in the experiment (SPLT and CL). According to the result, SPLT was statistically more effective than CL (F = 17.431, p < 0.01**). The participants' mean scores after using SPLT was 75.23%, while their mean scores after using CL was 61.18%.

Additionally, the post-study test scores in the first period were utilised to investigate any significant improvements in the problem-solving skills from the pre-study test scores. From the paired t-test conducted, both groups had better post-study test scores after the first period. Those who used SPLT in the first period had statistically better post-study score (M = 74.689, SD = 22.96) than their pre-test score (M = 48.63, SD = 15.95, t(35) = 9.609, p < 0.01**, d = 1.601). Similarly, those who used CL also had statistically better post-study scores (M = 60.91, SD = 15.51) than their pre-study test score (M = 48.64, SD = 15.95, t(34) = 4.532, p < 0.01**, d = 0.766). However, an independent t-test on both post-study test scores revealed that participants who used SPLT in the first period had statistically better mean scores than those who used CL (t

= 2.953, p = 0.004, d = 0.701). So, these results interpreted that SPLT had a better ability to improve the participants' problem-solving skills.

Table 2. Results of paired t-test on problem-solving skills after the first period

	N	Pre-test		Post-test		t
		M	***SD***	***M***	***SD***	
Group using SPLT	36	48.10	23.10	74.689	22.96	9.606**
Group using CL	35	48.64	15.95	60.91	15.51	4.532**

Note: ** p < 0.01

A possible explanation for this result might be the pseudocode playground adapted from [6], which effectively builds the participants' algorithmic thinking skills. The participants had to learn problem-solving by first identifying the input, process, and output rather than directly coding the solution. Thus, this finding confirms the pseudocodes' effectiveness to develop problem-solving skills, as claimed in [6].

Moreover, the feedback system might also play a vital role in the positive result. According to [36], students have higher chances of getting good grades if they grasp more knowledge about their learning. However, they discovered that not all students were proactive in viewing their learning charts. Therefore, we took a proactive approach by designing the system to display the learning progression charts as soon as the students logged in and completed an activity, either through recommendations or learning progression charts. The content analysis provided evidence that our proactive design assisted 22% of the participants (n = 8) who responded to the survey in understanding their progression and consequently helped them improve their problem-solving skills.

This study also supports the findings of [48], [49] on the effectiveness of homogenously pairing students based on their programming ability. Our content analysis showed that 11% of those who participated in the survey cited team effort as a factor that influences their perception of the efficacy of SPLT in enhancing their problem-solving ability. This finding demonstrates that randomly pairing the participants based on their skills had no detrimental impact on their learning outcomes.

5.2 Differences in collaborative skills

This study conducted a paired samples t-test to distinguish the difference in the participants' perceived collaborative skills before and after using SPLT. The result demonstrated a significant difference in mean perceived collaborative skills scores before (M = 3.838, SD = 0.353) and after using SPLT (M = 4.068, SD = 0.360), t(70) = 5.816, p < 0.01**, d = 0.6907, α = 0.05. The result concludes that there is an advantage in utilising our system for enhancing the perceived collaborative skills of the participants.

Table 3. Results of paired t-test on collaborative skills

	Pre-test		Post-test		t
	M	***SD***	***M***	***SD***	
Collaborative skills enhancement	3.838	0.353	4.068	0.360	5.816**

Note: ** $p < 0.01$

We believe that the cloud-based and collaborative-enhancing features embedded in SPLT positively impact the participants' collaborative skills. The most prominent feature was the inclusion of functions that support distributed pair programming, which was embedded to represent the social and cloud elements of SMAC. This feature allows the participants to work collaboratively in developing their problem-solving skills [50], where they were required to discuss the solution before submitting it for evaluation.

Consequently, this study indirectly compelled the pairs to interact by providing instruction and feedback, allowing two-sided communication. Rodríguez et al. [28] highlighted the importance of two-sided communication for ensuring a successful collaboration. Additionally, pair programming appoints roles to the participants, which changes after a while. These roles required both participants in a pair to continuously monitor each other's work and provide feedback, including gradually discussing their group performance. As a result, the participants eventually developed their collaborative skills through continuous feedback exchange [47].

Moreover, this study also scripted the participants' collaborative activities [30], including the period to change their roles. Thus, this finding confirms Tsompanoudi et al.'s [30] conclusion that the application of collaboration script influences the success of collaboration in distributed pair programming. Also, the positive result of this study is consistent with prior research on the effectiveness of a chat tool in facilitating student collaboration [12], [29], [30].

6 Conclusions and limitations

This study proposed a novel system architecture for a SMAC-based programming learning tool (SPLT) that combines the state-of-the-art features identified in [7] to enhance students' problem-solving and collaborative skills. This study developed a proof-of-concept system from the architecture and experimented with 71 introductory programming students from five different institutions in Brunei Darussalam with the tool. The overall findings and analysis showed improvements in problem-solving and collaborative skills. These findings suggest that our approach is a promising, supplementary learning tool for programming students to develop these two skills. The findings also indicate that the synergy of all four SMAC elements in a single programming learning tool has substantial benefits to the programming students. Based on these findings, we believe they would help respective educational sectors and future developers comprehend how the SMAC concepts could be used in programming education to enrich students' problem-solving and collaborative skills. Furthermore, the positive findings might entice future developers to use the proposed architecture to develop a more sophisticated and comprehensive SPLT.

However, our current experiment design still has its limitations. Firstly, this study only examined distributed pair programming to enable the social aspect of the system. Future studies might extend the feature by allowing more than two programming students to collaborate in the cloud-based system. Secondly, only a chat tool was used to support the communication between the distant students. We recommend that future studies examine how verbal or video communication could help improve collaboration.

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Development of a "Small Contractions" Sensor for Practical Work in Biology Using 3D Printing Technology

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Abstract—This article presents the development of a "small contraction" sensor fabricated using 3D printing and intended for practical works of biology; with the aim to replace the traditionally used system. This fabricated sensor is then integrated into a Computer Assisted Experiment (CAE) environment. CAE is a teaching technology that allows the students to carry out the acquisition and the processing of their data on computer (saving, adding comments, amplification…). The combination of these two technologies (CAE and 3D printing) has made it possible to equip low-cost multipurpose labs requiring minimal maintenance and where the work space is standardized. The result of a survey conducted with the students at the end of the lab sessions shows that 79.1% of them prefer the use of the new system, given the advantages it offers in terms of better understanding of the practical works objectives, time saving and the data processing functionalities it provides.

Keywords—computer assisted experiment, 3D printing technology, practical works in biology

1 Introduction

The practical activities in biology are designed to help students acquire basic scientific skills and improve their performance and achievement. practical work (PW) helps students practicing an experimental approach, develop critical thinking, develop hypotheses, design experiments and interpret results [1], [2][3][4].

In the Moroccan higher education system, these experimental activities undergo several obstacles as the massive retirements of professors and technical staff, poor recruitment of new professors and technicians, massive student enrolment and deterioration and poor maintenance of equipment and infrastructure.

In addition to the structural problems mentioned above, there are also technical problems. Indeed, most of these PWs are traditionally realized using an outdated equipment. Animal Physiology practical works for example depend on a mechanical mechanism that serves for data collection. This mechanism is made of a lever articulated around an axis. One of lever's ends is attached by a wire to the studied organ, the other one is equipped with a pen which registers the organ movement on a paper wrapped around a rotating cylinder.

This system has several disadvantages, namely: i) problems of initial adjustment of the system in order to reduce the friction of the pen on the cylinder, ii) the system does not offer an amplification of the signal resulting from the movements of the organ.

As a result of these problems, several experiments have been withdrawn from the animal physiology courses at the Faculty of Sciences of Rabat (FSR) in recent years, which has negatively impacted the scientific level of the laureates.

In this context, a collaboration between two teams from Biology and Physics departments at the Faculty of Sciences of Rabat has been initiated. The objective of this collaboration was to develop an acquisition system of small biological movements that will help overcome the limitations of the current system. This system must be user-friendly, allow the amplification of the obtained signals and be based on new technologies.

For this purpose, two technologies were used, which are the Computer Assisted experiment CAE and 3D printing.

CAE [5]–[9], is a teaching technology that uses the computer as a teaching tool, and whose didactic advantages are associated with the real-time graphic representation of the studied phenomenon. The fact that, the real experimental action and [10] its graphic representation are represented simultaneously, is illustrated by the metaphor of « the cognitive glasses » [11]. In addition to this, it allows the presentation of multiple measurements from different sensors simultaneously rather than sequentially. This allows the student to both save time and better understand the interaction between variables.

3D printing, on the other hand, is [12], [13] widely used in teaching either (i) in the development of courses and projects that explicitly focus on 3D printing skills, or (ii) as part of courses and projects to support the teaching of other subjects, and to facilitate multi- and interdisciplinary approaches [14]–[17], usually through the use of 3D printed artefacts [18].

In our case, the combination of these two technologies to produce sensors dedicated to practical work, constitutes a new form of use of 3D printing in teaching. In this article, we are describing the development of a new sensor dedicated to the study of biological contractions of muscles. This sensor will be connected to an acquisition board and the display of the results will be done on a computer using the driver software of this board.

The outcome of a survey conducted among students showed that 79.1% of them prefer to use the developed sensor, as this solution simplifies the data processing for them while increasing the time needed for reflection, analysis, and interpretation of the results. In addition to this, professors and technical staff find that this solution offers the possibility to equip multipurpose rooms requiring minimal maintenance at a low cost and to standardize the workspace.

2 Material and method

2.1 Modelization and design

The "small contraction" sensor is a measuring instrument that can detect very small contractions of muscle in situ in its natural state of activity and / or in response to mechanical, electrical or chemical solicitations: it is intended to measure the contractions of several muscles such as:

- Heart rate in mice or frogs
- Response of striated muscles in frogs
- Intestinal or uterine muscles contractions of the rat

The 3D printed sensor is composed of two parts, the first one is the mechanical part and the second one is the electronic part. The mechanical part of the sensor consists mainly of a mechanical lever encapsulated in a box to isolate the sensor from external light, and also to make it robust enough to be used by students. The electronic part is based on a light emitting diode and a photoresistance.

Mechanical study. The contractions of muscles like the uterus or the intestine being very weak, the idea is to amplify them mechanically using a mechanical lever.

In the initial state, the lever is in mechanical balance placed on a fixed support. The lever is equipped with a reflective layer at its far end and an adjustable mass at the end near the axis.

The power ratio of the lever is given by:

$$F1 = L2.F2/L1 \tag{1}$$

Or also according to the displacement of the ends:

$$dx1 = L2.dx2/L1 \tag{2}$$

with:

L1 is the shorter part, L2 is the longer part, where dx1 is the displacement proportional to the force F1 applied by the muscle attached to the end A of the lever and dx2 is the distance from the reflective surface to the measuring device.

When a substance is injected, the muscle relaxes or contracts and varies the force applied to the lever.

Fig. 1. Diagram of the mechanical lever

To make the mechanical gain variable, three values of L1 are possible (5 mm-10 mm-15 mm) while for L2 only one value (80 mm), giving multiplication factors of 16, 8 and 5.33.

According to the data collected from the graphs obtained by the used system, the maximum displacement of a muscle is 5 mm. For a mechanical gain of (L2 /L1) =5.33, the maximum amplified displacement obtained is 27 mm. The lever at equilibrium is placed in the middle in order to be able to detect also the release movements of the studied muscle, so the encapsulation box is 54 mm high (see Figure 3).

Electronic circuit. The electronic part of the system consists essentially of a photoresistor and a luminous LED placed in two compartments separated by a wall (see Figure 2).

The photoresistor is placed directly under the reflecting surface which allows the measurement of the reflected light quantity. This reflected light is proportional to the distance of displacement dx2 and therefore to the amplified distance dx1.

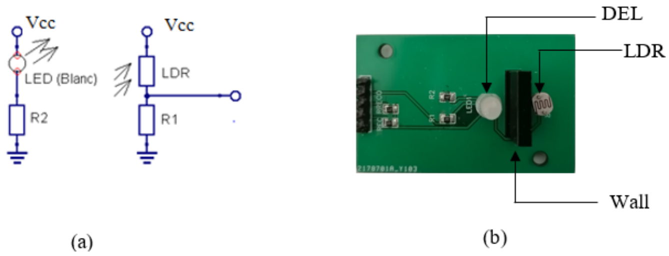

Fig. 2. (a) Schematic and (b) Picture of the electronic circuit

The sensor is then connected to a "MicroLab ExAO" acquisition board, for real-time signal acquisition. This board has four inputs, two of which are equipped with a programmable amplifier[19]. The driver software of this board offers the possibility to specify the interval of the signal to be amplified, so the continued component of the original signal is automatically subtracted and the result is then amplified, which allows to provide a high precision (see Figure 4).

3D printing. The 3D design of the sensor shown in Figure 3 is made with the Catia software. The design composed of a cell for the electronic circuit and another for the mechanical lever. To fabricate the small displacement sensor, we used the Volumic3D 3D printer based on fused deposition printing (FDM) technology. This technology uses a heated nozzle to fuse polymer filaments to form 3D objects.

The used machine is equipped with a single extruder nozzle which has a diameter of 0.3 mm, has a resolution of 25 µm, and allows to print objects with a maximum size of 290x200x300mm. To generate the Gcode, we use the Simplify3D software.

We chose this technology because it allows us to fabricate the sensor with a good quality at a very reasonable cost compared to other 3D printing technologies.

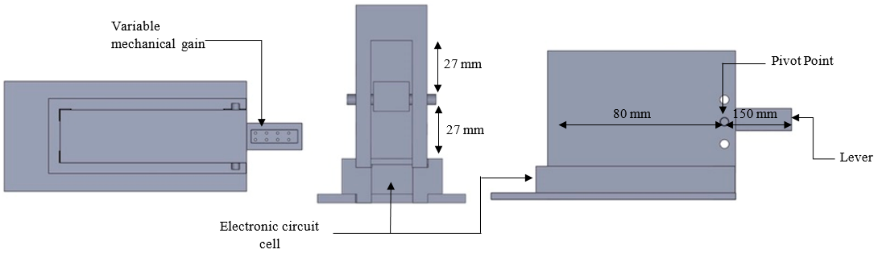

Fig. 3. 3D design of the sensor. (a) Top view. (b) back view. (c) side view

The most popular materials are PLA (polylactic acid) and ABS (acrylonitrile butadiene-styrene).

In our case, we used PLA, because according to [20], a comparative analysis between ABS and PLA parts produced by the FDM technique showed that, ABS filament was found to be more ductile than PLA, but the latter is stiffer and has a higher tensile strength. Thus, PLA parts behave in a more rigid manner.

The 3D printed sensor is shown in Figure 4.

(a) (b)

Fig. 4. Picture of the realized sensor, (b) picture of the acquisition board

3 Results

We will describe here a concrete comparative experiment, carried out using both the developed system and the mechanical cylinder system, in order to highlight the advantages and disadvantages of our new sensor and to verify via a questionnaire the students' opinion.

For their university curriculum, biological sciences students preparing their bachelor's degree have theoretical lectures and practical Lab courses helping them approach and understand certain physiological phenomena observed in animals and humans. In semester 4 of bachelor's degree, students study the properties of the muscular system and the contraction characteristics of different muscle types. Indeed, at this level, they become aware of the importance of vertebrate's skeletal muscles in movements genesis and the specific properties that help muscles fulfill their physiological responses, such as excitability (perceiving a stimulus and responding to it), contractility (contracting with force in the presence of appropriate stimulation), extensibility (stretching beyond their rest length) and elasticity (shortening and resuming the rest length). The theoretical lectures are complemented by an experimental work session during which the students are led to manipulate the gastrocnemius muscle of the frog and study the properties of its contraction. This practical work is done over a period of 4 hours during which the students work in pairs according to the experimental approach to define the muscular contraction properties. The objectives of the experimental work are to 1) Study the contraction of the isolated frog's gastrocnemius muscle. 2) Highlight the phenomena of muscle excitability, recruitment, summation, muscle fatigue and tetanus.

To do this, the gastrocnemius muscle is isolated in full compliance with the bioethics rules and guidelines. The muscle is then maintained in optimal conditions to keep the tissues alive for few hours, run the experiment and collect data. The muscle thus isolated is installed in suspension in a device which allows the recording of the contraction mechanics. Indeed, to limit lateral movements that may interfere with the recording, the muscle is attached on the lower side to a metal support using sewing thread. Parallelly, the muscle is attached by its upper side using a second sewing thread to a lever that carries a stylus that students fill with ink and put in contact with the recording paper placed around the recording cylinder that rotates at a predefined speed. After electrical stimulation of the muscle using an electric stimulator (Grass SD9 B Square Pulse Stimulator), the muscle contracts and pulls on the upper wire that pulls the lever down and therefore the stylus will move upwards, and its trajectory will be traced on the rotating paper. When the muscle is relaxed, the stylus returns to its initial position and the plot returns to the starting level. The muscle movement is thus recuperated on the cylinder paper (see Figure 5). This impractical system has several disadvantages. Indeed, students, accustomed to using computer and interactive tools, find it difficult to understand the principle of the assembly maneuver and ask to be assisted to make the assembly of their workstation. In addition, several parameters such as the weight of the muscle, the length of the lever and stylus, the friction between the stylus and the recording paper, make the reel movement sometimes exaggerated and other times reduced which makes it difficult to calculate the amplification factor. Also, the manipulation of the ink contaminates the fingers of the students and consequently the muscle, which can be toxic to the muscle and therefore affect the results obtained.

Fig. 5. Picture of the used system

To overcome all these obstacles, the CAE-based system was tested and compared to the cylinder system. Indeed, during the last two academic years, 4 CAE stations were used in parallel with 4-cylinder stations. Each pair of students randomly uses one of two system types. The CAE assembly was quickly adopted by the students, more comfortable with the use of computer tools, who quickly understand and adopt the CAE sequence (see Figure 6). The sensor being sensitive to minim movements of few millimeters, it allows to reproduce the contraction movement with respect for the real amplitude of the muscular contraction.

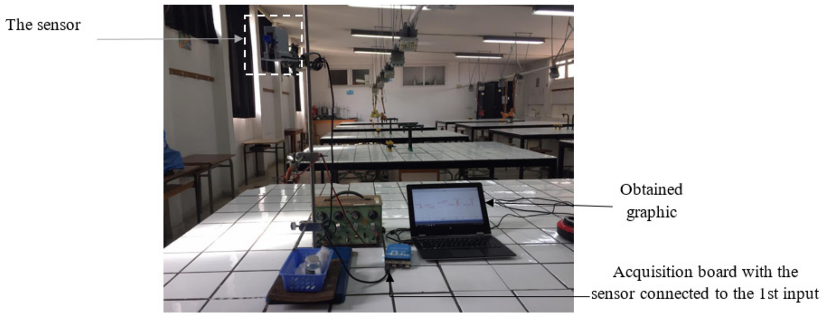

Fig. 6. Picture of the acquisition system based on the developed sensor

In addition, the graphic obtained is not a definitive, the student can amplify or reduce it to make the necessary measurements (see Figure 7 and 8). In the end, the developed system makes it possible to retrieve the results quickly and thus save the time that students often use to complete other tasks of analysis and interpretation of their results and preparation of reports. For subsequent sessions, students who have worked with the CAE system often ask at the beginning of the session to be placed again on a CAE station.

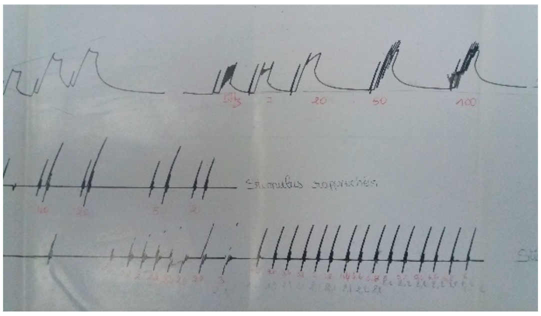

Fig. 7. Obtained results using the traditionnal system. Comments are added manuelly by students on the graph

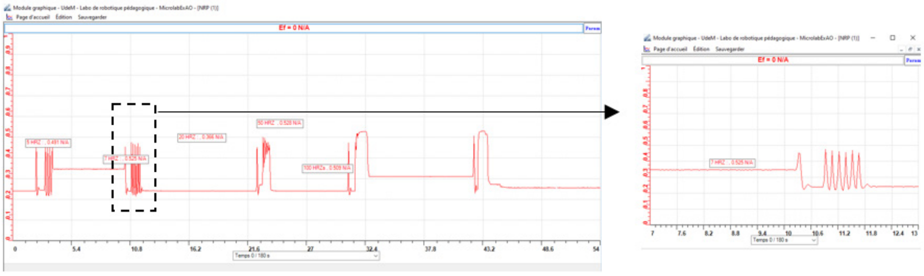

Fig. 8. Obtained results using the developed sensor. On the right the signal after zoom

4 Discussion

To evaluate the attitude of the students regarding the realization of the practical work with the realized sensor, we addressed an electronic questionnaire at the end of the sessions. 91 students aged between 18 and 26 years were interviewed, 74.7% of which are female and 83.5% have attended at least 4 sessions of animal physiology laboratory work.

The result of the survey shows that 79.1% of the population questioned (see Figure 9), prefer the use of the new sensor.

The reasons why these students prefer using the new system are mainly:

- easy understanding of the manipulation and the objectives to be achieved
- time saving, which allows more experimental activities during the lab session
- development of observations and scientific thinking skills
- possibility to adjust the precision of the results and to improve the presentation to facilitate the exploitation of the results
- ease of use of the developed system compared to the existing one

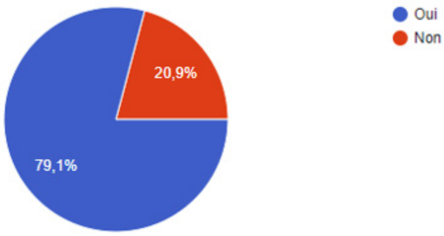

Fig. 9. Percentage of students according to their preferences, in blue the percentage of students who prefer to use the new system, in red those who prefer to work with the cylinder system

The students who prefer to use the cylinder system mainly mention the following reasons:

- the "MicroLab CAD/CAM" software is complicated and difficult to use
- the acquisition and processing of data is complicated

These reasons show indeed that these students prefer the old system because they have difficulties to handle the computer tools. Moreover, this percentage is in perfect agreement with that of the students who declared not having a personal computer (27.5%). Also, in the comment section, these students justified their preference for the cylinder system with comments such as "I prefer the cylinder, because don’t have a computer", "I don't master computer tools well" and "Because I have always worked with the cylinder" (see Figure 10).

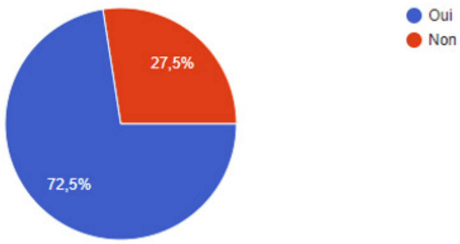

Fig. 10. Percentage of students, in blue those who have a personal computer, in red those who do not have a personal computer

5 Conclusion

Experimentation, an essential activity for developing students' critical thinking and manipulative skills, faces several problems. On a technical level, the system used for practical work in biology in higher education is expensive and presents several technical problems.

In this paper, we have presented a sensor of small biological movements realized with 3D printing and used in a CAD/CAM environment. According to the students, the didactic benefits of this new environment (i) facilitates their understanding of the PW, since they are more focused on the objectives of the PW and not on the adjustment of the system dedicated to the acquisition, (ii) which saves them time, (iii) facilitates the exploitation of the data, since the new system offers the possibility to amplify the sensor's output signal, to zoom in and to add comments on the graph in real time.

The 3D design and electronic schematics of the new system are open source, so the technical staff can repair and reproduce it at minimal cost.

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Evaluation of Comprehensive Services of an Online Learning Platform Based on Artificial Intelligence

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Abstract—With the college students having increasing needs for learning diversified knowledge and skills, online learning platforms for essential qualities enhancement have emerged one by one. However, due to lack of feedbacks from students, the comprehensive service quality of these platforms varies greatly. Therefore, it has certain practical significance to study how to evaluate the comprehensive services of online learning platforms. The current evaluation models are not suitable for online learning platforms, nor have they fully considered the dynamic and subjective feedbacks of students about their experience. To this end, this paper takes an online music education platform as an example and studies the evaluation on the comprehensive services of the online learning platform. First, the overall architecture design of an online learning platform for essential qualities enhancement was displayed, and the teacher-student interaction mode for the comprehensive services of the online learning platform was identified and analyzed. Then, the derivation process of the evaluation model was presented, the evaluation indicator system for the comprehensive service quality of the online learning platform constructed, and the comprehensive service evaluation model for the online learning platform consisting of the hierarchical model and the rough set-neural network evaluation model established. The experimental results verified the effectiveness of the constructed indicator system and evaluation model.

Keywords—neural network, online learning, evaluation on comprehensive services

1 Introduction

Driven and catalyzed by the "Internet +" trend, online learning platforms have broken through the constraints of time and space, with the market size maintaining year-on-year growth in recent years [1-5]. Particularly in the post-COVID era, thanks to their advantages, online learning platforms integrating information technology have become an important direction of higher education in China and even in the world [6-14]. To meet the needs of the future society, high-level professional talents need to be well-rounded, that is, they have to have knowledge, abilities and also essential qualities, which is why college students have increasing demands for learning diversified knowledge and skills. Along with this trend, online learning platforms specialized in enhancement of essential qualities such as music and sports have developed rapidly within a short period of time. However, due to lack of feedbacks from students about their experience, the comprehensive service quality of these platforms varies greatly [15-19]. Therefore, it has certain practical significance to study how to evaluate the comprehensive services of online learning platforms.

Boko et al. [20] leveraged the powerful functions of a highly interactive online learning platform to improve its interactivity and service quality. The platform was built on FFmpeg, Tvheadend and Verto-FreeSwitch, allowing teachers to provide online courses with better service quality. The FFmpeg streaming server performs MPEG-TS encoding and allows teachers to unicast a multimedia (audio/video) stream from his webcam to the Tvheadend server, and the interactive IPTV server multicasts the stream to learners. Through a web browser or IPTV client, students can interact in real time as instructed by the teacher. Tsai et al. [21] discussed the construction and use of online learning platforms on the basis of total quality management and knowledge management. The data collection method was semi-structured interviews. The results consisted of three parts, which were the results respectively before, during and after use, analyzed from three perspectives - total quality management, knowledge innovation and knowledge sharing. Militaru et al. [22] proposed an expert system that can be used to build a web-based learning platform quality model to improve usability, reduce cost and facilitate services. The quality framework used was called SEEQUEL and the proposed expert system was built on CLIPS. The final conclusion of the experiment is that the expert system can successfully perform the assigned task in place of human experts. The online learning quality evaluation of learners is an important function of an online learning platform, and also an important means for teachers to remotely check the learning effect of learners. Wang et al. [23] discussed the importance and purpose of learning quality evaluation on online learning platforms, and proposed a content framework for online learning quality evaluation from five aspects - participation in learning activities, interactions, use of resources, acquisition of knowledge and contribution to the learning community. It also put forward two effective strategies for learning quality evaluation on online learning platforms, in order to provide some references for improving students' learning quality. Braccini et al. [24] investigated end users' perceptions of the quality of the Moodle open source e-learning platform in terms of usability, functionality, reliability, efficiency and use quality.

According to the existing research results, it is found that the current evaluation models are not suitable for online learning platforms, nor have they fully considered the dynamic and subjective feedbacks of students about their experience. To this end, this paper takes an online music education platform as an example and studies the evaluation on the comprehensive services of the online learning platform. The paper consists of the following sections. Section 2 presents the overall architecture design of an online learning platform for quality enhancement, and identifies and analyzes the teacher-student interaction mode for the comprehensive services of the online learning platform. Section 3 shows the derivation process of the evaluation model, constructs the evaluation indicator system for the comprehensive service quality of the online learning platform, and establishes the comprehensive service evaluation model for the online learning platform consisting of the hierarchical model and the rough set-neural network evaluation model. The experimental results prove the effectiveness of the constructed indicator system and evaluation model.

2 Identification of the teacher-student interaction mode

Online music education is different from general online education, as the learning of almost all musical instruments is mainly about practicing, mastering skills, practical tutoring and error correction, rather than theoretical learning. Since different students have different problems in learning, the traditional one-to-many teaching mode is often not quite effective. In order to obtain a more accurate evaluation result of the comprehensive services of an online learning platform, the teacher-student interaction mode in the comprehensive services of the online learning platform was first identified and analyzed. Figure 1 shows the overall architecture design of an online learning platform for essential-qualities enhancement (music education). As can be seen, the constructed platform consists of three layers – a presentation layer, a business logic layer, and a data service layer. The presentation layer consists of the client and the management system; the business logic layer contains such modules as music theory learning, musical instrument practicing, teacher-student interaction management, music appreciation and comment, Q&A and platform administration; and the data service layer has functions like platform access management, information transmission management and data storage management.

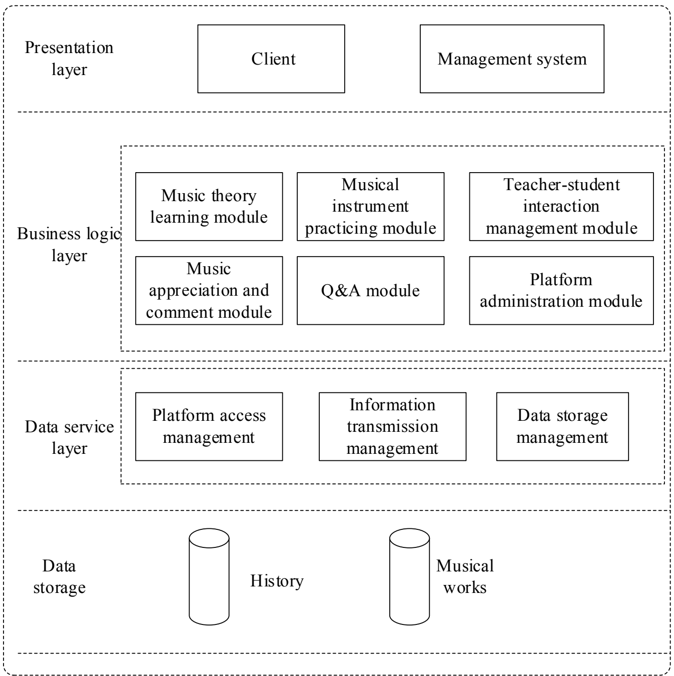

Fig. 1. Overall architecture design of an online music learning platform

During an online class, students will have interactive discussions with the teacher on some learning problems. To understand the question-based learning progress of all students, it is necessary to characterize the questions of each student. Therefore, in this paper, the interval between the question time and the start of an online class was used to generate the vector of students' question-based learning progress.

Assuming that the question-based learning progress vector of student s_1 is denoted as A, that the start time of the class as SD, that the end time of the class as ED, and that the time of the i-th question as PD, then the feature a_i represented by the question in A can be obtained according to Equation (1):

$$a_i = \frac{PD - SD}{ED - SD} \tag{1}$$

Suppose that there are n students studying this course X. The interactive behavior similarity was used in this paper to represent the behavior features of all students. Assuming that there are m behavior features of students, that the selection criteria is denoted as $A_1(a_1,a_2,a_3,a_4,a_5,a_6,a_7,a_8,a_9,\ldots a_m)$, calculate the similarity between $B1$, $B2$, .., B_n and the standard, and then $D_1,D_2...D_n$ are obtained. Calculate the number of students Ψ with D_i being greater than the behavior similarity threshold t, and then calculate the proportion of the students whose similarity with the standard is greater than δ in the total number of students:

$$\beta = \frac{\Psi}{n} * 100\% \tag{2}$$

If β is greater than x, it can be deemed that the teacher-student interaction mode of course X is task diving. If β is less than x, the teacher-student interaction mode is free learning. Since the students' questioning behavior data have no class reference, the *Calinski-Harabasz* clustering effect evaluation method was used in this paper to classify the teacher-student interaction modes. It is assumed that the data sample size is represented by N, that the number of data classes after clustering by l, that the covariance matrix between classes by Y_l, that the covariance matrix within each class of data by Q_l, and that the trace of the mean by Φ. Equation (3) gives the formula for calculating the fraction r:

$$r(l) = \frac{\Phi(Y_l)}{\Phi(Q_l)} * \frac{N-l}{l-1} \tag{3}$$

The larger the covariance between the teacher-student interaction modes and the smaller the covariance within each teacher-student interaction mode, the larger the value of r, that is, the better the clustering effect.

When the teacher-student interaction mode of a course is free learning, students's learning behaviors are active. In this paper, the teacher's interactivity was used to represent the course activity. Assuming that the total number of questions asked by students is represented by M, that the number of responses given by the teacher to the i-th question is represented by a_i, and that the total number of responses can be represented by $A(a_1,a_2...,a_m)$, then the teacher's response rate $\eta(A)$ to the students' questions can be calculated by Equation (4):

$$\eta(A)=\frac{\sum a_i}{M}*100\% \tag{4}$$

3 Construction of the evaluation model

3.1 Evaluation indicator system

The comprehensive service quality of an online learning platform targeting essential-qualities enhancement cannot be evaluated based solely on students' performance, but rather on multiple perspectives and criteria, including students' learning behavior data and skills acquisition level in the learning process. Aiming at the problems of the current essential-qualities-oriented online learning platforms, such as complicated content and poor functional experience, this paper made a comprehensive analysis from such aspects as students' experience feedbacks and intentions to continue use this platform. The derivation process of the evaluation model is shown in Figure 2. The constructed evaluation indicator system is presented as follows:

Layer 1 (evaluation objectives):

CS={CS_1, CS_2, CS_3, CS_4}={content experience, interaction experience, efficiency experience, process experience};

Layer 2 (evaluation criteria):

CS_1={CS_{11}, CS_{12}, CS_{13}, CS_{14}, CS_{15}}={frontier, practicality, comprehensiveness, generality, update progress};

CS_2={CS_{21}, CS_{22}, CS_{23}, CS_{24}, CS_{25}}={academic accomplishment, teaching organization ability, expression ability, patience, information-based teaching ability};

CS_2={CS_{21}, CS_{22}, CS_{23}, CS_{24}, CS_{25}}={Q&A effect, knowledge comprehension, skill acquisition, course completion, music appreciation ability};

CS_2={CS_{21}, CS_{22}, CS_{23}, CS_{24}, CS_{25}, CS_{26}, CS_{27}}={convenience, ease of operation, security, stability, response speed, resource abundance, functional completeness};

The evaluation model for the comprehensive services of online learning platforms constructed in this paper consists of two parts - the hierarchical model and the rough set-neural network evaluation model. The former is used to calculate the weights of the evaluation indicators on each layer, and the latter to calculate the actual efficacy value of online music learning by each student.

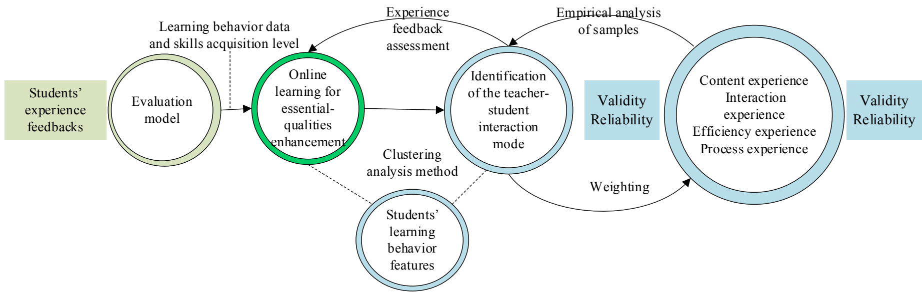

Fig. 2. Derivation process of the evaluation model

3.2 Hierarchical model

The first step is to carry out hierarchical single ranking for the hierarchical model, that is, to prioritize the evaluation criteria in the criteria layer corresponding to a certain evaluation indicator on the target layer. In order to obtain the composite weights of the evaluation indicators on each layer, the square root method was used to calculate the maximum eigenroot and eigenweight vector of the judgment matrix. Equation (5) shows how to calculate the product of the elements in each row of the judgment matrix *X*:

$$SN_i = \prod_{j=1}^{m} x_{ij}, i = 1, 2, ..., m \tag{5}$$

Equation (6) gives the formula for calculating the *m*-th root of SN_i:

$$\overline{SN_i} = \sqrt[m]{SN_i} \tag{6}$$

Normalize the required eigenweight vector Q_i based on Equation (7):

$$Q_i = \frac{\overline{Q_i}}{\sum_{j=1}^{m} \overline{Q_j}} \tag{7}$$

Suppose the *i*-th component of the vector *XQ* is represented by XQ_i, the maximum eigenvalue can be calculated as follows:

$$\mu_{max} = \sum_{i=1}^{m} \frac{(XQ)_i}{mQ_i} \tag{8}$$

Equation (9) shows how to calculate the consistency index of the judgment matrix:

$$SU = \frac{(\mu_{max} - m)}{m - 1} \tag{9}$$

Assuming that the value consistency index is represented by *TU*, and that the value of the consistency ratio by *ST*, based on *SU* and *TU*, the value *of ST* can be further calculated based on Equation (10):

$$ST = \frac{SU}{TU} \tag{10}$$

The next step is the hierarchical total ranking of the hierarchical model, that is, to rank the comprehensive weights of the evaluation indicators for the online learning platform on the objective layer. The calculation method is similar to that in hierarchical single ranking. And also like hierarchical single ranking, hierarchical total ranking requires consistency check. Equation (11) gives the calculation formula:

$$SU_T = \sum_{i=1}^{m} d_i SU_i TU_T = \sum_{i=1}^{m} d_i TU_i \tag{11}$$

The consistency index of the judgment matrix corresponding to D_i is represented by SU_i, and the consistency check value of the judgment matrix corresponding to D_i is represented by TU_i. Substitute SU_i and TU_i into the above equation to obtain ST_T. When the ST_T is less than 0.1, it can be considered that the consistency is satisfactory regarding the relative importance of all the comprehensive service evaluation indicators for the online learning platform in the hierarchical total ranking of the model.

3.3 Rough set-neural network evaluation model

A rough set-neural network model was constructed to evaluate the comprehensive service quality of the online teaching platform. The attribute reduction theory for the rough set was used to calculate the weights of the core evaluation indicators, and the calculation results were input into the BP neural network for training. The model can deal with the problem of insufficient prior information on evaluation indicators, and improve the training efficiency and calculation accuracy of BP neural network.

Figure 3 presents the architecture of the rough set model. First, discretize the collected comprehensive service evaluation data of the online teaching platform to further construct the two-dimensional decision table. Suppose that the conditional attributes in the decision table is represented by $D=(d_1,d_2,...,d_m)$, and that the decision attribute by *NCS*.

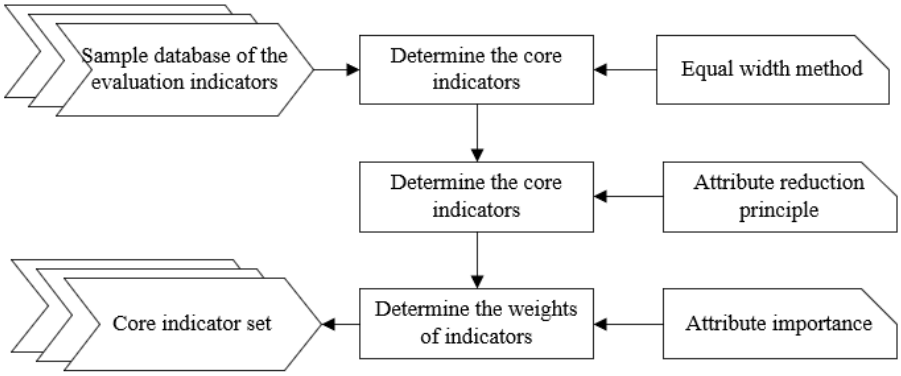

Fig. 3. Architecture of the rough set model

Equation (12) shows how to calculate the dependence of *NA* on the core attribute V_1:

$$\phi_{V1}\left(NA\right)=\frac{\left|\Gamma_{V1}NA\right|}{\left|RQ\right|} \tag{12}$$

After a certain core attribute V_i is removed, the dependence of *NA* on the core attribute set V_1-V_i can be calculated by the following formula:

$$\phi_{V_1-V_i}\left(NA\right)=\frac{\left|\Gamma_{V_1-V_i}NA\right|}{\left|RQ\right|} \tag{13}$$

The importance of each core attribute to *NA* can be calculated by Equation (14):

$$\chi_i=\phi_{V_1}\left(NA\right)-\phi_{V_1-V_i}\left(NA\right) \tag{14}$$

The weight coefficient of V_i can be obtained through normalization:

$$\varsigma_i=\frac{\phi_{V_1}\left(NA\right)-\phi_{V_1-V_i}\left(NA\right)}{\sum_{i=1}^{m}\left[\phi_{V_1}\left(NA\right)-\phi_{V_1-V_i}\left(NA\right)\right]} \tag{15}$$

Figure 4 shows the architecture of the neural network model. In the BP neural network, let the input of *m* evaluation indicator data be represented by $a=(a_1,a_2,\ldots,a_m)^T$, and the output of *n* units in the hidden layer be represented by $b=(b_1,b_2,\ldots,b_n)^T$, and the result of the output layer be denoted as *c* and the target output as *o*.

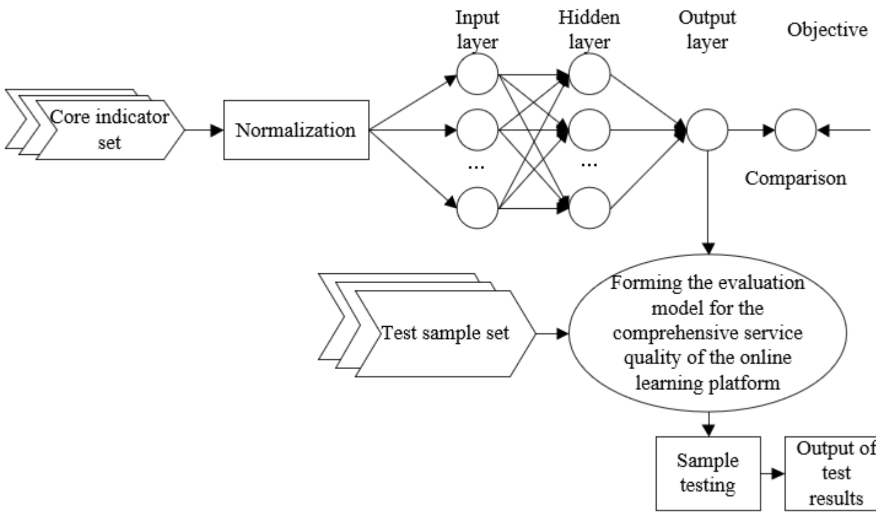

Fig. 4. Architecture of the neural network model

Suppose the transfer function of the hidden layer is denoted as e, and that the connection weight of neuron i in the input layer to neuron l in the hidden layer as Q_{il}. Equation (16) shows how to calculate the output result of the hidden layer of the network model:

$$b_l = e\left(\sum\nolimits_{i=0}^{m} q_{il} a_i\right) \tag{16}$$

Assuming that the transfer function of the output layer is represented by h, and that the connection weight of neuron l in the hidden layer to neuron k in the output layer by Q_{lk}, Equation (17) shows how to calculate the result of the output layer of the network model:

$$c = h\left(\sum\nolimits_{l=0}^{n} q_{lk} b_l\right) \tag{17}$$

The error between the output value and the target value of the network model can be calculated by the following formula:

$$E = \frac{1}{k}\sum\nolimits_{k=1}^{1}\left(o_k - c_k\right)^2 \tag{18}$$

Through adjustment of Q_{lk} and Q_{il}, E is reduced until it meets the preset error requirement.

4 Experimental results and discussion

The statistical mean values of the overall teacher-student interaction behavior features are given in Table 1. It can be seen that the average number of responses from the teacher to students attending in a musical instrument training course was 4.15, and the maximum number of responses from the teacher 114; the average number of questions from a student was 0.25, and the number of questions raised by the student who asked the most questions 85. It can be found that the students of this musical instrument training course received a lot of responses from the teacher but raised fewer questions. The standard deviation of the number of questions raised by students was 1.52, indicating that there was little difference between the number of questions raised by each student attending the course and the average number. The standard deviation of the number of responses from the teacher was 3.69, indicating that the number of responses received by each student attending the course was significantly different from the average number.

Table 1. Statistical results of the features of interactions between teachers and students

Feature description	Mean	Median	Max	Min	Standard deviation
Number of questions	0.25	2	85	0.1	1.52
Number of responses	4.15	5	114	0.3	3.69
Interval between the date when the student asked the most questions and the start time of class	0.16	-0.3	36	-0.2	2.41
Number of questions on the date when the student asked the most questions	0.08	0.2	15	0.5	0.38
Interval between the date when the student received the most responses from the teacher and the start time of class	19.62	21	35	0.3	11.57
Number of responses on the date when the student received the most responses	1.84	3	42	-0.1	2.58

After the maximum eigenroot and eigenvector of the judgment matrix corresponding to the evaluation indicator system were calculated based on the square root method, the weights of all indicators were obtained. The comprehensive weights of the comprehensive service evaluation indicators for the online learning platform are shown in Table 2. It can be seen that the consistency ratio of the judgment matrix of the evaluation indicator system is less than 0.1, and the weight of the overall objective of the comprehensive service evaluation of the online learning platform is 1. The consistency ratios of the judgment matrix of CS_1, CS_2, CS_3, and CS_4 are all less than 0.1, and their weights to the overall objective are 0.174, 0.276, 0.336, and 0.241, respectively, indicating that the judgment matrix passes the consistency check.

Table 2. Comprehensive weights of the comprehensive service evaluation indicators for online learning platforms

	Weight		Weight	μ_{max}	*CI*	*C.R.*
Comprehensive service evaluation indicator for an online learning platform *CS*	1	*CS*1	0.174	4.528	0.016	0.084
		*CS*2	0.276			
		*CS*3	0.336			
		*CS*4	0.241			
Content experience CS_1	0.174	CS_{12}	0.034	4.915	0.063	0.074
		CS_{13}	0.047			
		CS_{14}	0.059			
		CS_{15}	0.034			
Interaction experience CS_2	0.276	CS_{21}	0.095	5.286	0.047	0.038
		CS_{22}	0.074			
		CS_{23}	0.032			
		CS_{24}	0.058			
		CS_{25}	0.017			
Efficiency experience CS_3	0.336	CS_{31}	0.036	5.738	0.141	0.068
		CS_{32}	0.041			
		CS_{33}	0.043			
		CS_{34}	0.084			
		CS_{35}	0.132			
Process experience CS_4	0.241	CS_{41}	0.089	5.926	0.173	0.081
		CS_{42}	0.064			
		CS_{43}	0.026			
		CS_{44}	0.017			
		CS_{45}	0.015			
		CS_{46}	0.012			
		CS_{47}	0.018			

Figure 5 shows the training error curve of the BP neural network. It can be seen that after 400 iterations, the training of the network was over. At this time, the prediction accuracy of the model reached the preset target and met the preset requirement. This proves that the model can be effectively applied to the simulation of the comprehensive service evaluation of an online learning platform for essential qualities enhancement.

Eight samples were selected from each of the five ratings of the comprehensive service quality of the online teaching platform - “very high”, “high”, “moderate”, “low” and “very low”, that is, a total of 40 sample data, to test the constructed evaluation model. It can be seen from the Figure 6 that the simulated values of the 40 samples almost completely coincided with the output values, proving that the model has high accuracy in predicting the comprehensive service quality of online teaching platforms.

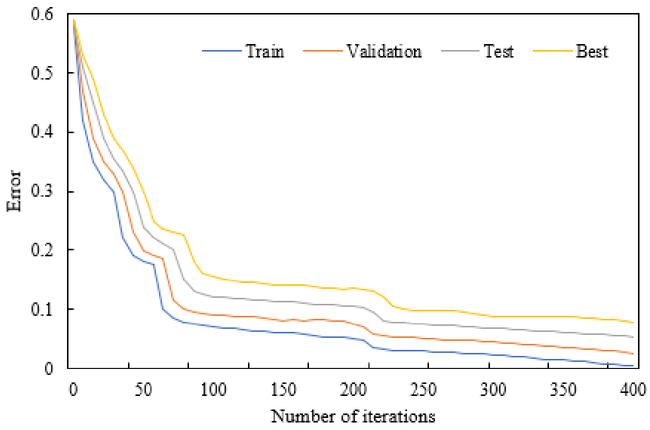

Fig. 5. Training error curve of the BP neural network

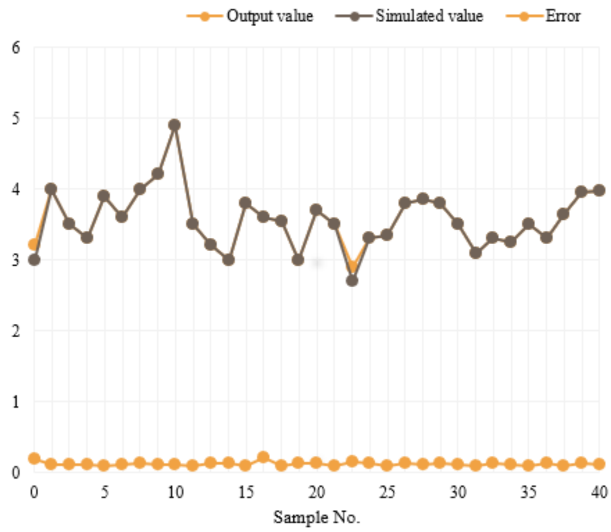

Fig. 6. Model test error comparison

5 Conclusions

This paper took an online music education platform as an example and studied the evaluation on the comprehensive services of the online learning platform. First, the overall architecture design of an online learning platform for essential qualities enhancement was displayed, and the teacher-student interaction mode for the comprehensive services of the online learning platform was identified and analyzed. Then, the derivation process of the evaluation model was presented, the evaluation indicator system for the comprehensive service quality of the online learning platform constructed, and the comprehensive service evaluation model for the online learning platform consisting of the hierarchical model and the rough set-neural network evaluation model established. The statistical results of the features of the teacher-student interactions in the course were given, from which it can be seen that the number of questions asked by each student attending the musical instrument training course was not much different from the average number, but there was a big difference between the number of responses from the teacher and the average number. Then, based on the square root method, the maximum eigenroot and eigenvector of the judgment matrix corresponding to the evaluation indicator system were calculated, and the comprehensive weights of the comprehensive service evaluation indicators for the online learning platform were obtained. The constructed judgment matrix also passed the consistency check. After that, the training error curve of the constructed BP neural network was presented, which verified the effectiveness of the model when applied to the simulation of the comprehensive service evaluation of online learning platforms. Finally, the errors of the model test were compared, which proves that the model has high accuracy in predicting the comprehensive service quality of online teaching platforms.

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Applying Learning Analytics for Designing Effective Pedagogy for Online Courses: Analysis and Recommendations

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Abstract—The countrywide lockdown since March 2020 due to COVID 19 pandemic has brought drastic changes in the Indian education system. Today, many higher education institutions offer online delivery as an alternative and/or addition to provide more flexibility to learners, specifically in the current COVID 19 Pandemic. The conventional teaching method to the technology-driven virtual mode of teaching provided opportunities with challenges to academic stakeholders. Now with the new session, discussions on the reopening of educational institutions are going on. Hence, it is time to review the learning that took place during this pandemic situation. Learners being confronted with such services come with different expectations of what that means to their learning paths and behaviors. Learning Analytics is a relatively new and innovative way of making learner behavior and performances explicit by analyzing significant learners' feedback data. In this study, we take the case of online courses offered by various educational institutions all over India, and the analysis encompasses the population of learners of the online courses during the COVID 19 Pandemic period. Primary data has been collected using Google form when journals, reports, and websites are secondary data collection sources. We classified the data into distinctive parts: the overall learning experience of this course, the fulfillment of the learners' objectives, the difficulty of the assignments, the quality of the material supplied, the difficulty level of the course, the quality of the live session, opinion about the virtual approach of teaching, opinion about the contribution of virtual academic programs on knowledge building, opinion about the impact of virtual mode of teaching on performance, and opinion about the causes affecting students' performance in the virtual mode of learning. The analysis outcomes will guide the host institutions and other similar institutions to design their pedagogy for future online courses more effectively, influencing learner engagement and retention.

Keywords—online learning, online teaching, online courses, feedback data, learning experience, COVID 19, learner behavior, quality of online course, pedagogy, learner engagement, and retention

1 Introduction

The coronavirus pandemic has changed the teaching-learning process at higher education institutions and affected teachers' and students' relationships. Due to the pandemic, universities and colleges can only perform activities online with students [1]. In this regard, many governments have taken measures to ensure the continuity of the education process, and nationally colleges have embraced online learning [2]. Online learning has become an essential part of sustained university/college activity [3]. The paradigm shift could shift students' understanding of the problem, and their perceptions could be different from those observed in past studies.

Online learning has many advantages because it requires student-centeredness; it is more flexible [4]. E-mail, video conferencing, forum discussion, and chat can also enhance learning [5], [6]. Internet technologies have enabled many users to share material simultaneously and have enabled online learning platforms to provide controlled content, controlled time, and controlled processes that respond to learners' needs and learning goals [7]. This can improve students' learning experience, despite some inherent difficulties brought on by this crisis period.

There may be challenges with some online learning platforms that affect motivation and input and may prevent people from feeling as if they are being "plugged in" to a community [8]. Allowing students to adjust to their learning goals, educators can adapt to their needs. Teaching experience and knowledge of online teaching are needed to do so. Since the educational process is mainly done online, these drawbacks might be more common [9]. Teachers may have had to adapt their teaching style because of the online nature of the learning and the time available to adapt. Students are not adequately prepared for an online experience. Therefore, problems have occurred in the institution and among students [10].

We felt it necessary, essential, and necessary to examine whether students are getting used to online learning and whether they are satisfied. This study aims to identify the effectiveness of the online learning experience during the Coronavirus pandemic so that institutions can design effective pedagogy for online courses. As this analysis shows, the transition to online learning will significantly affect students' educational process and understanding of the online environment. Thus, our research can contribute to the effective design and development of future online learning courses.

2 Learning analytics to assess the effectiveness of online courses

Learning Analytics is an evolving area of technology-enhanced learning research. It is based on the idea that online student experiences and other data sources (student feedback) use broad instructional datasets to recognize behaviors, attitudes, learning paths, and patterns that can illustrate potential challenges and areas for improvement in terms of student learning design, delivery, and administration [11]. Learning Analytics refers to data collection and analysis, which is then analyzed to determine learners' success and judge their past and predicted future results [12].

2.1 How learning analytics improves your online teaching

Some of the reasons why learning analytics improves online teaching include the following [13]:

- ***Predicts Learner Outcomes***: There is no end to the process of learning. Learners' progress can be tracked using learning analytics, but educators can use this data to predict how well their students will perform. Educators can compare students to other students and historical data to determine if intervention is necessary. Educators can help students succeed by providing extra resources like videos and readings or one-on-one assistance. They can also break up the class into smaller groups to help students work better together. Instead of waiting for students to fail, the ultimate goal should be to aid in their success. In order to make informed decisions, teachers can use learning analytics to get a glimpse of what might happen in the future.
- ***Increases Teacher/Trainer Effectiveness & Lesson Plans***: "It is not you; it is me." As teachers, we must constantly evaluate our performance. When students complete an online course, we typically ask for feedback in the form of a survey. This feedback is precious to identify areas for improvement by sifting through the data. As a result, some topics may have been overlooked or spent too much time on others. Learning analytics helps us better understand how to improve the effectiveness of our learning. Real-time data is also a benefit. We can learn how to improve as the course progresses, which is fantastic!
- ***Improves eLearning Content and Courses***: Learner and educator performance can be analyzed using data and online courses and content. Even if our video courses are visually stunning, we may need to revisit the content if most students fail to grasp the essential concepts. The presentation of some content may detract from its overall purpose. The inverse is also possible: We might discover that providing extra help for struggling students leads to excellent results. We can then ensure that the content is included in the course for the benefit of all students. Learning analytics allows us to get down to the nitty-gritty of how our content is performing. If they do not work, try something else. Make sure the content is available to as many students as possible if it is effective.
- ***Tailored Learner Experience***: Every learner has unique characteristics. They each bring a unique set of skills to the table because of their unique perspectives and personal experiences. Learning analytics can help us tailor learning experiences to suit the needs of different students. It is possible to tailor instruction to student's individual needs rather than imposing a rigid model on them all. Using microlearning activities or mobile learning, we may find that certain groups of students can retain information when delivered in small, bite-sized chunks. We know that some students prefer to learn in real-time, while others prefer to learn at their own pace and on their schedule. Learning analytics can help us better understand what our learners need, creating more personalized learning experiences that lead to better outcomes.

2.2 How can learning analytics data improve online courses?

In the process of evaluating your online course, it is critical to determine what is most important to your institution in terms of outcomes for your students and learners. Your online courses can be improved by using learning analytics. Analytics data can assist trainers in implementing measures that can help learners who fall short of the standards established to succeed in achieving the course objectives. Data from analytics reports can be used to determine whether or not an online course has achieved its stated goals, such as [14]:

- Make your online courses a success by highlighting the positive outcomes achieved by your students in terms of productivity, efficiency, and enhanced job performance (essentially showing an ROI)
- In order to help learners and employees fill in the gaps in their skill sets and knowledge, improve the design and development of your online training courses.
- Looking for better resources and topics that are relevant and interesting in order to increase student involvement
- Automated and timed delivery of reports and dashboards saves time and effort.
- Access to all of your eLearning course data in a safe and secure environment
- Spending more time analyzing your online course's data and looking at the overall picture

In terms of various variables, evaluating learners in this manner may be, such as their overall learning experience, the fulfillment of their learning objectives, the difficulty of assignments, quality of the material supplied, difficultly level of the course, quality of the live session might help the universities/colleges design effective pedagogies for their future online courses.

3 Objectives and methodology

The main objectives of the study are as follows.

- To assess the overall learning experience of students on online learning.
- To identify the fulfillment of the learners’ objectives.
- To identify the difficulty of the assignments.
- To check the quality of the material supplied.
- To identify the difficulty level of the course, and
- To analyze the overall quality of the live session
- To analyze the virtual approach of teaching
- To analyze the contribution of virtual academic programs on knowledge building
- To analyze the impact of virtual mode of teaching on performance
- To analyze the causes affecting students’ performance in the virtual mode of learning

The data is collected through a self-administered, online circulated, structured questionnaire, fetched 228 responses from 19 states of India. The study was conducted in December 2020, i.e., this online survey was done after completing almost one semester of online teaching for all undergraduate students' batches. The respondents were the students who are attending online learning courses to complete their regular courses. The simple learning analytics tool Microsoft Excel has been used to record and analyze the collected data.

4 Findings from the online survey

The total collected responses were 228 in number. The findings are presented in the study's sequence to examine students' experiences concerning online learning and determine the answers to stated study objectives.

4.1 Overall learning experience of students on online learning

The participants were asked to share their opinion on "How would you rate the overall learning experience of this course?" The question utilized a 5-point Likert scale (5-Excellent, 4-Good, 3-Average, 2-Poor, 1-Very poor). The responses are tabulated in Table 1.

Table 1. Overall learning experience of the students

	5	4	3	2	1	Total
No. of Respondents	37 (16.22)	66 (28.94)	91 (39.91)	23 (10.08)	11 (4.82)	228

4.2 Fulfilment of the learners' objectives

The participants were asked to share their opinion on "Did the course fulfill your professional/personal objectives?" The question utilized a 4-point Likert scale (4-Highly Fulfilled, 3- Fulfilled, 2-Average, 1-Unfulfilled). The responses are tabulated in Table 2.

Table 2. Fulfillment of learners' objectives

	4	3	2	1	Total
No. of Respondents	75 (32.89)	101 (44.30)	33 (14.47)	19 (8.34)	228

4.3 Difficulty of assignments

The participants were asked to share their opinion on "Rate the difficulty of the assignments." The question utilized a 5-point Likert scale (5-Very Difficult, 4-Difficult, 3-Moderate, 2-Easy, 1-Very Easy). The responses are tabulated in Table 3.

Table 3. Difficulty of assignments

	5	4	3	2	1	Total
No. of Respondents	48 (21.05)	98 (42.98)	39 (17.10)	32 (14.03)	11 (4.82)	228

4.4 Quality of the material supplied

The participants were asked to share their opinion on "How would you rate the quality of the material supplied?" The question utilized a 4-point Likert scale (4-Very Good, 3-Good, 2-Fair, 1-Poor). The responses are tabulated in Table 4.

Table 4. Quality of the material supplied

	4	3	2	1	Total
No. of Respondents	54 (23.68)	108 (47.36)	43 (18.85)	23 (10.08)	228

4.5 Difficulty level of the course

The participants were asked to share their opinion on "Rate the difficulty level of the course." The question utilized a 5-point Likert scale (5-Very Difficult, 4-Difficult, 3-Moderate, 2-Easy, 1-Very Easy). The responses are tabulated in Table 5.

Table 5. Difficulty level of the course

	5	4	3	2	1	Total
No. of Respondents	56 (24.56)	85 (37.28)	34 (14.91)	38 (16.67)	15 (6.57)	228

4.6 Quality of the live session

The participants were asked to share their opinion on "Rate the LIVE session." The question utilized a 5-point Likert scale (5-Excellent, 4-Good, 3-Average, 2-Poor, 1-Very poor). The responses are tabulated in Table 6.

Table 6. Quality of live session

	5	4	3	2	1	Total
No. of Respondents	34 (14.91)	77 (33.77)	30 (13.15)	48 (21.05)	39 (17.10)	228

4.7 Opinion about the contribution of virtual academic programs on knowledge building

The participants were asked to share their opinion about the contribution of academic programs (Webinars, lecture series, conferences, and training programs) attended by them in virtual mode on their knowledge building. Responses indicated that online academic programs have a very significant contribution to knowledge building (Table 7).

Table 7. Contribution of virtual academic programs on knowledge building

Contribution of Virtual Academic Programs on Knowledge Building	Number of Respondents (N=228)	Percentage (%)
Very Significant	109	47.8
Significant	63	27.6
Average	21	9.2
Minor	19	8.3
Minimal	16	7.0
Total	228	100.0

4.8 Opinion about the impact of virtual mode of teaching on performance

The participants who have been attending virtual classes were asked to share opinions about their academic performance based on the built knowledge to understand the impact of virtual teaching on the students' performance. A cross-tabulation result indicated that the majority of male (40.21%) and female (58.04%) students thought that the virtual mode of teaching was somewhat affecting their performance (Table 8).

Table 8. Impact of virtual mode of teaching on performance

Gender	NIL	Somewhat	Very Little	Very Much	Total
Female	12 (10.08%)	68 (57.14)	26 (21.84)	13 (10.92)	119
Male	18 (16.51)	42 (38.53)	26 (23.85)	23 (21.10)	109
Total	30 (13.15)	110 (48.24)	52 (22.80)	36 (15.78)	228

4.9 Opinion about the causes affecting students' performance in the virtual mode of learning

The participants were asked to mention the possible causes affecting performance in the online learning process. The response (Table 9) indicates that most participants (69.4%) shared that the internet connectivity issue is one of the major causes affecting students' performance.

Table 9. Causes affecting students‘ performance in the virtual mode of learning

Casual Factors	Frequency	Percentage (%)
Excess academic assignment	56	26.8
Fear of passing exams	51	24.4
Career-related worries	27	12.9
Default learning	50	23.9
Internet Connectivity	145	69.4
Absence of group learning	64	30.6
Personalized approach to learning	38	18.2
Technical know-how about gadgets	50	23.9

4.10 Opinion about the virtual approach of teaching

The question was asked to understand the perception of the students about the virtual approach of teaching. The participants were asked to share their opinion about the virtual teaching-learning approach. The participants' responses indicated that a virtual teaching-learning approach is helpful in higher education, followed by convenience, time-saving, and cost-effectiveness (Figure 1.).

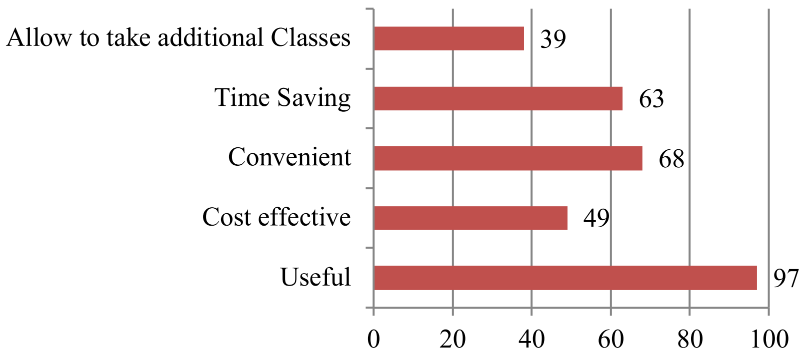

Fig. 1. Opinion about the virtual approach of teaching

5 Discussion

We helped facilitate two significant changes in the higher education system during the Coronavirus crisis: digitization and online learning. It depends on many factors, including the factors analyzed in this study. From the analysis performed, it can be identified that 45.17 percentage students are satisfied with the overall learning experience of online learning and 14.91 percentage of students are dissatisfied; 77.44 percentage of students stated that their learning objectives are achieved, and 8.34 percent of students stated that their learning objectives are not achieved; 64.03 percentage of students stated that the assignments are challenging and 18.85 percent of students stated that the assignment is easy; 71.05 students stated that the quality of the material supplied is good and 10.08 percentage stated that the quality of the material supplied is low; 61.84 stated the course is challenging and 23.24 stated that the course is easy; 48.68 stated that the quality of live session is suitable and 38.15 stated that the live session is poor.

6 Recommendations

Our rapid study results highlight several factors that can affect the kind of pedagogy that can be developed to improve future online courses' quality. However, it is crucial to highlight the several limitations of this study, starting with the sample size and, most importantly, the fact that it was conducted online, thus excluding the most vulnerable population who is not interested in participating in the survey.

Thus, there is a need for further in-depth research into COVID 19 on online learning. Based on the survey results and the discussions over the lockdown period amongst educationalists and policymakers, we put together the following recommendations. We do not claim that these results are conclusive, but they help identify alarming trends that need further research.

6.1 For policy makers

- Conduct a detailed review of university/college leadership perspectives, teachers, students, and parents to draw up educated post-COVID19 policies and strategies.
- Establish preparedness and recovery policies and procedures due to the lockdown and missed learning.
- Conduct professional training for teachers and students and the administrative staff on online learning/teaching platforms.
- Conduct technical training on the internet, smartphones, laptops, and tablets to teachers and students.
- Strengthen public, private, and non-formal education alliances and collaborations by establishing inter-institutional networks to exchange experiences with private, public, and deemed universities/colleges, students, teachers, and parents' associations.
- The need to enter into arrangements with private internet providers to provide internet to universities/colleges with concessions.
- Electricity is a crucial necessity for online learning and, thus, education ministries need to work on this issue before such a fundamental right is achieved.
- Guidelines and techniques need to be formulated concerning summative and formative assessments.
- Learn from other organizations' experiences, such as those in other countries that have undergone crises/conflicts and natural disasters, and have built programs to provide emergency education.
- Ensure that the right to quality education, particularly for students in rural and remote areas, is fulfilled by offering alternative solutions that do not rely solely on high technology or access to the internet/electricity and high equipment costs.

- Establish online platforms that are open to a wide range of clients.

6.2 For school leadership, administration, and teachers

- Supporting teachers, students, and parents to deal with the technical and psychological lockdown
- Provide online learning with career development
- Involve the students in planning and assessment
- Provide teachers and students with tablets and laptops and cover any extra expenses incurred by teachers and students due to online teaching and learning.
- Create self-administered online education platforms.

7 Conclusions

Our study's observations and conclusions contribute to two types of implications: practical and theoretical consequences. In a time of abrupt and multiple shifts in the higher education system, the study examines how the educational process took place. A set of valuable recommendations can be outlined to improve the educational process's efficiency in the online learning environment practically. Thus, after a long time of adaptation and familiarization of students and teachers with the online learning environment, it is likely that the educational process's consistency will increase and that the view of students about online learning will be more positive and compatible with the goals of online learning. On a theoretical level, another consequence of our results can be found. A Technology Transformation Model (TTM) regarding the plan to use online learning platforms could be built and improved, starting from the conclusions of the studies conducted before the pandemic. A variety of external variables could also be included in the model and evaluated in the sense of exclusive online teaching and learning.

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Trends of Augmented Reality Applications in Science Education: A Systematic Review from 2007 to 2022

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Abstract—A systematic literature review in the field of augmented reality (AR) in science education was conducted in the study. We performed a content analysis of 319 refereed articles from the Scopus database over the last 15 years (2007-2022). By adopting Cooper's guidelines, trends of AR applications in science education were viewed from various aspects, such as annual scientific growth, the number of authors, most active countries, most prolific journals, most cited articles, and most preferred research methods. The results indicated that: (1) research on AR applications has steadily increased since 2007 and peaked in 2020 and 2021; (2) the majority of publications have two authors followed by three authors and four authors; (3) the countries of the first authors of the AR studies were mostly from the US followed by Taiwan and Turkey; (4) the majority of articles were published by the *Journal of Chemical Education* and *Computers and Education* with 19 and 11 papers, respectively; (5) the most cited papers were written by Dunleavy, Dede, and Mitchell (638 citations), Potkonjak and colleagues (339 citations), and Squire and Jan (300 citations); and (6) more than one-third of the documents employed quantitative methods followed by mixed and qualitative methods. Discussion and suggestions are presented for future studies.

Keywords—augmented reality, science education, systematic analysis, literature review, research trends

1 Introduction

In the last three decades, augmented reality (AR) has been widely used as an interactive technology in various learning and educational settings. One of the most important reasons that AR technology is broadly utilized is that it can be used on various platforms such as desktops, tablets, smartphones, and notebooks. In a study, Klopfer and Squire [1] define AR as "a situation in which a real-world context is dynamically overlaid with coherent location or context-sensitive virtual information" (p. 205). As a popular technology tool, AR is extensively adopted at all levels of education [2]–[6]. Because it is useful for educational purposes, the use of AR has also been examined across disciplines, for example, in physics [4], biology [5], chemistry [6], and mathematics [7]. In general, AR is utilized to make connections between virtual objects and the real environment in order to simplify and clarify the visualization of complex materials [8]. This combination of virtual objects and the real world is referred to as "mixed reality", which was first introduced in the 1990s as a training tool as well as a new approach to education [9]. Since then, AR has continued to receive massive attention and study. However, despite the increasing popularity of AR studies in science education among researchers, understanding of research outputs, author numbers, most productive countries and journals, most-cited papers, and methodological trends of AR research is still limited. Limited understanding in this area may hinder the development of future AR studies. Thus, the current review fills this gap to guide future studies as well as serve as a reference point for AR researchers, policymakers, and educators in the field of science education.

2 Literature review

As a system, Azuma et al. [10] describe three important properties of AR, such as "(a) combines real and virtual objects in a real environment, (b) runs interactively, and in real-time, and (b) registers real and virtual objects with each other" (p. 34). According to the characteristics of the AR system, previous literature reported the main benefits of AR, such as effectively stimulating interest and increasing achievement and motivation to learn science [11][12]. In short, AR has offered potential opportunities for students to see the world around them in new ways thereby providing an engaging learning experience [13][14]. More importantly, AR provides a more realistic learning experience and helps students to be actively involved in authentic explorations in their real-life [15]. Thus, AR is believed to increase understanding of abstract concepts [16], improve spatial cognition abilities [17], reduce cognitive load [4], and make it easier for students to understand context-specific skills and knowledge [18].

As AR is believed to be effective in enriching teaching and learning experiences, literature reviews on the uses of AR have been documented in recent years. For example, Arici et al. [19] conducted content and bibliometric mapping analysis of 79 documents from the Web of Science (WoS) database in the period 2013-2018. The study revealed research trends over the last six years by content analysis and examined bibliometric results of articles related to the uses of AR in science education. Results showed that (i) the most cited journal is Computers & Education, (ii) quantitative design is the most used research method, and (iii) Azuma, Dunleavy, and Klopfer are the most cited authors in this area. Similarly, Tezer et al. [20] reviewed 1008 documents published (2001-2019) in various databases. They found that (i) researchers from the US have the most publications, followed by Taiwan and Germany, (ii) a quarter of publications have two authors, and (iii) qualitative methods are used more frequently than quantitative methods. In another contribution, Sirakaya and Sirakaya [21] reviewed 105 articles published between 2011 and 2016 from ERIC, EBSCOhost, and ScienceDirect databases. They reported that (i) the number of AR studies has increased over the years with a peak in 2016 and (ii) quantitative methods are more frequently adopted in publications, followed by literature review and mixed methods. Altinpulluk [22] reviewed 58 articles published (2006-2016) in 8 reputable journals from the WoS database. The author found that (i) no articles were published in 2006 and 2010, (ii) the most widely used method is mixed-method, followed by quantitative and design-based methods, and (iii) Taiwan has the largest number of publications, followed by the US and Spain. Lastly, Chen et al. [23] reviewed 55 articles published (2011–2016) from the WoS database. They reported that (i) most of the research was published in 2018, (ii) the most productive journals are Computers & Education, followed by Computers in Human Behavior, and Journal of Science Education and Technology, (iii) the Taiwanese researchers contributed the most articles followed by Spanish and US researchers, and (iv) the most frequently employed of research methods is mixed methods, followed by quantitative and qualitative methods.

The aforementioned literature describes in detail the current state of AR use in education; thus, they make a valuable contribution to the trends in this field. When trend research in the previous literature is analyzed [19]−[23], it can be observed that the variables examined are similar to those in this review. However, the current status of the use of AR in science education has not been reported. It should be noted that previous evidence identified AR publications up to 2019. In addition, previous studies indicated that trends and results of studies on AR usage in education, particularly in science education, were unclear. Hence, the current review focuses on applications of AR in science education research published from 2007 onwards. These documents were then analyzed with respect to examined variables, such as annual scientific growth and author numbers. In addition, the most productive countries, most productive journals, most cited papers, and most preferred research methods were examined. It is clear that the increasing volume of empirical studies in AR applications requires a comprehensive and systematic synthesis. Subsequently, a comprehensive review of AR research in science education is addressed. In the existing literature, science education is defined as a discipline related to the teaching and learning of science in schools, colleges, and universities [24]. Science is a field of education where AR technology is frequently adopted. Subjects included in science education are chemistry, biology, and physics. By considering recent peer-reviewed journal articles related to the uses of AR for teaching and learning, the current review aims to complement previous studies and improve the literature on research trends and patterns of AR in science education.

Specifically, this study aims to capture and map the latest trends in usability research in AR in the last 15 years. For this purpose, we performed an extensive literature review. Through this comprehensive systematic review, the current findings are expected to make a valuable contribution to policymakers, researchers, and educators studying the use of AR in science education. Also, it is intended to reveal the results that will shed light on future studies. In order to accomplish this goal, the research questions (RQs) set out in the current study are:

- RQ1: What is the annual scientific growth rate of publications on the topic of AR in science education between 2007 and 2022?

- RQ2: How is the distribution of the documents reviewed with regard to the number of authors in the 2007-2022 period?
- RQ3: Which countries contributed the most to the publications in the academic journals from 2007 to 2022?
- RQ4: Which are the most productive journals publishing articles on the applications of AR in science education between 2007 and 2022?
- RQ5: Which are the most cited articles related to the applications of AR in science education in the 2007-2022 period?
- RQ6: What were the most preferred research methods in articles on the applications of AR in science education from 2007 to 2022?

3 Methods

To address research questions, we conducted a systematic review using content analysis. As stated by Petticrew and Roberts [25], a systematic literature review should "comprehensively identify, appraise and synthesize all relevant studies on a given topic". Specifically, content analysis was used to make repeatable and valid deductions from texts concerning their contents in a particular field [26]. In this review, we then followed Cooper's [27] guidelines to conduct a systematic content analysis; (1) formulate the research problem, (2) collect data, (3) evaluate the data, (4) analyze the data, and (5) present the results. It aimed at presenting a comprehensive overview of the literature on the use of AR in science education.

3.1 Data collection

The search process was carried out in the Scopus database—one of the most prestigious journal article collections—on February 24, 2022. Scopus is a world-class database that includes high-quality journals and holds daily updates enabling the discovery of peer-reviewed articles. The Scopus database was preferred because it provides appropriate data for systematic review purposes. The date range was determined as 2007–2022 at a 15-year interval to ensure that there were sufficient data to analyze research patterns and trends. The year 2007 was chosen as the baseline due to the fact that studies on the use of AR in education began to develop gradually [22]. In the initial search, there were 1573 journal articles found using Boolean commands based on Title-Abstract-Keywords search: "Augmented Reality" AND "Science" OR "Chemistry" OR "Biology" OR "Physics" AND "Education" OR "Learning" OR "Teachers" OR "Students". The review was restricted to English peer-reviewed journal articles. In addition, they had to meet the following inclusion criteria: a) published in a reputable academic journal, b) discussed the application of AR in science education, c) published during the last fifteen years, and d) indexed in the Scopus database. Only articles with access to the full text were included. In this review, the authors set exclusion criteria for the following types of documents: conference paper, conference review, review, book chapter, book, editorial, note, and erratum to accurately identify the final articles. After the initial screening, a total of 461 published papers that met the research criteria were identified. After meeting the inclusion and exclusion criteria, the full text of all articles was then downloaded. The identified articles were read and analyzed to ensure that these articles were truly related to AR in science education. Each paper was checked by all researchers, taking into account the inclusion and exclusion criteria. We further removed any paper that did not meet the inclusion criteria, which was reduced to 319 papers. All articles were analyzed to answer the research questions.

3.2 Data analysis

In the current study, we adopted descriptive content analysis [28] as the analytical method. Content analysis is a method that involves coding, creating meaningful categories, comparing categories and making connections between them, and concluding and interpreting results [29]. This study focused on applications of AR in science education articles published between 2007 and 2022. All selected articles were next analyzed in terms of annual scientific production, author numbers, most cited papers, and nationality of the first author. In previous studies, the first author is seen as the individual who made the most significant intellectual contribution to the design and implementation of the study and development of the paper [30][31]. As such, we awarded one credit point only to the first author in selected papers. Also, the most productive journals and method trends were investigated in this review. For example, the coding scheme for research methods included quantitative, qualitative, mixed, and non-empirical methods.

The screening was based on titles, abstracts, and full texts. A total of 319 articles published from January 2007 to February 2022 were analyzed in the study. In the coding scheme stage, the first and second researchers read each document carefully and then started to code independently. After that, all researchers checked and discussed the inconsistent coding results and negotiated to reach a consensus. The inter-rater coding agreement was found to be 93%. The information obtained from each article reviewed was then inputted and organized through Microsoft Excel according to the research questions. Aiming at analyzing the findings, descriptive statistics were also employed. Frequencies and percentages were presented in graphics and tables.

4 Findings

The current study is intended to map the research characteristics of previous studies investigating AR applications in science education. In this section, we will discuss the findings of the study based on six proposed research questions.

4.1 Annual scientific growth

A total of 319 articles have been published in the Scopus database from 2007 to 2022. To answer the first research question, we analyzed the volume of annual publications in AR research. Figure 1 depicts the number of papers published per year. The annual number of publications is increasing over the past 15 years but with some fluctuations.

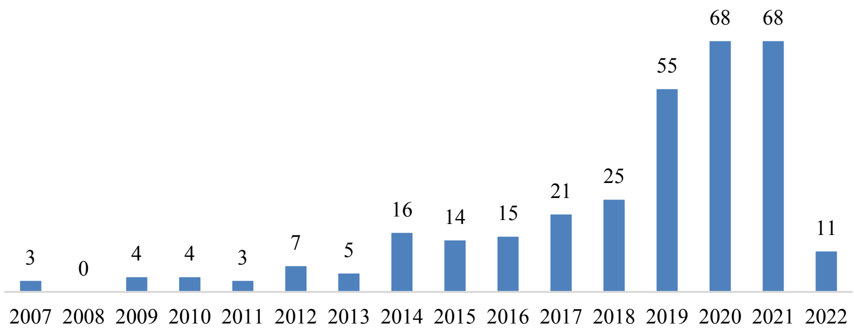

Fig. 1. Frequency of publications in augmented reality

The number of articles by year can be seen in Figure 1. Figure 1 illustrates the trend of publications since 2007. A total of 3 papers were recorded in 2007, indicating the beginning of the growth of publications in the field. No output appeared in 2008, while 2020 and 2021 had the highest productivity with 68 papers each. Since the dataset was taken at the end of February 2022, the number of papers for 2022 was less than for the last 15 years. A significant increase in the number of articles was seen from 2018 to 2020, where 2020 and 2021 were the most productive years. According to Figure 1, 2019 (n = 55), 2020 (n = 68), and 2021 (n = 68) saw a sharp increase in publications. In total, 59.87% of the articles found were from these three years. Compared to 2018 with twenty-five articles, publications in 2020 and 2021 have nearly tripled in both years. Overall, it was observed that there was an increase in the number of AR studies by publication year.

When analyzed by citation (see Figure 2), no citations were reported in 2008 because there were no publications related to AR applications in science education that year. In addition, we found that the highest number of citations occurred in 2014, where 930 citations were recorded. This is closely followed by 2016 with 922 citations and 2009 with 863 citations. A total of 3 articles published in 2007 have been cited 667 times and 68 articles published in 2021 have been cited 77 times to date. Overall, 319 works have been cited 7532 times over time. This explains why there have been many studies on AR applications in the last decade.

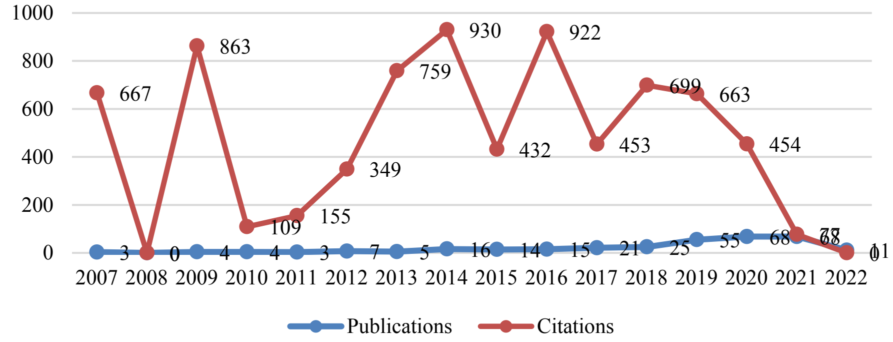

Fig. 2. Publications and citation trends in AR from 2007–2022

4.2 Author numbers

In order to answer the second research question, we examined the annual number of authors in the publication. Figure 3 depicts the change over time in the number of authors.

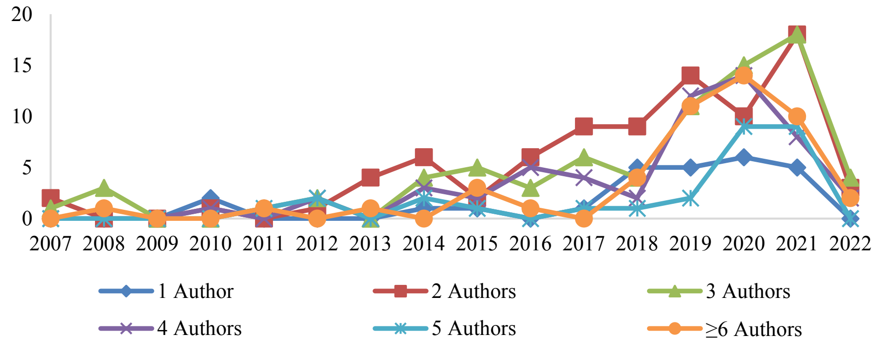

Fig. 3. Number of authors by year

As can be seen in Figure 3, there is also a noticeable increase in the number of collaborations over time. This reflects that there has been an increase in the number of publications on AR applications. With respect to the number of authors, it is worthy to note that only 26 single-author articles were published during this period. In addition, 85 articles have 2 authors with a proportion of 26.65%. This finding indicates that two-author articles were commonly published in this field throughout the year. A total of 77 articles were written by 3 authors. Furthermore, the number of articles with 4 authors experienced a rapid increase between 2018 and 2020. It is important to note that more than half of publications (65.20%) were written by at least 3 authors.

4.3 Top countries in terms of the number of publications

Aiming to respond to the third research question, we summarized the top 15 countries with regard to scientific production (see Table 1).

Table 1. The number of publications by country

Country	Number of Articles	Percentage (%)
United States	57	17.87
Taiwan	39	12.66
Turkey	27	8.77
Malaysia	23	7.47
Indonesia	17	5.52
Germany	17	5.52
Spain	16	5.19
China	11	3.57
Cyprus	7	2.27
South Korea	7	2.27
Australia	6	1.95
United Kingdom	6	1.95
Greece	5	1.62
Chile	4	1.30
Finland	4	1.30
Japan	4	1.30
Mexico	4	1.30
Portugal	4	1.30
Thailand	4	1.30

Based on the analysis, most of the first authors of the studies came from the US (n = 57, 17.87%), Taiwan (n = 39, 12.66%), and Turkey (n = 27; 8.77%). North Carolina State University and the University of Wisconsin–Madison (USA), National Taiwan Normal University and National Taiwan University of Science and Technology (Taiwan), and Ataturk University and Near East University (Turkey) were the most influential institutions. Twenty-three articles (7.47%) came from Malaysia and seventeen (5.52%) from Indonesia. In addition, there were studies from Germany (n = 17; 5.52%), Spain (n = 16; 5.19%), and China (n = 11; 3.57%). Cyprus and South Korea each produced seven articles (2.27%). Meanwhile, Australia and the UK published six articles (1.95%) and Greece published five articles (1.62%). The remaining six countries each published four articles (1.30%). Out of the top 15 countries, 9 countries (e.g., Canada, India, Italy) contributed three articles, 8 countries (e.g., Brazil, Denmark, Hong Kong) contributed two, and 14 countries (e.g., Croatia, Brunei, Bulgaria) contributed one. Of the 50 countries contributing to the articles, the studies came predominantly from Asia (n = 117; 36.68%), Western Europe (n = 77; 24.14%), Northern America (n = 60; 18.81%), and Middle East (n = 36; 11.29%). Besides, there were 12 articles that studied AR in Eastern Europe (3.76%) which was slightly more than the 11 studies that took place in Latin America (3.45%). These six locations were followed by Pacific Region (n = 6; 1.88%).

4.4 The most productive journals

Scientific journals that publish applications of AR in science education are identified. In order to address the fourth research question, we summarized the top 15 common relevant sources of AR (see Table 2).

Table 2. Top 15 most productive journals

Journal	*N*	Publisher
Journal of Chemical Education	19	American Chemical Society
Computers and Education	11	Elsevier
Journal of Science Education and Technology	9	Springer
International Journal of Emerging Technologies in Learning	9	Kassel University Press
Interactive Learning Environments	9	Taylor and Francis
Biochemistry and Molecular Biology Education	8	Wiley-Blackwell
Education Sciences	7	MDPI
Journal of Educational Computing Research	6	SAGE
International Journal of Interactive Mobile Technologies	6	Kassel University Press
Educational Technology and Society	6	National Taiwan Normal University
Physics Education	5	IOP Publishing
Eurasia Journal of Mathematics, Science and Technology Education	5	Modestum
Educational Technology Research and Development	5	Springer
Applied Sciences (Switzerland)	5	MDPI
Computers in Human Behavior	5	Elsevier

It is observed that the Scopus database has accommodated 164 journals that publish articles related to AR applications in science education. When the findings are examined, the most productive journals were *Journal of Chemical Education* with 19 publications (5.96%), followed by *Computers and Education* with 11 publications (3.45%), and *Journal of Science Education and Technology, International Journal of Emerging Technologies in Learning,* and *Interactive Learning Environments* with 9 publications each (2.82%). It reflects that these journals frequently published documents on the subject. Also, our analysis indicates that there were fewer AR user studies published in *Physics Education, Eurasia Journal of Mathematics, Science and Technology Education, Educational Technology Research and Development, Applied Sciences (Switzerland),* and *Computers in Human Behavior* (5 documents each, 1.57%). In the remaining sources, 4 journals have 4 papers, 8 journals have 3 papers, 27 journals have 2 papers, and 110 journals have 1 paper. Among the top 15 most productive journals, a total of two journals each owned by Elsevier, Springer, Kassel University Press, and MDPI. In contrast, American Chemical Society, Taylor and Francis, Wiley-Blackwell, SAGE, National Taiwan Normal University, IOP Publishing, and Modestum owned one journal, respectively.

4.5 The most cited papers

In order to address the fifth research question, we visualized the most cited studies in the field of AR in science education (see Table 3).

Table 3. Top 10 most cited publications

Authors	Title	Year	Journal	Citations
Dunleavy M., Dede C., & Mitchell R.	Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning	2009	Journal of Science Education and Technology	638
Potkonjak V., Gardner M., Callaghan V., Mattila P., Guetl C., Petrović V. M., & Jovanović K.	Virtual laboratories for education in science, technology, and engineering: A review	2016	Computers and Education	339
Squire K. D. & Jan M.	Mad city mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers	2007	Journal of Science Education and Technology	300
Kamarainen A. M., Metcalf S., Grotzer T., Browne A., Mazzuca D., Tutwiler M. S., & Dede C.	EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips	2013	Computers and Education	271
Squire K. & Klopfer E.	Augmented reality simulations on handheld computers	2007	Journal of the Learning Sciences	257
Wojciechowski R. & Cellary W.	Evaluation of learners' attitude toward learning in ARIES augmented reality environments	2013	Computers and Education	257
Ibáñez M. -B. & Delgado-Kloos C.	Augmented reality for STEM learning: A systematic review	2018	Computers and Education	250
Chiang T. H. C., Yang S. J. H., & Hwang G. -J.	An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities	2014	Educational Technology and Society	244
Cai S., Wang X., & Chiang F. -K.	A case study of Augmented Reality simulation system application in a chemistry course	2014	Computers in Human Behavior	221
Akçayir M., Akçayir G., Pektaş H. M., Ocak M. A.	Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories	2016	Computers in Human Behavior	216

According to Table 3, the most cited paper was written by Dunleavy, Dede, and Mitchell in 2009 [8], with a total of 638 citations and an average of 53.16 citations per year. It was followed by the work of Potkonjak and colleagues [32] with 339 citations within 5 years and Squire and Jan [33] with 300 citations. Specifically, this article focused on how middle and high school teachers and students understand the ways in which participating in an AR simulation aids or hinders the teaching and learning process. The second most cited article in this area was Potkonjak et al. [32]. This review article aimed to look at new technologies that can overcome some of the potential difficulties in the teaching of science, technology, and engineering. Interestingly, the document published by Ibáñez and Delgado-Kloos [34] was cited 250 times within less than 3 years. This review article overviewed the use of AR technology to support student learning in science, technology, engineering, and mathematics (STEM)-related subjects. Without a doubt, STEM education has come to be the concern of researchers and educators around the world recently [35]. The other valuable publications in this area were Kamarainen et al. [36], Squire and Klopfer [37], Wojciechowski and Cellary [38], Chiang et al. [12], Cai et al. [39], and Akçayir et al. [2]. When examined by country, data analysis informed that the top ten publications belonged to the US (n = 4), Serbia, Poland, Taiwan, Spain, China, and Turkey (1 article each).

4.6 The most preferred research methods

The latest research questions are visualized in Figure 4. Figure 4 presents the change over time in the research method by year.

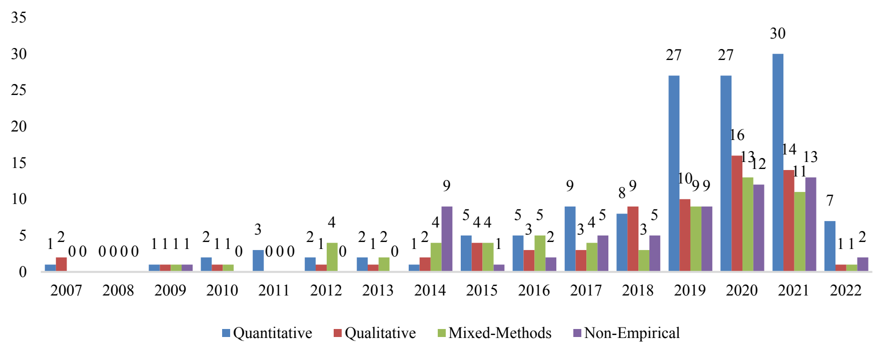

Fig. 4. Change in research method by year

When the research methods used in reviewed studies were examined, of the 319 studies, the most popular method used was quantitative (n = 130; 40.75%). The second most popular method was mixed methods (n = 68; 21.32%). Then, 19.44% of the articles adopted a qualitative approach (n = 62) and 18.50% preferred non-empirical research (n = 59). Figure 4 reflects the non-empirical approach gradually increased in the 2015-2021 period. However, the non-empirical approach still has the lowest ratio among all approaches. In 2019, the most widely employed research method in selected documents was quantitative design. Since 2020, the number of articles using qualitative or mixed methods started to decrease, while the number of articles using the quantitative method increased. In relation to the distribution of research methods over the years, quantitative design has been used throughout [6][35].

5 Discussions and implications

Within this section, we provided the research status and the development trend of future AR research from the perspective of academic research. When analyzed by the chronological evolution of research, the number of research literature shows a considerable growth tendency between 2007 and 2022. The current findings are in line with previous evidence [20][22][40]. For example, Akçayır and Akçayır [41] conducted a systematic review of the literature on AR used in educational settings from 2007 to 2015 and found an increase in the number of AR studies during the last four years. In a bibliometric study, Karakus et al. [42] also identified 437 publications related to AR in education between 1999 and 2018 and reported that the number of publications increased gradually after 2011 with a peak in 2017. Thus, the current review enriched the existing literature. A possible reason for increasing outputs during this period is the widespread use of AR through mobile devices. Nowadays, learning through mobile AR is becoming increasingly popular because of the small form of mobile devices and their ability to allow students to move freely while studying [43]. As an ideal platform for AR applications, previous evidence also claimed that mobile devices are very cost-effective and easy to use and offer a high level of social interactivity and independent operability [44]–[46]. Recently, Statistia [47] also released an increase in the number of mobile devices worldwide between 2020 and 2025. This systematic review implied that AR research has improved significantly over the years, fueled by the interest and attention of AR academics. Taking this trend into account, we predict that research interest in this area will continue intensely in 2022 and beyond.

With regard to author numbers, two-author papers accounted for almost a third of publications. In fact, the majority of publications were written by at least three authors. The result demonstrates that AR has attracted the attention of researchers and the research community as technological advances offer convenience for teachers and students in teaching and learning science. Given this pattern, it is likely that this research trend will continue in the coming year. In addition, this topic will be more interesting in the future as the number of research collaborations increases. The current findings are also supported by a study conducted by Dey et al. [48]. They systematically reviewed 10 years of the most influential AR user studies between 2005 and 2014 and reported that the average number of authors for each paper was 3.24. In a similar way, Tezer et al. [20] analyzed studies in AR applications published between 2001 and 2019 using meta-analysis methods. Of the 1008 articles, they concluded that a quarter of the publications (25.8%) had 2 authors and nearly 60% of the publications had at least 3 authors. This indicates that these papers are the result of collaborative research among researchers. Abramo and D'Angelo [49] claimed that articles written by more than one author have the potential to increase their visibility and impact. Thus, the current systematic review suggested that cross-country and cross-cultural research collaborations should be enhanced to play an important role in optimizing AR studies and dissemination in the future.

In relation to the prolific countries, the US outnumbers all the other countries with respect to the number of publications. Taiwan and Turkey are also among the top 15 countries whose contribution to the AR field has an essential influence. These three countries played a key role and account for more than a third of the total outputs of AR technology in science education. Unfortunately, there were no studies from African countries. Thus, there was a gap in the growth of publications among countries. It implies that more research from different countries is definitely needed. In this context, Avila-Garzon et al. [50] also reported that the US and Taiwan were in the top three productive countries in AR publications between 1995 and 2020. The findings are similar to those of the study conducted by Altinpulluk [22] and Buchner et al. [40]. This is a natural result of the long-term investments made by these countries in technology and education. When analyzed by region, Asian countries have the highest number of publications. This result is consistent with the findings of Altinpulluk [22] and Hedberg et al. [43], which noted that Asia is more dominant than Europe and America in terms of publication volume. We predict that countries that invest more in technology will benefit in a number of ways, particularly in education. As revealed by Pathania et al. [51], AR is an interactive technology that will bring massive changes to science education by providing a better and more effective environment. Therefore, the results of this review can stimulate science educators and other fields around the world to adopt AR technology in their teaching and learning.

In terms of the most productive journals, *Journal of Chemical Education* and *Computers and Education* topped the rankings. They were the most prolific journals on the use of technology in science education between 2007 and 2022. The results corroborate the findings of a study conducted by Karakus et al. [42]. The scope of these top journals indicates that the AR concept is widely studied in the field of science education during this period. The results of the analysis suggest that technology-related journals are dominant in AR publications. As the most productive resource in this review, *Journal of Chemical Education* published the most articles on AR. Founded in 1924, this journal has published numerous works on the applications of technology (e.g., software, media) to support the teaching and learning of chemistry at various levels of education. In addition, *Computers and Education*, founded in 1976, is highly committed to publishing papers focusing on the use of digital technology to improve education in general. Moreover, these two prestigious journals published peer-reviewed articles more than 12 times per year. This is a possible reason why these leading journals dominated research trends and were superior to other academic journals.

Regarding the most influential papers, the work of Dunleavy, Dede, and Mitchell [8], published in 2009, stands out as the most cited paper among the reviewed documents. This suggests that Dunleavy and his colleagues authored the most-cited studies in the field. As we know, Dunleavy is probably the leading author on AR in the literature. This result is in line with the findings of Avila-Garzon et al. [50], who noted that Matt Dunleavy is among the most cited authors in the field of AR in education over the past 25 years. Of the top 10 papers reviewed, most were from the US. It can be concluded that researchers from the US have made a significant contribution to this topic.

Surprisingly, the manuscript of Ibáñez and Delgado-Kloos [34] from Spain, which tends to be new in terms of year of publication, is ranked seventh in terms of total citations based on our dataset. This implies that this work has a major impact on AR applications in science education. In sum, researchers from developed countries have made valuable contributions to AR studies in science education. These researchers have significantly promoted the field and demonstrated consistency by contributing to the body of research in this area.

With regard to the distribution of research methods, the use of quantitative designs increased in recent years, especially between 2014 and 2021. This suggests that quantitative research methods are used more frequently than other research methods. The finding obtained in this review is supported by the literature. For instance, Arici et al. [19] conducted a bibliometric analysis of 147 articles related to the use of AR in science education in the period 2013-2018 from the WoS database. They reported that 81% of the documents employed quantitative design and only 6% preferred review or meta-analysis research. This is confirmed by Buchner et al. [40], who stressed that quantitative approaches are preferably employed in the period 2007-2019.

In the context of educational technology, quantitative studies generally evaluate the success of intervention when applied to a group of students in a particular setting. A possible reason why quantitative methods are often adopted may be related to the fact that the potential of AR technology in science education is well documented. For example, using AR has a positive influence on enthusiasm [6], academic achievement and spatial intelligence [7], STEM interest [35], and attitudes [5]. This implies that there are numerous research studies in the literature that investigate the effect of AR applications on student learning quantitatively. Another reason why quantitative designs are mostly employed in educational AR studies may be related to the familiarity of the scholars and researchers with quantitative methods and the wide acceptance of quantitative approaches than others [4]–[6]. This explains why there is a lot of research on AR technology adopting a quantitative approach. Therefore, the widespread use of quantitative designs is not surprising. Accordingly, there is an urgent need for more qualitative, mixed, and non-empirical studies in the future to bridge this gap. This literature review will serve as a reference for current and future researchers, policymakers, and practitioners involved in science education.

6 Conclusions

The current review presented a comprehensive view of the previous studies and offered some possible directions for researchers for further AR studies. A total of 319 papers were evaluated, encompassing annual scientific outputs, number of authors, most productive countries, most prolific journals, most cited articles, and most preferred research methods. It was found that the number of articles on AR applications in science education is increasing rapidly, and the field is gaining momentum. The peak is in 2020 and 2021. In terms of the number of authors, articles with two authors predominate in AR studies. Regarding the most productive countries, the United States, Taiwan, and Turkey are the three leading countries in publications on AR in the field of science education. In relation to the most productive journals, *Journal of Chemical Education, Computers and Education, Journal of Science Education and Technology, International Journal of Emerging Technologies in Learning,* and *Interactive Learning Environments* are among the most important journals publishing documents on AR in science education. It is well known that the authors with the most cited papers in the field of AR are Matt Dunleavy, Chris Dede, and Rebecca Mitchell with 638 citations, followed by Veljko Potkonjak and colleagues with a total of 339 citations and Kurt Squire and Mingfong Jan with 300 citations. From a methodological perspective, quantitative methods are the most frequently used but there have been only a limited number of non-empirical studies in the last 15 years. Therefore, it can be said that the results of the current review are important to guide future studies in this area and can be used as a reference for all stakeholders.

7 Limitations

This work has shed light on the status and trends of AR literature in science education. However, the current review is limited to documents published in the Scopus database; thus, the results of the current study may not represent the trends and developments of AR applications in science education. We recommend searching for relevant articles from other databases, such as WoS, ERIC, Google Scholar, and ProQuest in order to generate more representative data. Then, only articles published from the year 2007 onward and in English were included in this study; consequently, the literature search process may not identify all of the published articles over time. Since we only involved peer-reviewed journal articles, future researchers need to analyze conference papers, editorials, books, book chapters, theses, and dissertations. In addition, future studies may be able to combine bibliometrics and meta-analysis to present the findings as comprehensively as possible.

8 References

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Determinants of Zoom Fatigue Among Graduate Students of Teacher Education Program

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Abstract—Videoconference applications gained popularity when online learning became the new way of delivering instruction at all levels of education including graduate programs. However, excessive videoconferencing led to reports of fatigue among its users. Identifying the factors contributing to the videoconference exhaustion experience of graduate students is necessary. This study examined Zoom fatigue and selected associated factors among graduate students. An electronic one-shot survey using the Zoom Exhaustion and Fatigue scale was conducted among 109 graduate students of the College of Teacher Education in the Philippines. Correlation and predictive analysis were performed. Results of the study demonstrated a moderate level of Zoom fatigue with the highest level of fatigue in the general fatigue dimension. Pearson's correlation analysis revealed a significant inverse correlation between attitude toward videoconferencing and Zoom fatigue. Non-verbal mechanisms of mirror anxiety, feeling physically trapped, hyper gaze, and cognitive load in producing non-verbal cues were significantly positively related to Zoom fatigue. Regression analysis revealed that the sense of being physically trapped and cognitive load in producing non-verbal cues remained significant predictors of Zoom fatigue. While videoconferencing supported educational activities and made schooling possible during the global disease outbreak, it is recommended to be mindful of the non-verbal factors contributing to Zoom fatigue.

Keywords—graduate students, teacher education, videoconferencing, Zoom fatigue

1 Introduction

Recently, there has been a growing recognition and usage of virtual distance education and remote learning [1]. The rapid transition to online learning in all levels of education, including the graduate program during the global coronavirus disease outbreak, resulted in a boom in videoconference applications use [2, 3]. It has been observed that participants of videoconference tools like Zoom increased by 2900 percent during the global outbreak of coronavirus disease [4]. Zoom was one of the fastest-growing and leading videoconferencing software during the pandemic because it was free and easy to use [4, 5].

Videoconferencing applications have many advantages and have been an essential tool for work, school, and social interaction because of their ability to resemble face-to-face conversations seamlessly [5, 6]. Videoconferencing permits participants from different places to participate in live audio-visual communication and collaboration [7]. However, like any technology, there are also concerns about videoconferencing tools [5, 8]. Because of the rapid transition to the new platform, many universities focused on the technical aspect of technology and did not give attention to the basic understanding of the pedagogy in this new learning space [9]. A new phenomenon of feeling tired and exhausted during virtual meetings of spending hours on video chat platforms dubbed as Zoom fatigue began to emerge [6, 10]. Zoom fatigue is posited as part of a larger experience of exhaustion with computer-mediated communication [11]. And given the Zoom application has become a very common videoconferencing software, it has been used to replace videoconferencing. However, it must be noted that Zoom fatigue is synonymous with videoconferencing fatigue or exhaustion experienced with any videoconferencing software [5, 10].

Meanwhile, there is also a growing body of evidence on Zoom meetings' likely negative physical and psychological consequences [12-15]. Overuse of technology has resulted in technostress affecting physical and mental health [16]. Several reasons have been hypothesized why videoconferencing applications are said to be more psychologically demanding. These include the novel experience of the very close proximity to facial images and a greater need to concentrate during video calls [17]. For Stanford University researchers, they hypothesized that non-verbal mechanisms specific to videoconference use contribute to fatigue with Zooming [5, 18]. Personal, organizational, technological, and environmental factors have also been identified as possible causes of fatigue during videoconferencing [7].

Given that this new phenomenon appeared only recently with the pandemic and early research on Zoom fatigue mainly was conducted abroad, there is growing research regarding the exhaustion that is linked with virtual meetings. There is a need to explore Zoom fatigue in the educational context, particularly among graduate students, as online remote learning is likely to play a substantial role in teaching and learning beyond the pandemic [2, 19]. Evidence shows that students find it harder to focus and are often less responsive during online synchronous Zoom classes, which undesirably affects the nonverbal dynamics in online courses [20]. Identifying and addressing the factors contributing to the videoconference exhaustion and fatigue experience of graduate students is necessary. This study determined the level of Zoom fatigue among graduate students in the Philippines. This study also tried to examine if attitude toward virtual meetings and non-verbal factors are significantly associated with Zoom fatigue in the context of graduate teacher education.

2 Methods

2.1 Research design, participants, and data gathering

We used a quantitative, cross-sectional research design for this study. A-priori sample size calculator for multiple regression was utilized to determine the minimum required sample size (n=97) for a multiple regression study given .05 desired probability level, 6 number of predictors in the model, .15 anticipated effect size, and 80% desired statistical power level. A total of 109 graduate students of the College of Teacher Education in one government-funded university in the Western Visayas region of the Philippines were included in the analysis of this study. Inclusion criteria for the study were: a) officially enrolled graduate students of the college, b) currently on their course-work, c) attending online classes in the graduate program, d) reported more than one hour of video calls during online classes, and e) agreed to participate in the study. We excluded those who were writing their thesis or dissertation and reported less than an hour duration of videoconferencing during their graduate classes. The school granted administrative clearance for this academic research applying the principles of research ethics. We administered the electronic survey using Google Forms in March 2022. The link to the survey was sent to the registered email addresses of the students and was also posted on the official social media accounts of the college. Respondents had to give electronic consent before answering the actual surveys. Following the Data Privacy Act of the country, respondents were assured of their anonymity and the confidentiality of their responses.

2.2 Measures

The Zoom Exhaustion and Fatigue (ZEF) scale was adopted as the primary research instrument for this study. Researchers from Stanford University developed the ZEF scale as a valid and reliable measure for Zoom fatigue [10]. The scale is composed of 15-items with five dimensions having three items for each dimension, namely: general fatigue, social fatigue, emotional fatigue, visual fatigue, and motivational fatigue. The items on the scale are measured on a 5-point Likert-scale ranging from 1 = "Not at all" to 5 = "Extremely," except for the two frequency questions from 1 = "Never" to 5 = "Always." Higher scores indicate higher levels of fatigue. Evaluation of the psychometric properties of the ZEF scale found good internal consistency [10, 21]. The ZEF scale for this study had high internal reliability with a Cronbach's alpha = .94. A three-item Likert-scale was adopted to assess attitude toward videoconferences [10]. The responses ranged from 1 = "Not at all" to 5 = "Extremely". We also adopted measures to assess the five non-verbal mechanisms specific to videoconference use [18]. First, mirror anxiety was measured by three items on a 5-point Likert-scale from 1 = "not at all" to 5 = "extremely" to assess how self-viewing while videoconferencing would associate with Zoom fatigue. Second, the sense of being physically trapped was measured by three items on a 5-point Likert scale from 1 = "never"/ "not at all" to 5 = "always"/ "extremely" to examine how limited physical mobility imposed by the need to be in front of the camera while video conferencing would associate with Zoom fatigue. The third mechanism of hyper gaze was measured by a single-item scale on a 5-point Likert from 1 = "never" to 5 = "always" to investigate the perceived gaze of constantly having peoples' eyes in your field of view. The other two nonverbal mechanisms are related to the increased cognitive load of managing (producing and interpreting) nonverbal cues were assessed by single items answerable on a 5-point Likert scale from 1 = "not at all" to 5 = "extremely." We also collected the demographic profile (age, sex, marital status, degree program) of students.

2.3 Data analysis

Analysis of data gathered was done using IBM SPSS version 26. Frequency, percentage, mean, and standard deviation were used for univariate analysis, and Pearson's r was utilized for correlation analysis. Multiple linear regression using the enter method was employed to identify predictors of Zoom fatigue. A p-value of less than .05 was considered statistically significant.

3 Results

The demographic profile of the respondents is shown in Table 1. The average age of the respondents was 28.77 years old, 82.6% were female, and 74.3% were single. There were 75.2% master's degree students and 24.8% doctoral students.

Table 1. Demographic profile

Profile	f	%
Age [Mean=28.77 (SD=7.58]		
Sex		
Male	19	17.4
Female	90	82.6
Marital status		
Single	81	74.3
Married	28	25.7
Degree program		
Master's	82	75.2
Doctoral	27	24.8

Table 2 shows that respondents generally had a positive attitude toward videoconferences with a mean of 3.76 (SD=.62). Among the non-verbal mechanism, respondents reported a high sense of feeling physically trapped during videoconferences (M=3.79, SD=.63), moderate levels of cognitive load in producing (M=2.96, SD=1.10), and interpreting (M=2.95, SD=.90) non-verbal cues in computer-mediated communication, and an average level of mirror anxiety (M=2.86, SD=.82) and hyper gaze from a grid of starring faces (M=2.57, SD=.98).

Table 2. Attitude and non-verbal mechanisms

Variables	Mean	SD
Attitude toward videoconferences	3.76	.62
Non-verbal mechanisms		
Sense of being physically trapped	3.79	.63
Cognitive load in producing non-verbal cues	2.96	1.10
Cognitive load in interpreting non-verbal cues	2.95	.90
Mirror anxiety	2.86	.82
Hyper gaze from a grid of starring faces	2.57	.98

It can be gleaned on Table 3 that respondents generally reported a moderate level of Zoom fatigue with an overall ZEF score of 3.37 (SD=.79). Based on the ZEF subscales, respondents reported a high level of general fatigue (M=3.80, SD=.73), visual fatigue (M=3.61, SD=.96), motivational fatigue (M=3.51, SD=.97), and moderate levels of social (M=3.11, SD=1.16), and emotional fatigue (M=2.81, SD=1.06).

Table 3. Level of Zoom fatigue

Zoom fatigue and subscales	Mean	SD
General	3.80	.73
Visual	3.61	.96
Motivational	3.51	.97
Social	3.11	1.16
Emotional	2.81	1.06
ZEF score	3.37	.79

Correlational statistical analysis (Table 4) using Pearson's r revealed a weak inverse correlation but significant (r=-.301, p=.001) between attitude toward videoconferencing and Zoom fatigue. Non-verbal mechanisms of cognitive load in producing non-verbal cues (r=.397, p=.000), sense of being physically trapped (r=.386, p=.000), hyper gaze from a grid of starring faces (r=.320, p=.001), and mirror anxiety (.240, p=.012) showed weak to moderate significant positive correlation with Zoom fatigue.

Table 4. Correlation of attitude and non-verbal factors to Zoom fatigue

Variables	Pearson's r	p-value
Attitude	-.301	.001
Non-verbal mechanisms		
Cognitive load in producing non-verbal cues	.397	.000
Sense of being physically trapped	.386	.000
Hyper gaze	.320	.001
Mirror anxiety	.240	.012
Cognitive load in interpreting non-verbal cues	-.104	.284

The multiple regression analysis (Table 5) revealed that when the six independent variables were entered into the regression model, the sense of being physically trapped (B=.379, p=.001) and cognitive load in producing non-verbal cues (B=.156, p=.044) remained significant predictors of Zoom fatigue explaining 30.4% of the variance in Zoom fatigue.

Table 5. Regression analysis of Zoom fatigue predictors

Variables	B	t	p-value
(Constant)	2.107	2.702	.008
Sense of being physically trapped	.379	3.478	.001
Cognitive load in producing non-verbal cues	.156	2.044	.044
Attitude	-.175	-1.514	.133
Mirror	.082	.878	.382
Hyper gaze	.065	.769	.444
Cognitive load in interpreting non-verbal cues	-.129	-1.741	.085

R Square = .304, F = 7.419, p = .000

4 Discussion

This study examined Zoom fatigue in graduate teacher education. We demonstrated in this research that graduate students generally had a moderate level of Zoom fatigue. Virtual platform communication is more mentally exhausting than traditional face-to-face communication [22]. While a high fatigue level was reported among undergraduate nursing students [23], comparable levels of fatigue were noted in the Stanford study [18], among Indonesian university students [14], and Filipino teachers [8]. Approximately 41-56% prevalence of Zoom fatigue was reported among medical school students in Brazil [19]. We also noted in this research that graduate students experienced the highest level of fatigue in the general fatigue domain, followed by the visual fatigue domain, a similar finding from the study of undergraduate students [23] and faculty and school administrators [8, 12]. Steps to lessen the fatigue experienced in video calls in graduate education may be made, such as better video conference management and technical improvements in videoconferencing applications [24]. Nevertheless, it is important to acknowledge that meetings generally can be pretty tiring regardless of the medium [5].

This research also noted that among the five nonverbal factors, the sense of being physically trapped is the most significant predictor of Zoom fatigue. This result replicates the findings of prior studies based abroad and locally [8, 12, 18]. Zoom users need to stay within the camera's field view resulting in reduced mobility when sitting down and staring straight ahead for most of the time during videoconferencing [5]. Being non-responsive when attending synchronous Zoom classes can exacerbate fatigue symptoms and decrease learning capacity and attention [25]. Moreover, cognitive load in producing non-verbal cues predicted higher levels of fatigue. This finding corroborates that of the Stanford study result [18]. Cognitive load in creating non-verbal cues was also found to be correlated with Zoom fatigue in studies conducted in the Philippines [8, 12]. Users of Zoom need to work harder to send nonverbal signals contributing to higher levels of fatigue [5]. A qualitative study also noted themes that Zoom fatigue causes stress and increases mental and cognitive load [15].

We also demonstrated in this research that hyper gaze and mirror anxiety were significantly correlated with Zoom fatigue which corroborates prior research results [8, 18]. In this study, a higher level of hyper haze was associated with greater levels of Zoom fatigue. In Zoom and other video conferencing platforms, people get front-on views of all other people for hours consecutively, and the amounts of close-up eye contact can be intense [5]. Additionally, this study also found that a higher level of mirror anxiety was linked to higher fatigue. It has been explained that staring at oneself can result in negative self-focused attention. In other words, seeing a mirror image of oneself for several hours in a virtual meeting can likely lead to self-evaluation that can be stressful [5, 26].

This study also found that while not a significant predictor, a more positive attitude toward videoconferences was significantly correlated with lower levels of Zoom fatigue. Similar findings were found in other studies conducted in other countries [10,18] and among undergraduate students and teachers in the Philippines [8, 23]. Perhaps, the tiring and exhausting experience during videoconferencing influenced these two related variables. Students' negative attitudes and acceptance of online learning have also been recorded [27, 28]. Understanding the role of attitudes is important because it may influence the strength of intention and acceptance of videoconferencing platforms in the future [29, 30].

Nonetheless, the authors of this study acknowledge limitations in this research that could influence the generalizability and reliability of findings, which future works may address. First, this study only involves a sample of graduate students in teacher education in one university in the Philippines. Also, while the study was able to examine associations between variables, the cross-sectional design has temporal limitations. Likewise, the research design cannot establish a causal effect between the variables tested in this study. Moreover, bias in self-report measures in the use of questionnaires and the need for a more robust psychometric evaluation of measures to assess nonverbal factors [18] may have also influenced the result of our study. Despite these limitations, our research adds to the body of knowledge on the understanding of Zoom fatigue in graduate education. This research will be useful in informing the design and implementation of effective strategies against the unintended negative effects of technology use [6].

5 Conclusion

This study highlights an overall moderate level of fatigue associated with the use of videoconferencing tools among graduate students. Moreover, the present study generally supports previous research on the association of attitude toward videoconferences and the role of non-verbal mechanisms specific to the use of virtual conferences on Zoom fatigue experience. While videoconferencing applications have been beneficial and supported educational activities during the global disease outbreak, it is recommended to be mindful of the non-verbal factors that contribute to Zoom fatigue and know how to optimize the current videoconferencing features to help minimize the exhaustion during virtual meetings. For instance, having short breaks between a series of Zoom calls, turning one's video off periodically during meetings, or turning on the video only when necessary can be good ground rules during videoconferencing or virtual sessions. The findings of this study contribute to the growing literature on Zoom fatigue and can serve as a basis for crafting policies regarding videoconferencing application use in higher educational institutions.

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Training Mode and Quality View of High-Class Talents

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Abstract—Building a sound system for assessing the training quality of high-class talents with talent introduction as the target is helpful for effectively analyzing the training mode of high-class talents in colleges and universities and discovering the underlying problems and weak links, thereby further optimizing the current mode, and improving the training level of high-class talents in the region. However, existing papers generally focus on macroscopic research of the training quality of high-class talents, so this paper attempts to study the training mode and quality view of high-class talents under the intervention of talent introduction policy. At first, this paper elaborated on the strategies for adjusting the training mode of high-class talents under the intervention of talent introduction policy, gave a diagram of the research model, and assessed the quality view of colleges and universities for talent training using four selected evaluation indexes, including solid knowledge base, independent research ability, rich practical ability, and sound personality and career outlook. Then, to figure out the changes in the training quality of different high-class talent training modes under the intervention of talent introduction policy, this paper built a high-class talent training quality prediction model based on Gated Recurrent Units (GRU) deep neural network, and gave the statistics of the prediction results of high-class talent training quality in the experiment. At last, this paper compared the differences in the quality view of high-class talent training of different colleges and universities under the intervention of talent introduction policy.

Keywords—talent introduction, high-class talent training, training quality, training mode, quality view

1 Introduction

As human society has entered an era of knowledge economy, now the economic activities have transcended borders, and world countries and regions have formulated various talent introduction policies to compete for high-class talents [1-5]. Via researching and sorting out these high-class talent introduction policies, we can better understand the changing features of student training modes of colleges and universities under the intervention of these policies [6-11], predict and analyze the optimization direction of the student training view of these schools to cope with the development trend of regional economy, thereby enriching the regional policies for introducing high-class talents and improving the decision-making level of high-class talent introduction, therefore, it is of certain value to research the training mode and quality view of high-class talents under the intervention of talent introduction policy [12-14]. Building a sound system for assessing the training quality of high-class talents with talent introduction as the target is helpful for effectively analyzing the training mode of high-class talents in colleges and universities and discovering the underlying problems and weak links, thereby further optimizing the current mode, and improving the training level of high-class talents in the region.

Academic contests are important means to examine the teaching ability of colleges and universities and the application ability of students. In order to effectively improve the training quality of students, Li [15] took academic contests in local application-oriented undergraduate colleges and the application of industrial robots in the e-commerce logistics as subjects to study the role of academic contests in promoting the deep integration of production and education, in the hopes of driving comprehensive transformation and developing application-oriented colleges so that they could better serve the local economy and society. Lin and Geng [16] proposed and implemented a multi-party collaborative education (MPCE) model of in-depth cooperation between universities, enterprises, research institutions, industry organizations, and governments, the paper suggested that the systemic, synergistic, and complete policies are crucial to the training quality of high-class talents. Ju and Rao [17] pointed out that contemporary college students pay more attention to actively showing high level moral standards and noble personalities, while ignore the mid and low level moral standards, and the personalities they are showing are incomplete; therefore, emphasis should be laid on the education of mid and low level moral norms, and rational spirit and values. Self-learning ability, teamwork ability and practical operation ability are core competencies for graduates majoring in computer network technology in higher vocational schools, Bi and Xu [18] analyzed the current situation in the training of high-class application-oriented internet technology talents, and proposed a training mode for this type of talents based on their core competitiveness. The developing higher education in China has put forward higher requirement for the comprehensive quality of talents, to respond to this requirement, Zhang and Dong [19] studied the topic of introduction and training of high-class talents in colleges and universities, discussed the main content of human capital, expounded the necessity, existing problems, and research methods of this topic, and analyzed the attained conclusions; the research revealed that, for the introduction of high-class talents in colleges and universities, there is still a big room for improvement, and this conclusion laid a good foundation for future studies on the construction of faculty teams in colleges and universities. Special economic zones in China closely follow the pulse of the times, relying on high-end research institutions and high-tech industries, they have formed an innovative high-class application-oriented talents training mode participated by multiple parties including governments, universities, and industrial enterprises, Zhou et al. [20] discussed the situations and problems of the newly emerging characteristic colleges and gave some suggestions for the promotion of this type of colleges.

After carefully reviewing the research results of world field scholars, we found that existing studies generally focus on the macroscopic research of the training quality of high-class talents, most of them are qualitative research on the current situation, training necessity, and training strategies of high-class talents. Few of them have concerned about the analysis of the quality view of high-class talents or the specific influencing factors under the intervention of talent introduction policy. Thus, to fill in this research blank and provide data support and useful evidences, this paper researched the training quality of high-class talents of colleges and universities under the intervention of talent introduction policy, and the content of this paper includes these aspects: 1) The paper elaborated on the strategies for adjusting the training mode of high-class talents under the intervention of talent introduction policy, gave a diagram of the research model, and assessed the quality view of colleges and universities for talent training using four selected evaluation indexes, including solid knowledge base, independent research ability, rich practical ability, and sound personality and career outlook. 2) To figure out the changes in the training quality of different high-class talent training modes under the intervention of talent introduction policy, this paper built a high-class talent training quality prediction model based on GRU deep neural network. 3) This paper gave the statistics of the prediction results of high-class talent training quality, compared the differences in the quality view of high-class talent training of different colleges and universities under the intervention of talent introduction policy, and verified the effectiveness of the constructed model.

2 Strategies for adjusting the training mode of high-class talents under the intervention of talent introduction policy

In terms of the factors in the organizational structure, people are the most active factor in enterprises and institutions, and talents are the biggest resource for these units. The introduction of high-class talents plays a decisive role in the smooth and sustainable development of enterprises and institutions. For units who have not handled the talent management work well, there will be many unfavorable factors in their development process. Only after experiencing the process of talent introduction, cultivation, growth, and maturity, can they develop better, accelerate the merging of talents and the units, and promote them to grow together. For talents and units (enterprises/institutions), if there're great differences in their employment standards, the reasonable flow of talents becomes a necessity for the development of both parties, otherwise it will cause waste of human resources and affect the sustainable, stable, and healthy development of enterprises and institutions. Whether an enterprise or institution can introduce good talents depends on three aspects: first, whether the leadership of the units is aware of the role of talent introduction and whether they are willing to introduce high-class talents; second, whether the human resource department has the vision to identify talents suitable for the units; third, whether the units have a good environment to retain high-class talents. If enterprises and institutions pay more attention to talent introduction and recruit high-class talents from colleges and universities, then they can realize sustainable and stable development.

Figure 1 gives a diagram of the research model. As can be seen in the figure, for different types of talents, there are certain differences in the training mode of high-class talents in colleges and universities. For example, for academic type, engineering type, technical type, and skill type talents, the training content involves the lecturing of professional knowledge, the training of analytical ability in specialized fields, the proficient use of tools, and the familiarity with relevant regulations and policies; as for literary type and management type talents, the training mode is to ensure that the talents could master the knowledge and skills in a specific field.

The "high class" of talents is a complete system. The quality view of talent training in colleges and universities generally contains these aspects: solid knowledge base *EQ1*, independent research ability *EQ2*, rich practical ability *EQ3*, and sound personality and career outlook *EQ4*. These require the talents to have certain professional quality, sense of belonging in profession, ideological and political quality, psychological quality, cultural and technological quality, and physical quality, etc.

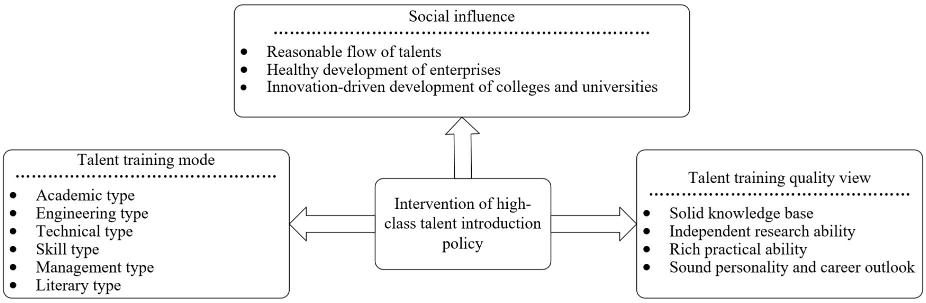

Fig. 1. The research model

3 Prediction of training quality of high-class talents

To figure out the changes in the training quality of high-class talents under different training modes with the intervention of talent introduction policy taken into consideration, this paper built a high-class talent training quality prediction model (hereinafter referred to as "prediction model" for short) based on GRU deep neural network. When running the constructed prediction model, the reset gate and update gate of the network determine the sample data information of the hidden layer at the current moment, and the update gate of the network determines whether the sample data information of the network at the next moment will be transmitted to the memory of the current moment; the greater the value output by the update gate, the larger the sample data information volume that the network is allowed to pass down at the next moment. The forgetting of the sample data information at the next moment is determined by the reset gate of the network, the smaller the value output by the reset gate, the larger the sample data information volume been forgotten by the network at the next moment. Figure 2 gives a diagram of constructed neuron network model.

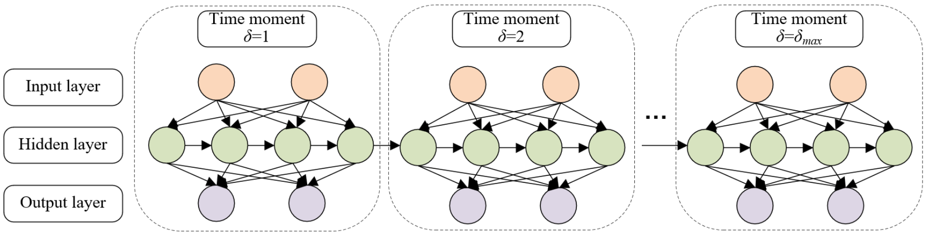

Fig. 2. The constructed neuron network model

Formula 1 gives the calculation formula of the activation f^j_δ of the j-th neuron node in the hidden layer at current moment δ; the value is calculated based on the linear interpolation of the activation $f^j_{\delta-1}$ at the next moment and the candidate activation $\dot{f}^j_\delta$:

$$f^j_\delta = \left(1 - c^j_\delta\right) f^j_{\delta-1} + c^j_\delta \dot{f}^j_\delta \tag{1}$$

During the update and iteration process of the network hidden layer, the update gate memorizes and forgets the sample data at the same time. The more feature information of the sample data retained in memory, the closer the value output by the update gate is to 1; the more feature information of the sample data that is selected to be forgotten, the closer the value output by the update gate is to 0. The update gate memorizes and forgets the sample data at the same time, assuming: Q_s, V_s, Q, V, Q_c, V_c, Q_b represent weight coefficients; n represents the number of input layer nodes of the unit; r represents the number of hidden layer nodes of the unit; m represents the number of output layer nodes of the unit; $Q \in R^{n\times r}$ and $V \in R^{r\times r}$ represent the connection matrices from the input layer and the hidden layer at time moment δ-1 to the state to be activated f; $Q_s \in R^{n\times m}$ and $V_s \in R^{r\times r}$ represent the connection matrices from the output layer and the hidden layer at time moment δ-1 to the reset gate c; $Q_b \in R^{r\times m}$ represents the weight matrix of the structural transformation calculation from the *GRU* unit hidden layer to the output layer; ε represents the *sigmoid* activation function, then Formula 2 gives the calculation formula of the update gate c^j_δ:

$$c^j_\delta = \varepsilon\left(Q_c a_\delta + V_c f_{c-1}\right)^j \tag{2}$$

Assuming: Ψ represents the *tanh* activation function; $\oplus$ represents the *Haadamard* product; s_δ represents the reset gate group; then Formula 3 gives the calculation formula of unit candidate activation $\dot{f}^j_\delta$:

$$\dot{f}^j_\delta = \Psi\left[Qa_\delta + V\left(s_\delta \oplus f_{\delta-1}\right)\right]^j \tag{3}$$

Formula 4 gives the calculation formula of reset gate s^j_δ:

$$s^j_\delta = \varepsilon\left(Q_s a_\delta + V_s f_{\delta-1}\right)^j \tag{4}$$

Based on the activation f_δ at current moment, the output value of the network can be calculated:

$$b_\delta^j = \varepsilon\left(Q_b f_\delta\right)^j \tag{5}$$

In above formula, weight coefficients Q_s, V_s, Q, V, Q_c, V_c, Q_b are all parameters attained by the trained network model, then Formula 6 gives the network loss function at time moment δ:

$$D_\delta = \frac{1}{2}\left(b_{e,\delta} - b_\delta\right)^2 \tag{6}$$

The expression of the sample loss is:

$$D = \sum_{\delta=1}^{T} D_\delta \tag{7}$$

Let $\xi^b{}_\delta=\partial D/\partial GRU^b{}_\delta$, $\xi^c{}_\delta=\partial D/\partial GRU^c{}_\delta$, $\xi_\delta=\partial D/\partial GRU^f{}_\delta$, $\xi^s{}_\delta=\partial D/\partial GRU^s{}_\delta$, wherein the input of the corresponding activation function satisfies $GRU^b{}_\delta=Q_b f_\delta$, $GRU^c{}_\delta=Q_c a_\delta+V_c f_{\delta-1}$, $GRU^s{}_\delta=Q_s a_\delta+V_s f_{\delta-1}$, $GRU^f{}_\delta=Qa_\delta+V(s_\delta \oplus f_{\delta-1})$, then there is:

$$\xi_\delta^f = \frac{\partial D}{\partial_\delta^f} = \xi_\delta^b Q_b + \xi_{\delta+1}^b V_c + \xi_{\delta+1} \oplus Vs_{\delta+1} + \xi_{\delta+1}^s V_s + \xi_{\delta+1}^f \oplus \left(1 - c_{\delta+1}\right) \tag{8}$$

Assuming: ε' and $\Psi'=tanh'$ represent the derivatives of activation functions, then after adjusted by the stochastic gradient descent method, the expressions of the network weight coefficients are:

$$\xi_\delta^b = \left(b_e - b_\delta\right) \oplus \varepsilon' \tag{9}$$

$$\xi_\delta^c = \xi_\delta^f \oplus \left(f_\delta^\% - f_{\delta-1}\right) \oplus \varepsilon' \tag{10}$$

$$\xi_\delta = \xi_\delta^f \oplus c_\delta \oplus \Psi' \tag{11}$$

$$\xi_\delta^s = f_{\delta-1} \oplus \left[\left(\xi_{f,\delta} \oplus c_\delta \oplus \Psi'\right) V\right] \oplus \varepsilon' \tag{12}$$

The weight gradient expressions are:

$$\frac{\partial D}{\partial Q_c} = \xi_\delta^c a_\delta \tag{13}$$

$$\frac{\partial D}{\partial V_c} = \xi_\delta^c f_{\delta-1} \tag{14}$$

$$\frac{\partial D}{\partial Q}=\xi_{\delta}a_{\delta} \tag{15}$$

$$\frac{\partial D}{\partial Q}=\left(s_{\delta}\oplus f_{\delta-1}\right)\xi_{\delta} \tag{16}$$

$$\frac{\partial D}{\partial Q_b}=\xi_{\delta}^{b}f_{\delta} \tag{17}$$

$$\frac{\partial D}{\partial Q_s}=\xi_{\delta}^{s}a_{\delta} \tag{18}$$

$$\frac{\partial D}{\partial V_s}=\xi_{\delta}^{s}f_{\delta-1} \tag{19}$$

For the output data attained from the calculation of forward propagation of input sample data, its difference with the actual sample data was calculated to get the network calculation error. The network weight matrix was constrained by the learning rate of key parameters of the network, and the prediction performance of the network was improved through a certain number of iterations.

This paper adopted an improved firefly algorithm to optimize the constructed network model. Under the intervention of talent introduction policy, the changes in the high-class talent training quality view exhibited a certain regularity. The random walk model has been successfully applied in many fields such as finance, computer science, and environmental science, it can help us explore and study the change laws and development directions of the high-class talent training quality view under the intervention of talent introduction policy. Assuming: A_i represents the random walk step size constructed for different random distributions; R_M represents the continuous summation of A_i; then Formula 20 gives the expression of the random walk *Lévy* flight model selected in this paper:

$$R_M=\sum_{i=1}^{M}A_i=A_1+...+A_M \tag{20}$$

Formula 21 gives another expression form of this model:

$$R_M=\sum_{i=1}^{M-1}A_i+A_M=R_{M-1}+A_M \tag{21}$$

According to above formula, the R_{M-1} at the current moment and the transfer amount A_M at the next moment together determine the R_M at the next moment. Formula 22 gives the calculation formula of the random walk step size of *Lévy* flight:

$$r=\frac{v}{|u|^{1/\zeta}} \tag{22}$$

In above formula, random numbers v and u obey normal distribution and they satisfy:

$$v \sim M\left(0, \varepsilon_v^2\right), u \sim M\left(0, \varepsilon_u^2\right) \tag{23}$$

where,

$$\varepsilon_v = \left\{ \frac{\Phi(1+\zeta) sin(\pi\zeta / 2)}{\Phi\left[(1+\zeta)/2\right] \zeta 2^{(\zeta-1)/2}} \right\}^{1/\zeta}, \varepsilon_u = 1 \tag{24}$$

When the step size factor of the firefly algorithm takes a small value, in the early iteration stage of the algorithm, the movement speed of individual fireflies slows down, which will affect the search progress of the optimal solution; on the contrary, if the step size takes a large value, in the later iteration stage of the algorithm, the distance between individual fireflies is too small, which will result in oscillations near the optimal solution, and the accuracy of the optimal solution will be affected. Assuming: s_i^* represents the distance from the i-th firefly individual to the brightest individual s^* in the firefly population; e_{max} represents the maximum distance between firefly s^* and other individuals in the population; β represents the step size factor of standard firefly algorithm, then Formula 25 gives the expression of dynamic step size:

$$\beta_I = \beta \cdot \frac{s_i^*}{e_{max}} \tag{25}$$

The prediction accuracy and training efficiency of the prediction model are greatly affected by the initial weight of the network, and the optimal weight matrix is mainly related to the number of neuron nodes in each layer. Since the number of features of the evaluation data of high-class talent training quality had been determined already, the numbers of neuron nodes in each layer corresponding to the weight matrix were determined as well. This paper took the number of hidden neuron nodes in the prediction model and the network learning rate as the optimization objects, and applied the improved firefly algorithm to search for optimal solution iteratively. The position information corresponding to the firefly individual with the highest brightness output by the algorithm was the optimal combination result of the number of hidden neuron nodes and the network learning rate (Figure 3).

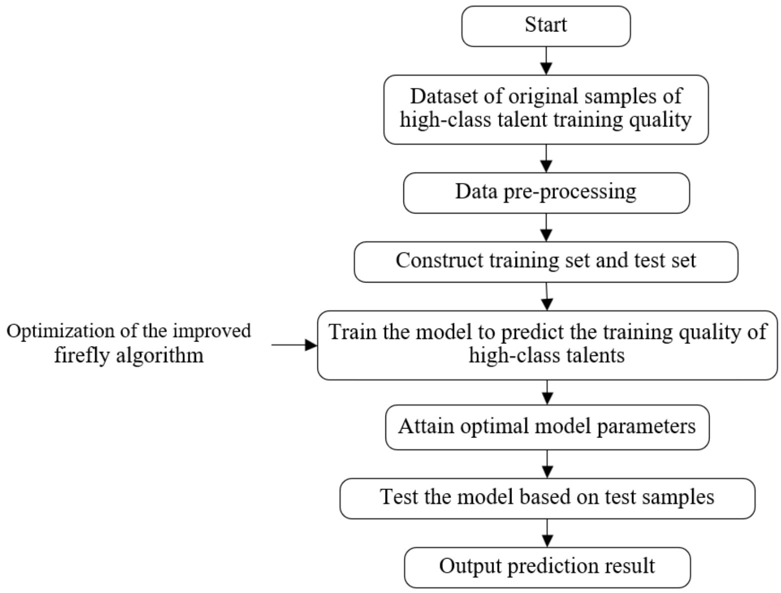

Fig. 3. Flow of the optimized neural network model

4 Experimental results and discussion

Table 1 shows the statistics of the prediction results of training quality of high-class talents. According to the data in the table, the average value of the current status of the quality view of high-class talent training was 67.63, which was close to the theoretical median value of 68, indicating that the quality view of colleges and universities for high-class talent training was close to the ideal effect. Among the four dimensions of *EQ1*, *EQ2*, *EQ3* and *EQ4*, the average value of *EQ4* was 13.68, which was greater than the theoretical median value of 12, indicating that the high-class talents had complete and healthy personality and positive career outlook, but in terms of knowledge base, research ability, and practical ability, there's still big room for improvement.

By default, the high-class talent introduction policy follows the "accelerated-stabilized" response law. Figure 4 shows the time-series distribution of the response to high-class talent introduction policy. According to the figure, after the study region had issued the high-class talent introduction policy, the policy quickly spread among enterprises and institutions, and the response speed was fast. In this paper, the responses of seven colleges and universities to the high-class talent introduction policy during the study period were compared, on the whole, the responses of different schools showed a stable state.

Table 1. Statistics of prediction results of training quality of high-class talents

Variable	*EQ*1	*EQ*2	*EQ*3	*EQ*4	Training quality
Number of items	5	3	6	9	17
Minimum	13	8	5	9	13
Maximum	22	25	21	27	23
Average	16.25	12.84	16.39	13.68	67.63
Mean of each item	4.68	3.92	3.27	3.05	3.68
Standard deviation	2.05	2.74	2.69	2.38	8.53
Theoretical median	17	13	19	12	68

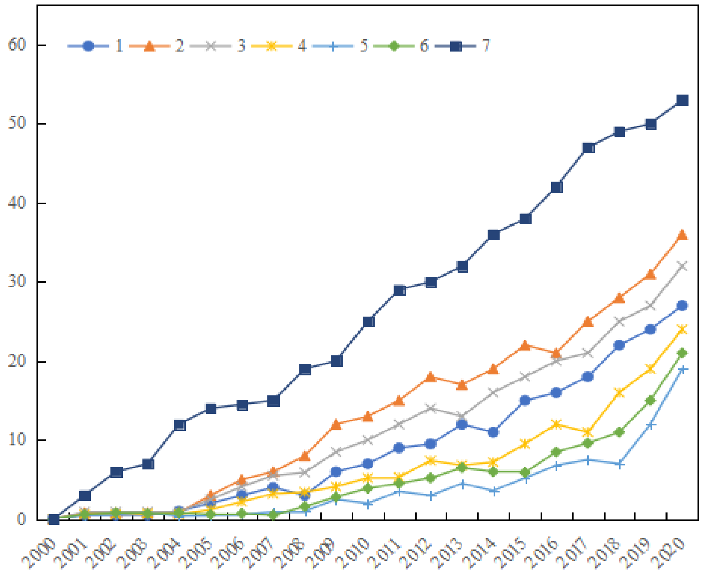

Fig. 4. Time-series distribution of response to high-class talent introduction policy

This paper selected seven colleges and universities for research. Figure 5 shows the cumulative number of adjustments on the high-class talent training mode made by the seven schools under the intervention of talent introduction policy over time. As can be seen from the figure, for schools that responded fast to the high-class talent introduction policy, the cumulative numbers of adjustments on the high-class talent training mode were much greater than other schools. Schools of this type generally located in economically developed coastal areas, the regional development platform for high-class talents is broader, and the preferential conditions guaranteed by the talent introduction policy are more attractive in the eyes of high-class talents, which has further promoted the update of high-class talent training mechanism in these schools. As for schools that responded slower to the policy, they generally located in economically underdeveloped areas and haven't paid enough attention to the introduction of high-class talents, which has resulted in insufficient training platform and resources, and the update of high-class talent training mechanism is slow.

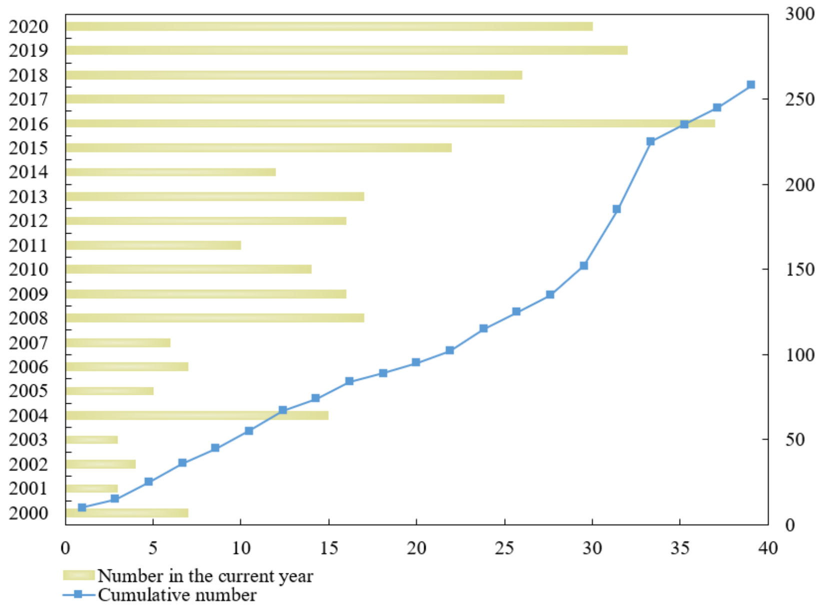

Fig. 5. Spatial distribution of response to high-class talent introduction policy

The total number of evaluation data samples participated in the research was 167, wherein 55, 57, and 55 samples were respectively from Schools 1, 2, and 3. One-way variance analysis was adopted to study whether students of different grades have significant differences in the four aspects of knowledge base, research ability, practical ability and sound personality and career outlook, and the variance analysis results are given in Table 2. Judging from the results, the significance values of the four test variables of students from different schools under the intervention of talent introduction policy were all greater than 0.05, indicating that under the intervention of talent introduction policy, there's no significant difference in the quality view of these colleges and universities in training students of different grades, and post hoc comparison was not necessary. Compared with the training mode of focusing on the research ability of a single discipline or the mastery of a single skill, under the intervention of talent introduction policy, colleges and universities should emphasize more on the improvement of students' practical ability and the shaping of professional ethics and values in them, and such a training mode has a long-term beneficial effect on students, to a certain extent, it is the reason for the small difference in the quality view of high-class talent training in different grades.

Table 2. Comparison of test variables in terms of the quality view of high-class talent training

Test variable	School No.	Number of samples	Average	Standard deviation	*F*-test	Significance
*EQ*1	1	55	15.36	2.15	1.43	0.36
	2	57	13.25	3.62		
	3	55	12.95	1.84		
*EQ*2	1	55	15.42	2.98	1.39	0.31
	2	57	19.15	3.37		
	3	55	13.62	2.05		
*EQ*3	1	55	18.23	3.24	0.38	0.74
	2	57	15.04	2.61		
	3	55	19.26	2.48		
*EQ*4	1	55	14.28	2.37	0.29	0.72
	2	57	16.19	2.24		
	3	55	17.42	3.69		

5 Conclusion

This paper studied the training mode and training quality view of high-class talents under the intervention of talent introduction policy. At first, this paper elaborated on the strategies for adjusting the training mode of high-class talents under the intervention of talent introduction policy, gave a diagram of the research model, and assessed the quality view of colleges and universities for talent training using four selected evaluation indexes, including solid knowledge base, independent research ability, rich practical ability, and sound personality and career outlook. Then, to figure out the changes in the training quality of different high-class talent training modes under the intervention of talent introduction policy, this paper built a high-class talent training quality prediction model based on GRU deep neural network. After that, via experiment, this paper gave the statistics of the prediction results of high-class talent training quality, and compared the differences in the quality view of high-class talent training of different colleges and universities under the intervention of talent introduction policy. In the later part, this paper gave the time-series distribution and spatial distribution of the response to high-class talent introduction policy, and compared the differences in the quality view of high-class talent training among different colleges and universities under the intervention of talent introduction policy, and attained the conclusion that, compared with the training mode of focusing on the research ability of a single discipline or the mastery of a single skill, under the intervention of talent introduction policy, colleges and universities should emphasize more on the improvement of students' practical ability and the shaping of professional ethics and values in them.

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Digital Teaching Competence of University Teachers: Levels and Teaching Typologies

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Abstract—Today, university teachers need to have not only basic digital skills, but to be able to use technologies in teaching-learning processes, in their professional development and that of their students. This article focuses on analysing digital teaching competence (DTC), and exploring its dimensions based on the self-perception of a sample of 558 teachers from a Spanish university, following the European DigCompEdu framework. According to the results, university teachers perceive themselves to have an intermediate level of DTC. Technical and professional aspects were higher than the pedagogical ones and those that refer to the effect on student's digital competence. The ANOVA test did not show significant differences in DTC according to the academic position, but it did according to the scientific area. One of the most significant findings is that the DTC would not be a unitary construct; after the factorial analysis of the items, three categories were obtained that can constitute different teaching typologies: the inspiring teacher, the creator and the tutor. This study provides a new instrument to explore university teachers' level of DTC. Although this study is an exploratory one, it contributes to the debate on this competence by exploring the categories that underlie it, providing data that can be useful both at a scientific level and in the development of practices and policies for teaching improvement.

Keywords—digital competence, higher education, self-assessment, teacher training, didactic competence, professional development

1 Introduction

The use of information and communication technologies (ICT) in education has been a common practice on university campuses and classrooms for decades. In recent years, universities have stepped up their efforts, through institutional initiatives fostering digital transformation [1], to incorporate these technologies as means to modernise the management of their training processes and introduce innovation [2]. At the same time hybrid and flexible learning environments are becoming increasingly common [3]. The period of lockdown established in 2020 due to the COVID-19 pandemic and the subsequent gradual return to teaching activity has highlighted, more than ever, the need for higher education institutions to have sufficient technological resources and, above all, the need for digital training for all members of the educational community [4]. Many authors and international institutions have stressed the importance of adequate digital competence among teachers [5]. However, despite the importance of this issue, the volume of literature dealing with this subject in higher education is significantly lower than that covering the pre-university level [6]. As highlighted in previous research [7], it is very relevant to have more investigations that analyse in-depth the level of digital competence of university teachers. University teaching staff is a highly heterogeneous group, both in terms of areas of specialisation and professional categories, in contrast to previous levels of education. Furthermore, and especially in universities with a Napoleonic tradition [8] such as the one in which this study is placed; there is an even wider variety in terms of teaching staff. In this specific type of university, the teaching staff also has a dual role of teacher and researcher, between which there is not always an appropriate balance [6]. The above situation impacts on selection processes as well as on teachers' career development. This further highlights the need to explore in-depth digital teaching competence (DTC), as well as possible differences between teachers, which is often considered in most studies as a unitary construct. This information is not only of interest in scientific terms, but also allows educational institutions to design and implement teacher training strategies for an increasingly digital world [9]. The purpose of this study is to provide a new instrument to explore university teachers' perception of their level of DTC that can be useful for teachers themselves and their professional development. Based on the described research gap above, this study seeks to contribute to the debate on this competence by exploring the teaching categories that underlie it and providing data about the level held by higher education teaching staff.

1.1 Digital competence and digital teaching competence

[10] defined digital competence as the set of skills, knowledge and attitudes required when using digital technologies in an effective, efficient, critical or creative way, whether for work, learning, leisure or participating in society. It is a competence identified as key [11], which everyone should develop throughout their training [12]. In addition to this generic digital competence for any citizen, different authors have highlighted the importance of digital competence in the field of teaching [13], [14], [15]. In this regard, digital teaching competence (DTC) comprises the set of skills, knowledge and attitudes required by teachers to promote student learning, in a digitally rich world, by designing and transforming classroom practices and enriching their own professional development [16].

[17] distinguished several different areas or dimensions that make up DTC, namely, (1) basic digital skills, i.e. information, communication or technological aspects; (2) competence in using ICT in teaching; and (3) lifelong learning strategies. In addition to these three major areas, other authors have also added, as part of the teachers' digital teaching competence, the capacity to empower their students and exercising their social commitment as educators [14], [18], as well as the ability to develop their students' own digital competence. There are also other frameworks that, at the institutional level and

in different contexts, have attempted to define this digital teaching competence [19], [20], such as the ISTE's teacher standards [21] or UNESCO's ICT competence standards for teachers [22]. Different countries have also promoted their own frameworks, such as the Chilean model [23], the British model known as DigiLit [24] or, in Spain, the Common Framework for Digital Competence for Teachers (Marco Común de Competencia Digital Docente) of the National Institute of Educational Technologies and Teacher Training (Instituto Nacional de Tecnologías Educativas y de Formación del Profesorado) [25]. More recently, for Europe, we find the European Framework for the Digital Competence of Educators (DigCompEdu), designed by the European Commission’s Joint Research Centre (JRC) [26], which defines this competence in six areas: (1) professional engagement, which includes both collaborative work, communication, and professional and reflective development; (2) digital resources, i.e. their selection, creation, modification or management; (3) teaching and learning, which includes aspects of teaching, support, and collaborative and self-directed learning; (4) assessment, which includes strategies for evaluation, evidence analysis and feedback; (5) empowering learners, which incorporates aspects of accessibility and inclusion, personalised learning and active participation; and (6) facilitating learners' digital competence. This will be the framework that we will take as a reference in this study. According to [27], it was designed to fit the contexts of the different European countries and is sufficiently generic to allow it to be adapted to the different levels of education.

1.2 The digital teaching competence of university teachers

In a previous related work [7] a systematic review of the literature was conducted, providing a detailed account of the current status of DTC in university teaching staff. In relation to the level of DTC among university teachers, according to various studies, the vast majority of them rate themselves as having a medium or medium-high level in terms of their basic or technical digital skills [28], [29], [30]. This dimension includes skills related to the use of office automation tools, browsers and tools for sending files or communication by email. However, the educational use of social tools to communicate, or the capacity for multimedia audiovisual editing tends to reflect lower values [31], and even arouses certain reservations among teaching staff [32]. Similarly, lower scores are also observed in aspects related to security, data protection or the management of intellectual property [29]. Furthermore, some research has shown that, although teachers may have adequate technical skills, they are often inferior to those of their students [33]. With regard to pedagogical competence in the use of ICT, the levels achieved tend to be more varied. While some studies show that teaching staff have adequate competence in the design of online activities [34] or in the educational use of digital resources in teaching-learning processes [35], other research presents evidence running in the opposite direction. [36] or [37] showed that university teachers have low capacities for designing learning experiences enriched by digital tools, or for monitoring and assessing students through ICT. Likewise, [29] pointed out that teaching staff have low levels of use of ICTs for their own professional development, highlighting, for example, the lack of knowledge of online professional forums and networks, and the scant use of repositories or spaces for exchanging teaching innovation experiences. In a similar vein, [35] pointed to the low level of knowledge and maintenance of their personal learning environments (PLE) by teaching staff. As regards the ability of teaching staff to develop the digital competence of their students, although a large number of university teachers believe that they encourage the use of ICTs among their students through collaborative work, online environments or by making use of bibliographic databases [38], there is a shared belief that students enter university with sufficiently developed digital competence and do not see the need to work on it in class [32]. In addition to the analysis of DTC according to the areas or dimensions it is made up of, several studies also analyse the differences that exist according to the type of university teacher. [39] showed that teachers in lower professional categories –assistant lecturers, assistants and associate lecturers –and with ages between 35 and 45, rate their level of competence higher than members of teaching staff with higher categories –senior lecturers and full professors –and are older (55-65). They also found significant differences in terms of the area of knowledge. According to these same results, university teachers in the Technical or Engineering field and Humanities have a higher level of self-perceived digital competence than those in the Social Sciences [39]. [38] analysed possible differences according to gender, age or teaching category, the only differences in the level of DTC being found exclusively according to age.

1.3 Research questions

This is an exploratory study and we have no prior hypothesis. This article attempts to answer the following research questions:

- What is the self-perceived level of DTC among university teachers?
- Are there any differences in teachers’ DTC according to their professional category?
- Are there any differences in teachers’ DTC according to the field of knowledge?
- What are the categories that underlie university teachers' DTC?

2 Method

2.1 Participants

This study was carried out during the academic year 2019-2020 at a medium-sized Spanish university. A non-probabilistic sampling was carried out and participants were selected by convenience sampling [40]. A total of 558 university teachers participated in it (48% women), which represents a sampling error margin of 4.5 and a reliability index of 99%. The average age of the teaching staff participating in the study was 45.6 years (SD = 9.42), with ages ranging from 24 to 68 years. In terms of professional categories, the following distribution was presented: full professors, 9.6%; senior lecturers, 28.1%; contract lecturers (PhD), 13.2%; postdoctoral assistant lecturers and pre-postdoctoral researchers, 18.8%; and associate lecturers, 30.3%. As regards the area of knowledge, the following distribution was observed: sciences, 12.9%; health and behavioural sciences, 10.8%; engineering and architecture, 21.1%; law and economics, 19%; social sciences, 19.5%; and arts and humanities, 16.7%. The study was approved by the University's Ethics Committee and participation was voluntary, after signing an informed consent document outlining its purpose and assuring confidentiality.

2.2 Instruments

To collect the data, a self-perception questionnaire was designed for the university teachers, developed online with the LimeSurvey tool and hosted on a university server (available at XXXXXX). The design of the questionnaire was based on the European DigCompEdu framework [26], as well as on the versions developed by the JRC in the DigCompEdu Check-In and the CRUE (Conference of Spanish University Rectors), all of which were adapted to the context of the university itself. In addition to a first section in which the biodata were collected, the questionnaire had 22 items evaluated with a Likert-type scale from 1 (never) to 5 (always).To ensure that the items were understood by the potential users, two focus groups were organised (6-8 members per group), one with specialised teaching support staff and the other with university teachers. After these sessions, the wording of some items in the questionnaire was modified and it was administered to a pilot group of 61 university teachers, from the different areas of knowledge, obtaining a high reliability index (α= .94), according to Cronbach's alpha.

2.3 Analysis of the data

First, the basic descriptors (frequencies, means and standard deviations) of the different items and areas of the questionnaire were calculated. To compare the means among the different professional categories and among the areas of knowledge, an analysis of variance test (ANOVA) was performed. In the case of the areas of knowledge, the Tukey post-hoc test was carried out to determine which groups had significant differences between them. Finally, a factorial analysis was carried out with all the items of the questionnaire in order to explore previously unknown grouping of variables to seek underlying clusters [41] and the resulting categories were rotated using the varimax method to facilitate their interpretation. In addition, the KMO measure of sampling adequacy and the Bartlett sphericity test were run to determine the adequacy of the factor analysis. The IBM SPSS v. 25 software package was used to perform all the analyses in this study.

3 Results

3.1 The digital teaching competence of university teachers

According to the results obtained (Table 1), the university teachers obtained an overall average of 3.7 out of 5 (SD = .75) on their DTC, considering themselves to be close to "quite" competent. If we analyse the mean values of the constituent areas, it can be seen that the teaching staff perceived themselves to be more competent in everything related to their professional engagement (M = 4.19, SD = .68). The areas of digital resources (M = 3.87, SD = .87), teaching and learning (M =3.75, SD = .90) and assessment (M = 3.82, SD = .96) lay in an intermediate position. The areas with lower scores, and greater dispersion in the results, had to do with empowering learners (M = 3.30, SD = 1.0) and facilitating their digital competence (M = 3.23, SD = 1.0), areas in which the average university teacher only considered themselves competent "sometimes".

Table 1. Percentage distribution and descriptive results of DTC

Items	1	2	3	4	5	M(SD)
1. Professional engagement (PE)						4.19(.68)
1. Digital communication	.2	.2	5.0	24.4	70.2	4.64(.60)
2. Collaborative work with ICTs	2.2	5.0	10.8	26.3	55.7	4.28(.99)
3. Critical reflection on ICTs	2.0	5.9	26.0	35.1	31.0	3.87(1.9)
4. Digital professional development	1.6	7.0	21.3	33.0	37.1	3.97(1.0)
2. Digital resources (DR)						3.87(.87)
5. Location and selection	.4	3.1	10.3	31.8	54.4	4.37(.82)
6. Creation of resources	5.9	11.8	22.9	29.9	29.5	3.65(1.2)
7. Sharing open contents	7.5	14.2	20.0	28.8	29.5	3.59(1.3)
3. Teaching and learning (T&L)						3.75(.90)
8. Planning digital teaching	2.2	7.1	21.4	33.6	35.7	3.93(1.0)
9. Tutoring and interaction	1.3	6.3	17.3	33.3	41.8	4.08(.98)
10. Fostering collaborative learning	5.0	14.1	21.5	35.0	24.4	3.60(1.2)
11. Encouraging reflection	7.1	18.0	24.1	28.2	22.6	3.41(1.2)
4. Assessment (A)						3.82(.96)
12. Using ICTs in evaluation	3.5	10.3	15.6	32.4	38.2	3.92(1.1)
13. Collecting digital evidence	4.6	12.7	23.7	30.4	28.6	3.66(1.2)
14. Using ICTs for feedback	2.8	9.4	20.6	32.2	35.0	3.87(1.1)
5. Empowering learners (EL)						3.30(1.0)
15. Tools for accessibility	10.2	17.0	24.3	27.4	21.1	3.32(1.3)
16. Personalised learning	10.4	18.7	26.6	27.5	16.8	3.22(1.2)
17. Fostering digital participation	7.9	15.5	27.6	28.1	20.9	3.39(1.2)
6. Facilitating learners' DC (FLDC)						3.23(1.0)
18. Facilitating information	6.6	12.8	27.5	29.6	23.5	3.51(1.2)
19. Facilitating communication	10.4	18.9	23.9	28.2	18.6	3.26(1.3)
20. Facilitating the creation of contents	20.2	23.7	22.1	19.8	14.2	2.84(1.3)
21. Facilitating well-being & security	15.5	21.4	24.9	23.1	15.1	3.01(1.3)
22. Facilitating problem solving	7.8	13.2	24.8	29.4	24.8	3.50(1.2)
Digital teaching competence (DTC)						3.70(.75)

Table 1 also shows the frequency of each of the items that make up the different areas, as well as their mean score and standard deviation. More than 94% of university teachers always or very frequently (values 4 or 5) use different digital channels to communicate with their students and, similarly, more than 82% do so to work with other colleagues. Similarly, more than 86% always or almost always use different internet sites to select digital resources. However, and in this same dimension of digital content, about 22% never or hardly ever (values 1 or 2) share them by considering the possibility of using open licenses. As regards teaching and evaluation, more than 75% of the teaching staff interact and conduct tutoring in collaborative environments and over 70% of them use different evaluation tools. In contrast, only 25% rarely or never encourage students to use ICTs to reflect on their own learning. As for the items in the two areas with the lowest scores, around 50% of the teaching staff always or nearly always encourage active and creative student participation through digital media or teach students how to search for information and critically evaluate it. However, about 30% of university teachers never or hardly ever use ICTs to provide students with personalised learning opportunities. Finally, around 40% never or hardly ever design activities for their students to encourage them to create contents, nor do they teach their students to use ICTs in a healthy, safe and responsible manner. These two items had the lowest mean scores in the whole questionnaire, with 2.84 and 3.01 respectively.

3.2 Comparison of means in digital teaching competence

Firstly, we analyse the differences in teachers' DTC depending on their professional category. As can be seen in Table 2, the teaching staff with the highest scores are those in the group of associate or part-time lecturers (3.77), and that of postdoctoral assistant lecturers and contract lecturers (PhD) (3.72, in both cases). In contrast, senior lecturers (3.66) and, especially, full professors (3.50) are the groups with the lowest overall scores. Among the areas with the highest scores, it is worth highlighting professional engagement, which exceeds an average of 4 in all the professional categories. In contrast, it is worth noting a particularly low score in the area of empowering learners in the case of full professors (2.97) and facilitating learners' digital competence in the case of full professors (3.07) and senior lecturers (3.10).

Table 2. Descriptive results of DTC according to professional categories

	Full professor	**Senior lecturer**	**Contract lecturer**	**Assistant lecturer**	**Part-time lecturer**
	M (SD)	***M (SD)***	***M (SD)***	***M (SD)***	***M (SD)***
1. Professional engagement	4.09 (.77)	4.22 (.65)	4.20 (.75)	4.25 (.61)	4.16 (.71)
2. Digital resources	3.71 (.93)	3.85 (.91)	3.85 (.90)	3.97 (.78)	3.88 (.88)
3. Teaching and learning	3.61 (1.0)	3.76 (.90)	3.77 (.98)	3.62 (.91)	3.86 (.83)
4. Assessment	3.53 (1.2)	3.75 (.99)	3.84 (1.02)	3.99 (.99)	3.87 (.88)
5. Empowering learners	2.97 (1.2)	3.26 (1.1)	3.34 (1.06)	3.24 (1.0)	3.44 (.98)
6. Facilitating learners' DC	3.07 (1.1)	3.10 (1.0)	3.29 (1.02)	3.19 (.95)	3.37 (1.0)
Digital teaching competence	3.50 (.89)	3.66 (.76)	3.72 (.78)	3.72 (.73)	3.77 (.73)

Yet, from the results of the analysis of variance test (ANOVA), it was found that differences according to professional categories were not significant in the overall result of DTC nor in the areas that it is made up of.

Secondly, the differences in DTC were analysed according to areas of knowledge. As can be seen in Table 3, engineering and architecture (3.80) and social sciences (3.78) are the areas with the highest scores, while science (3.55) and law and economics (3.56) are the ones that obtain the lowest values. A one-way between subjects ANOVA was conducted to compare DTC level according to their areas of knowledge.

Table 3. Descriptive results of DTC and ANOVA results according to areas of knowledge

	Area of knowledge	**M**	**SD**	**F**	**p**
1. Professional engagement	Sciences	4.19	.74	1.555	.171
	Health	4.17	.70		
	Engineering	4.29	.62		
	Law	4.05	.74		
	Social sciences	4.22	.64		
	Arts	4.22	.65		
2. Digital resources	Sciences	3.87	.87	4.744	< .001*
	Health	3.84	.83		
	Engineering	4.13	.78		
	Law	3.57	.98		
	Social sciences	3.89	.80		
	Arts	3.88	.89		
3. Teaching and learning	Sciences	3.59	.95	.675	.642
	Health	3.79	.90		
	Engineering	3.78	.87		
	Law	3.73	.90		
	Social sciences	3.81	.88		
	Arts	3.79	.93		
4. Assessment	Sciences	3.54	1.0	2.441	.033*
	Health	3.89	.87		
	Engineering	3.95	.98		
	Law	3.71	.94		
	Social sciences	3.96	.93		
	Arts	3.81	.97		
5. Empowering learners	Sciences	3.11	1.0	1.037	.395
	Health	3.36	.96		
	Engineering	3.34	1.0		
	Law	3.18	1.1		
	Social sciences	3.36	.98		
	Arts	3.41	1.1		
6. Facilitating learners' DC	Sciences	2.95	1.0	2.948	.012*
	Health	3.09	1.0		

	Engineering	3.24	.99		
	Law	3.13	.96		
	Social sciences	3.46	1.0		
	Arts	3.35	1.0		
Digital teaching competence	Sciences	3.55	.80	2.131	.060
	Health	3.69	.70		
	Engineering	3.80	.73		
	Law	3.56	.78		
	Social sciences	3.78	.71		
	Arts	3.75	.78		

* Significant differences between groups.

According to the ANOVA test, although there are no significant differences in DTC at a general level according to the area of knowledge, some were detected in three of the areas it is made up of. The first was the area of digital resources [F (5, 552) = 4.744, P = < .001], in which, according to Tukey's post-hoc test, the engineering and architecture group scored significantly higher than the law and economics group. Differences were also detected in the area of assessment [F (5, 543) = 2.441, P = .033], with the social sciences group obtaining significantly higher values than the science group. Finally, significant differences were also detected in the area of facilitating students' DC [F (5, 537) = 2.948, P = .012], where the social sciences group obtained significantly higher values than the science group.

3.3 Analysis of the structure of digital teaching competence

A factorial analysis was then carried out on the 22 items in the questionnaire. The KMO measure of sampling adequacy was .96, while the Bartlett sphericity test was highly significant (p = < .001), indicating the adequacy of the factor analysis. By means of this latter, three categories were extracted and rotated with the varimax method. Table 4 shows the score of each of the items in the factor analysis, with factor loadings ranging from .59 to .77, as well as the values of the three categories, which account for more than 60% of the cumulative variance.

Table 4. Analysis of the categories according to the items of DTC

Item	Categories			Eigenvalue	Cumulative	Cronbach's alpha
	1	*2*	*3*			
C1. Inspiring teacher				10.560	60.25 %	.921
10. Fostering collaborative learning	.59					
11. Encouraging reflection	.66					
15. Tools for accessibility	.57					
16. Personalised learning	.67					
17. Fostering digital participation	.73					
18. Facilitating information	.66					
19. Facilitating communication	.65					
20. Facilitating creation of contents	.76					

21. Facilitating well-being	.77					
22. Facilitating problem solving	.69					
C2. Creator				1.628		.859
2. Collaborative work with ICTs		.60				
3. Critical reflection on ICTs		.60				
4. Digital professional development		.65				
5. Location and selection		.62				
6. Creation of resources		.69				
7. Sharing open contents		.66				
8. Planning digital teaching		.61				
C3. Tutor				1.068		.822
1. Digital communication			.61			
9. Tutoring and interaction			.68			
12. Using ICTs in evaluation			.63			
13. Collecting digital evidence			.63			
14. Using ICTs for feedback			.62			

As can also be seen in Table 4, these categories are not consistent with the areas of the DigCompEdu model itself, although they do have a high internal consistency, ranging from .822 to .921. After analyzing the approach of each of the items, three denominations were proposed (inspiring teacher, creator and tutor), which can give rise to different types of teachers and will be addressed in more detail in the discussion.

4 Discussion and conclusions

This study has focused on analysing university teachers' self-perception of their digital teaching competence based on the DigCompEdu framework. In relation to the first research question, university teachers perceived themselves as having an average general level, with special emphasis on technical and professional aspects, as opposed to pedagogical aspects and those related to transferring these outcomes to their students. As also occurred in the studies conducted by [28], [29] or [30], members of teaching staff often use technology to work with other colleagues, communicate with their students and locate resources. Nevertheless, aspects such as using ICTs to cater for student diversity, ensure accessibility or tailor learning opportunities all need to be improved. According to [42], empowering university students goes beyond teachers taking accessibility issues into account in the design of materials or in the use of certain platforms. This is undoubtedly fundamental, but following the approaches of these same authors, it is also necessary to consider the students' digital competence, that is, to ensure that they are familiar with the technologies and have suitable strategies and levels of confidence to be able to use them adequately. Yet, promoting learners' digital competence does not seem to be a dimension of competence that is generally carried out by university teachers [32], perhaps because it is assumed that they enter university sufficiently prepared in this area.

To answer the second question, possible differences in DTC according to the professional category were explored. According to the results, associate, assistant and contract lecturers obtained higher results than senior lecturers and full professors, which are similar to the findings presented by [39]. Nevertheless, after analysing the differences, they were not found to be statistically significant. These data seem to be in line with those presented by [43], who stated that factors such as professional category or age are not determining factors in the use of ICT.

The third research question focused on analysing possible differences according to the field of knowledge. As described in the results, teachers from engineering and social sciences had higher scores than those from science, law and economics. This result was statistically significant in certain areas related to their students' pedagogical use of such technology and their digital competence. Other studies, such as those by [39] or [44], also highlighted the more technical digital skills of engineering teachers. However, depending on the scientific field, they present different results in terms of the use of ICTs for educational purposes. These results show, beyond the actual value in the context of study, the wide range of levels of competence of teaching staff at a global level, as well as their need for pedagogical training, as suggested by [36]. Although it was not the main focus of the study, possible differences according to gender were also analysed. Similar to previous studies, no significant differences were found [45]. In relation to the fourth research question, the possible categories underlying university teachers' DTC were analysed. After conducting the factor analysis, three categories were obtained, which were highly consistent, but did not coincide with the areas of the DigCompEdu model [26]. This may be because, although the DigCompEdu model is a widely used framework in Europe, it is essentially constructed in a theoretical manner. These theoretical constructs, developed by the Joint Research Center of the European Commission, are based on the aggregate analysis of previous literature and expert review. However, we believe that it is necessary to deepen in a critical vision of the areas that make up the competencies, as well as in their analysis and validation in terms of research. These types of institutions generate frameworks that are instantly adopted by national and local administrations, which makes the analysis of these models even more relevant. From an analysis of the items, they are composed of, they could indicate three types of teachers according to our results. On the one hand, the inspiring teacher, who encourages his or her students to participate and carry out activities using ICTs. This approach may have some similarities with transformative teaching, in which the teacher, assuming the role of facilitator, not only fosters learning and knowledge acquisition, but also their students' personal development and attitudes towards learning [46]. As proposed by [47], it is a volitional type of learning, based on curiosity, which must be aided by the teacher who, through discovery, generates a certain feeling of ‘discomfort’ that drives knowledge. It is a theoretical approach that makes a lot of sense in practices that are based on collaboration and enriched by ICTs [48]. On the other hand, there is the creative teacher (creator), who generates digital artefacts and uses technologies to create and share resources. To a certain extent, this is a concept of the educator linked to the figure of craftsman proposed by [49], in an increasingly digital world [14]. In this sense, digitally competent university teachers must be capable of generating and managing emerging teaching practices and enriched digital content. And the ICTs, which have promoted phenomena such as the maker culture, are an excellent arena for learning and professional development, reducing the learning curve through interaction with the community, with which materials, videos and advice are shared through networks and forums [50]. Finally, the tutor is one who interacts with, accompanies, evaluates and follows up the work of his or her students. As proposed by [51], digital technologies, such as social networks, allow for a great deal of interaction between teachers and students, which can have a clear impact on the learning process of the latter. There are also other technologies, such as digital portfolios, virtual environments or simulations, which can be useful to assess learners' competences [52]. Through these media, teachers can supervise student activity, facilitate reflective thinking and establish a greater relationship based on trust [53]. As mentioned in the introduction, Spanish universities bring together a wide variety of teaching profiles. Moreover, the teaching function is not always valued at the same level as research [6], generating an even broader profile of teaching staff. Digital technologies are a key factor in shaping alternative professional scenarios, transforming teachers' performance and leading to the updating of existing competences and new professional roles [36]. Notwithstanding this, frameworks defining DTC often have a restrictive conception of the definition of competence (analytical and decontextualised) as well as an instrumental view of technology [14], which impedes the visibility of this variety of profiles. However, as shown above, the teacher's digital profile is not a unitary construct. DTC frameworks and questionnaires can be useful if they are able to reflect these nuances; they must provide a contextualised and formative approach to help teachers, support teacher empowerment and accountability as well as promote teacher ownership [27]. This research has a number of limitations that could be addressed in future research, especially in relation to the sample of participants. Although the sample size allows for a representative image of the university under study, future lines of research could extend this instrument to other Spanish or international universities. On the other hand, the questionnaire used is a valid and reliable instrument for analysing this competence in this context, although, like many of the instruments currently employed, it is based on the teachers' own self-perception. While self-perception is undoubtedly an important element and one which needs to be taken into account, it also has its limitations and biases. In future lines of work, this information should be complemented with other evaluation instruments and strategies in order to have a more complete picture of the actual level of university teachers' DTC. Additional future considerations would be related to addressing whether the instrument used in this study would obtain similar results when applied in different contexts within higher education, such as public or private universities.

To sum up, this study is an exploratory one, but it shows a first validation of a new instrument to explore university teachers' level of the DTC assessment questionnaire, in which an exploratory factor analysis was carried out to detect structures and commonalities in the relationships between variables [41]. The present analysis allowed the extraction of three categories, which were interpreted as typologies of teaching. However, it could be complemented in future research by further analysis through structural equation modelling to analyse the relationships in depth, as well as to determine the multiple directions of causality.

Despite these limitations, the results of this research have important implications at several levels. On the one hand, they suggest that, although university teachers are generally digitally competent, aspects such as their use for teaching/learning purposes, student empowerment and the development of their digital competence are aspects to which the university should pay more attention through teacher training programmes [36], [54]. The differences that exist between the different groups, although they should be taken into account in the development of these training plans at university level, do not seem to be generalisable beyond this local context. On the other hand, this study also offers the scientific community and staff responsible for teachers' professional development a new instrument, based on self-perception, for exploring this competence in the university domain. As mentioned above, most of the literature and evaluation instruments continue to be clearly focused on pre-university settings [6], [55]. Although this trend is beginning to revert [38], this instrument can be useful in the analysis and debate on this digital teaching competence at universities. This research has intended to offer a source of information on aspects of digital competence in the university context that contribute with valuable knowledge to both researchers, teachers and decision-makers. From a practical viewpoint, the findings provide an understanding of the DTC in university teachers that can be useful both at a scientific level and in the development of practices and policies for teaching improvement. At the same time, it contributes to the debate on this competence by exploring and highlighting the importance of the categories that underlie it. While the research herein has been in Spain these findings are also relevant to other contexts.

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Exploring the Reliability of a Cross-Cultural Model for Digital Games: A Systematic Review

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Abstract—In recent years, the game industry has become one of the most popular and competitive industries. To quickly expand game markets and attract more game players and consumers, a variety of types of games are developed by the companies and developers. Cross-region games are also common in the current game markets. Consequently, a multi-national competition across different cultures or countries is inevitable. For successful expansion of game market, the existence of cultural differences of game players with various cultural backgrounds is one of the notable issues we cannot ignore. Even though there are studies focusing on the relevant cultural differences, there are no study summarizing the past findings. Additionally, no powerful norm has yet been defined, therefore this paper will investigate whether it is feasible to apply the Hofstedes' Cultural Dimensions Theory, often utilized in Management, to game industries and to be a reliable guidance for game design and development for cross-culture game players.

Keywords—cross-culture, digital games, culture model, Hofstedes' cultural theory, cultural differences

1 Introduction

Over the last decade, the game industry has grown rapidly, developing into the core of the world cultural industry and as one of the most popular industries in existence. According to Grand View Research (2020), global gaming market was worth USD 151.06 billion in 2019 and is expected to reach USD 398.15 billion by 2027, growing at a Compound Annual Growth Rate (CAGR) of 12.9% from 2020 to 2027. IBISWorld Company (2020) reported that the scale of U.S. video game industry increased by more than 8 percent annually from 2016 to 2021. In 2021, the video game industry in the United States is worth USD 65.5 billion. An economic impact study, conducted by Economists Incorporated and released by Entertainment Software Association (ESA) in 2019, indicated that generated direct economic output in 2019 exceeding $40.9 billion, over 143,000 direct jobs, and contributed $59.76 billion in value-added (growth in GDP) [13]. As a result, the U.S. video game industry substantially contributes to the

American economy. In China, an important constituent of the global games industry, the gaming market reached $31.96 billion in 2018 (which accounts for 23.6% of the global game market), achieving a 20% year-on-year growth, according to the China Game Publishers Association Publications Committee (GPC). This explosive growth implicates the importance of game development in the future.

Due to the fast growth and potential development of game market, targeting and positioning in local areas has not satisfied the managers and developers of game companies. Expansion of game market by penetrating other foreign game markets has been an inevitable trend. Many publishers have developed games for markets of different countries through localization in order to obtain foreign consumers. However, what was found is that not all of game companies could attract their foreign target audience, unless they understood the customers' characteristics (e.g. attitudes, preferences, regional features, etc.) as well as trends of foreign market, and further responded to the major needs of customers [7, 15, 32, 49]. To expand the scale of game market by attracting more foreign players/consumers, understanding what kinds of characteristics of games are most important for consumers or players to choose/play games is necessary. Xu, Turel, and Yuan [50] found that people play the online game due to the need for relationship and escapism. The interactive and collaborative or competitive features involved in the games are attractive to individuals [25, 36]. Gender and cultural differences may influence people's gameplay habit, preferences of game types and the choices of game characters [3, 4, 11, 19, 28, 34, 39]. However, for the sake of developing game markets in different countries, presumably the cultural difference, one of the obvious characteristics between diverse game markets of different countries is an inevitable issue.

Lots of cross-cultural research about the differences of gaming between various countries has been conducted. Hofstede [17, 18] indicated that the psychological activities of human beings coming from distinct cultures are different, which leads to the diversities of conceptual structures and different qualities or strengths in different cultures. The cultural differences can be discovered in a variety of conditions. Yuki, Maddux, Brewer, and Takemura [37] explored differences in depersonalized trust (trust toward a relatively unknown target person) across cultures and differences in discussing distal consequences [47]. When interacting with people, individuals coming from different cultures often show different behaviors or generate different understanding [1, 12, 26, 27, 42-45] or effects [6, 23] under a similar condition. The differences of cultures also affect the attitudes toward games [26, 27, 29] and product reviews of games which can be viewed as reflections of cultural values [2]. Furthermore, the cross-cultural effects lead to distinct motivations, habits and decision-making for purchasing games [31, 32, 40].

In this paper, a study based on literature review is conducted for exploring whether the game preferences of player in different cultures are consistent with corresponding cultural dimensions or characteristics. A cultural dimensions theory, which has been widely utilized in defining the feature of cultures, will be introduced in Section 2. Next, a method concerning the process of literature review will be stated in Section 3. Finally, all findings or results discovered from literature review will be discussed and the conclusion will be made in Section 4.

2 Cultural dimensions theory

In this section, a cultural dimensions theory, Hofstede's Cultural Dimensions Theory, is described, which has been widely utilized in defining the features of cultures for the field of Management.

2.1 Hofstede's cultural dimensions theory

To identify the cultural differences, Hofstede proposed a cultural dimensions theory and defined the systematic differences in national cultures on six primary dimensions: Power Distance (related to the different solutions to the basic problem of human inequality); Uncertainty Avoidance (related to the level of stress in a society in the face of an unknown future); Individualism/Collectivism (related to the integration of individuals into primary groups); Masculinity/Femininity (related to the division of emotional roles between women and men); Long/Short Term Orientation (related to the choice of focus for people's efforts: the future or the present and past) and Indulgence/Restraint (related to the gratification versus control of basic human desires related to enjoying life) [8, 16, 18], which has been widely utilized in distinguishing characteristics of different cultures.

Generally, the differences of cultures between Eastern World (e.g. China, Japan, Korea, Taiwan, etc.) and Western World (e.g. USA, Canada, Europe, etc.) are significant. Individualism and collectivism has been considered the most important characteristic to differentiate between Eastern cultures and Western cultures. For instance, a cross-culture research was carried out by Tse, Lee, Vertinsky, and Wehrung [9] and they concluded that individualism and collectivism are the prime distinction between North American and Chinese cultures. Schimmack [46] pointed out that individualism is a valid construct for cross-cultural comparisons. To be specific, Eastern culture is often characterized as collectivistic. People of this culture may emphasize interdependence and tend to have self-concepts on relationships and social obligations. In contrast, Western culture is often characterized as individualistic. People of this culture typically focus on the independence and tend to have self-concepts on their own aspirations and achievement [20, 21, 38, 48].

3 Methods

In this section, the specific research questions and the data collection procedure are identified first. To address the research questions through literature review, the approach of data analysis about how to organize related studies in the past years are described.

3.1 Research questions

The purpose of this study is to explore whether the game preferences of players in different cultures are consistent with corresponding cultural dimensions or characteristics. In this study, the primary research questions to be addressed in this paper are as follows:

1. Are the preferences or experience of digital games of people from diverse cultures relevant to the characteristics of cultures?
2. To what extent is the Hofstede's cultural dimensions theory (or other optional cultural dimensions theories) compatible with the preferences or experience of digital games of people from diverse cultures?

3.2 Data collection

The databases adopted in this study for search were EBSCO (including Academic Search Complete, Academic Search Premier, Communication & Mass Media Complete, Education Source, ERIC, OpenDissertations, and Primary Search), APA PsycInfo, and APA PsycArticles. The search terms used to search the relevant literature in these databases included:

First search term. [("game*") AND (cultur* OR "cross-cultur*" OR "multi-cultur*" OR multicultur* OR "multiple culture*" OR intercultur* OR "inter-cultur*") NOT ("cultural game*" OR "culture game*")]

Second search term. [("digital game*" OR "computer game*" OR "video game*" OR "console game*" OR "mobile game*" OR "online game*") AND (China OR Chinese OR "United States" OR America* OR USA OR "U.S." OR Japan* OR Korea* OR Germa* OR "UK" OR United Kingdom OR England OR Franc* OR Canad* OR Spain OR Spanish OR Ital* OR Russia* OR Mexic* OR Brazil* OR Australia* OR Taiwan*)]

Third search term. [("game*") AND (prefer* OR favorite* OR type* OR genre* OR style*) AND (cultur* OR countr* OR ethnic* OR rac* OR background*)]

3.3 Eligible inclusion and exclusion criteria

Inclusion criteria. To be included in the study, papers should be qualified by the following characteristics: (1) The papers should be written in English and have been published between 2000 and 2021; (2) The source types of articles should be academic journals, conference papers, and dissertations; (3) The full-text of papers must be available online or in hardcopy form; (4) The papers should focus on the digital games, such as computer games, video games, online games, and mobile games; (5) The papers should show empirical or theoretical evidence/results regarding to the behaviors, attitudes, motivations or psychological activities of different cultures or countries toward digital games.

Exclusion criteria. Several characteristics are identified for ensuring the validity and pertinence to this study: (1) Newspapers, websites and short articles are excluded;

(2) The papers did research about countries but not cover the Hofstede's cultural dimensions theory (or not cover other cultural dimensions or categories relevant or similar to Hofstede's cultural dimensions theory) will not be discussed; (3) The papers only focusing on one country or culture will not be considered; (4) The papers concerning application of digital games for learning, training, or management are not included in this study.

3.4 Data collection

The approach to systematic reviews adopted in this study is the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-analyses) proposed by Page et al. (2021) [35]. The flow of study selection process of PRISMA includes four steps: Identification, Screening, Eligibility, and Included (See Figure 1). The previous-mentioned eligible inclusion and exclusion criteria are involved in the process.

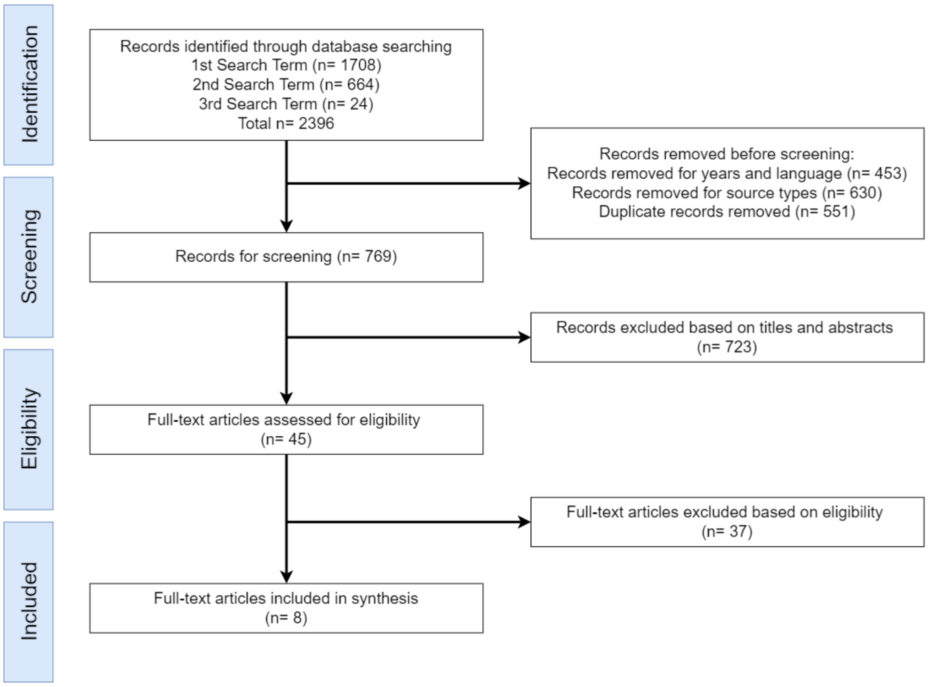

Fig. 1. The flow diagram of the study selection process based on PRISMA

3.5 Data analysis

Two steps are developed to analyze and organize the involved papers, which are described as follows:

Step 1. Based on the definitions of cultural dimensions proposed by the Hofstede's cultural dimensions theory, all papers involved in this study will be classified into six categories corresponding to the six cultural dimensions (i.e., Power Distance, Uncertainty Avoidance, Individualism, Masculinity, Long-Term Orientation, and Indulgence).

Step 2. In order to examine the association between the preferences or experience of digital games and cultural features, the findings or evidence, about the similarities/differences of game preferences between diverse cultures in the involved papers will be compared to the matrix of dimension data established by Hofstede. The Hofstede analytical tool published in 2021 is used to obtain the score information of each country of the dimensions in the Hofstede culture model.

Notice that the scores listed in the matrix of dimension data will not be utilized for quantitative analysis; on the other hand, this study primarily depends on the cultural tendency or distinction of country reflected by the scores to conduct the research. Additionally, the information of experimental design (e.g. participants/sampling, types of games, environments, countries, etc.) employed in the chosen papers will be briefly described.

4 Conclusion and Implications

According to the result of study selection process in the previous section, eight papers with several interesting findings were chosen to be discussed in this section. James [48] used a website, called VGChartz, which tracks video game sales worldwide to investigate the American and Japanese consumers for video games in 2009. The results showed that all of the top 10 games sold in the United States in 2009 are console multiplayers; however, the top 10 popular games sold in Japan in the same year are barely multi-player games (only three games are console multi-players). The author concluded that America has a group-oriented society and Japan is an individualistic society, which is inconsistent with the conclusion of Hofstede's culture model (See Figure 2). The culture model shows that the United States belongs to high individualism and Japan belongs to low individualism (Score of U.S.: 91; Score of Japan: 46) [14].

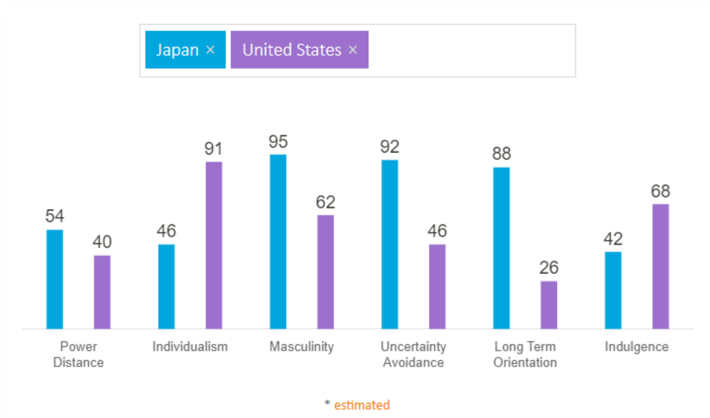

Fig. 2. United States vs. Japan (by the scores on the Hofstede's culture model)

Colwell and Kato [27] investigated the difference in video gameplay between the adolescents in the United Kingdom and Japan. There are 204 British adolescents and 305 Japanese adolescents involved in the survey. The result shows that self-esteem in the gameplay is higher in the United Kingdom than in Japan and it is also higher for boys when compared to girls. Additionally, aggressive games are more popular among U.K. adolescents. However, according to the dimension data matrix by Hofstede (2021), the expression of masculine society in Japan (score: 95) is stronger than that of United Kingdom (score: 66), which means Japanese often draws more self-esteem from their tasks than people in the United Kingdom (See Figure 3). It appears that the two results oppose each other.

On the other hand, the dimension data matrix indicates that the United Kingdom shows many of the characteristics of an individualistic society (Score: 89); on the contrary, Japanese society shows the characteristics of a collectivistic society (Score: 46) [14]. Individualistic societies, such as the United Kingdom, usually show a loss of self-esteem. It seems that the two results are also contradictory on the perception of Individualism/Collectivism.

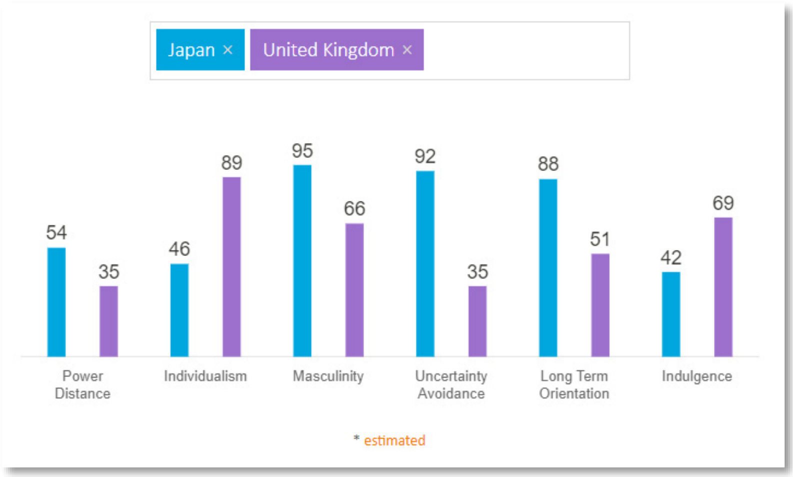

Fig. 3. Japan vs. United Kingdom (by the scores on the Hofstede's culture model)

Hou [8] employed content analysis to investigate avatars representation in ten multiplayers online role-playing games (MMORPGs) selected from the most popular games in Taiwan and the United States respectively. There are 71 avatars (from U.S. games) and 63 avatars (from the Taiwanese games) categorized into four types of facial expressions (including Happy/Cute, Aggressive, Sexy, and others). The number of aggressive avatars in Taiwan MMORPGs (Aggressive: 36.5%) are less than U.S. aggressive avatars (Aggressive: 45%). The Taiwan MMORPGs (Happy/Cute: 31.7%) include more happy/cute avatars than U.S. MMORPGs (Happy/Cute: 1.4%). Additionally, Hou (2008) examined 48 male avatars and 32 male avatars respectively from the ten games in Taiwan and the United States. Most of the male avatars (88%) in U.S. MMORPGs show non-androgyny. However, in Taiwan MMORPGs, only 20 percent of the male avatars are non-androgyny and over 60 percent of the male avatars (65%) express more than 60% degree of male androgyny. Moreover, over 60 percent of the male avatars in U.S. MMORPGs were evaluated as more than 80% degree of male masculinity. On the contrary, 59 percent of the male avatars in Taiwan MMORPGs were evaluated as non-masculinity. The male avatars in Taiwan MMORPGs are significantly more aggressive, more androgynous, and less masculine than the male avatars in the United States. That is, in the MMORPGs, the masculinity of avatars in the United States is stronger than that in Taiwan (See Figure 4). The femininity of avatars in Taiwan is higher than that in the United States.

Wohn and Lee [10] found distinct differences in expected outcomes and usage patterns between Asian and Caucasian (located in the Colombia) respondents in their survey of Facebook game players. Asians were more likely to report social expected outcomes than Caucasians, and were more likely to engage in avatar customization activities than Caucasians, suggesting that cultural differences may affect expected outcomes and usage patterns of Social Network Games. If the kind of behaviors is likely judged as a way to "show off" to people, the Asian tends to be seen as individual players, which is in opposition to the conclusions of previous research described in Section 2.1 and Hofstede's culture model (See Figure 5).

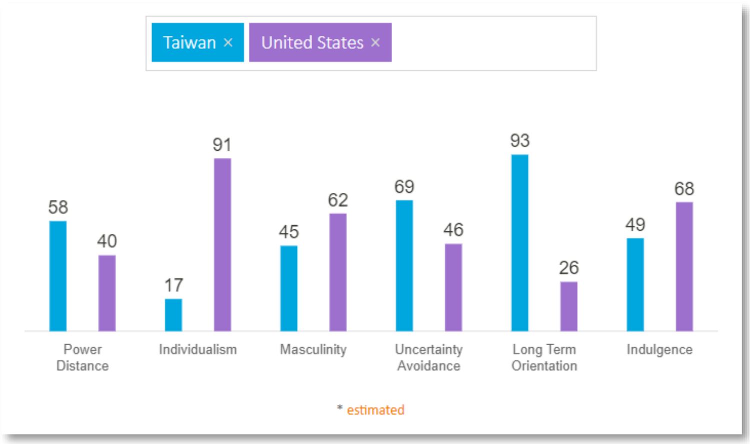

Fig. 4. United States vs. Taiwan (by the scores on the Hofstede's culture model)

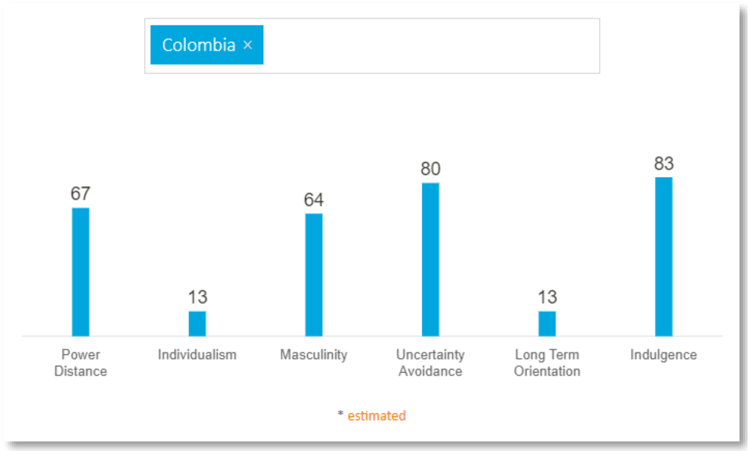

Fig. 5. Colombia (by the scores on the Hofstede's culture model)

Shadid, Krahmer and Swerts [41] conducted an experiment in which children with different cultural backgrounds (48 Dutch children and 48 Pakistani children) were invited to play a number guessing game alone or together with their friends. Results show that the correct classification in both cultures is higher for children playing games in pairs, thus children in pairs are more expressive than individuals. Furthermore, both Pakistani individuals and pairs are more expressive than Netherlands ones. According to the Hofstede's dimension model, cultures with a high score on the Uncertainty Avoidance are often very expressive. Consequently, the Uncertainty Avoidance score of Pakistani is certainly larger than that of Netherlands (See Figure 6).

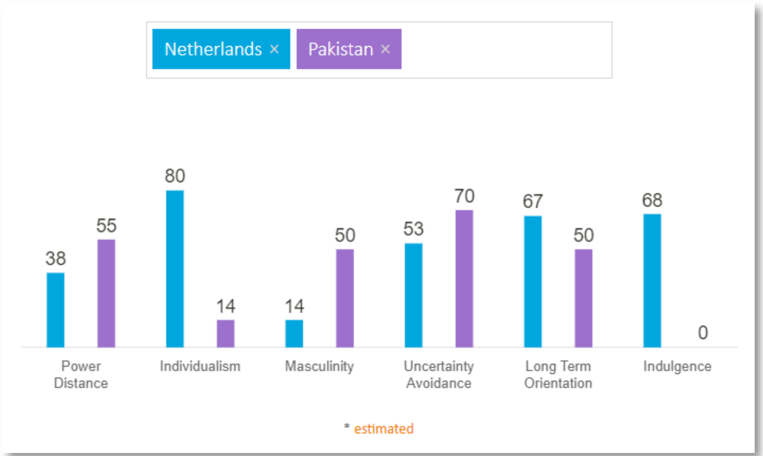

Fig. 6. Netherlands vs. Pakistan (by the scores on the Hofstede's culture model)

Cirnu and Tuncay [5] analyzed the metaphors in digital games based on two different cultures (Romania and Turkey) and other related results based on participants' gender and culture. The author chose Cypriot to represent the culture of Turkey. A total of 181 Romanian students and 220 Cypriot students were involved in this study. Based on the property of gameplay, Driving/Racing, Fighting, First Person Shooter and Sports, which strongly highlight the value of competition and success, may be utilized to determine the tendency of Masculinity/Femininity. Thus, in terms of the type of game genre (See Table 1), both the Romanian's preference of those four game genres (Driving/Racing: 33%, Fighting: 22%, First Person Shooter: 28% and Sports: 24%) and the Cypriot's preference of game genre (Driving/Racing: 32%, Fighting: 18%, First Person Shooter: 18% and Sports: 23%) makes their societies closed to being masculine. The finding may be similar to the results of the Hofstede's dimension data matrix (Score of Turkey: 45; Score of Romania: 42, see Figure 7).

However, according to the frequency of playing games (See Table 2), the results show that the frequency of Cypriot participants is not significantly different from that of Romania. If the frequency of playing games and Indulgence/Restraint culture dimension are probably considered to be associated— more playing times mean the inclination to indulgence because indulgent societies prefer to put much more emphasis on leisure time and control the gratification of their desires, the results will differ from the data in the Hofstede's dimension data matrix (2021) showing that Turkish people are more indulgent than the Romanian (Score of Turkey: 49; Score of Romania: 20, see Figure 7) [14].

Table 1. Type of Game Genre [5]

	Romanian		Cypriot	
Answer options	***Male***	***Female***	***Male***	***Female***
Adventure	44	45	40	41
Arcade	17	20	60	25
Driving/Racing	39	20	46	25
Educational	10	36	2	3
Fighting	27	12	35	5
First Person Shooter	39	12	30	10
Platform	10	4	7	4
Puzzle	14	31	10	3
Role Playing Game	18	19	3	5
Simulation	21	18	2	18
Sports	31	12	40	10
Strategy	46	59	50	10

Table 2. Frequency [5]

	Romanian		Cypriot	
Answer options	***Male***	***Female***	***Male***	***Female***
Once a week	13	37	9	67
Twice a week	13	25	12	27
Three days a week	3	13	13	14
More than three days a week	9	3	9	5
Everyday	36	29	42	23

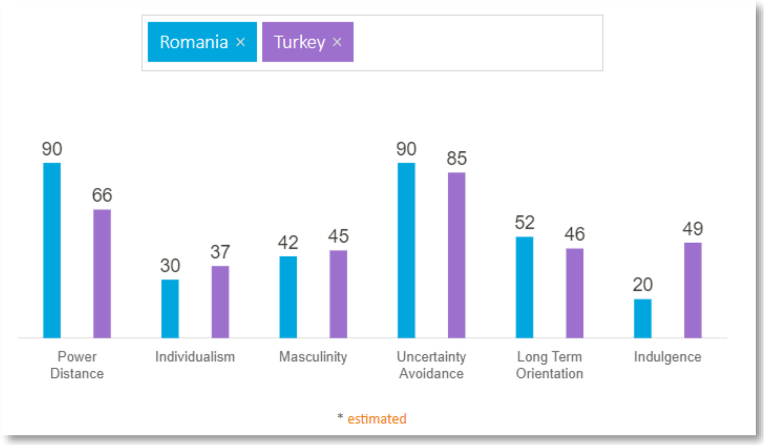

Fig. 7. Romania vs. Turkey (by the scores on the Hofstede's culture model)

Ćwil and Howe [33] investigated the game genre preference and hours of gameplay in Poland and the United States. There are 99 participants from Poland and 119 participants from the United States. The top three preferred game genres of the Polish participants are First-Person Shooter (26.3%), Strategy (16.2%), and Sports (14.1%). The top three preferred game genres of the American participants are First-Person Shooter (31.1%), Sports (19.3%), and Social (17.6%). The First-Person Shooter and Sports games are generally considered as masculinity-oriented games. These two game genres are included in the top three games in both Poland and U.S. Thus, their degree of masculinity may be similar, which is consistent with the scores of the masculinity dimension in the Hofstede's culture model (Score of U.S.: 62; Score of Poland: 64, see Figure 8) [14]. The difference between Polish and American participants is the Strategy and Social games. Social games focus more on the social interaction and network construction, which can be associated with the individualism dimension. Ćwil and Howe [33] found that social games are the third game genre preference of the American participants. This probably implies that American participants have lower score of individualism than the Polish participants; however, this implication is opposed to the Hofstede's culture model (Score of U.S.: 91; Score of Poland: 60, see Figure 8) [14]. Additionally, Ćwil and Howe [33] found that there is no significant difference in the hours of gameplay between Poland and U.S. This may indicate that Poland and U.S. have similar degrees of indulgence. Nevertheless, the Hofstede's culture model shows that U.S. culture has higher scores of indulgence than Poland culture (Score of U.S.: 68; Score of Poland: 29, see Figure 8) [14].

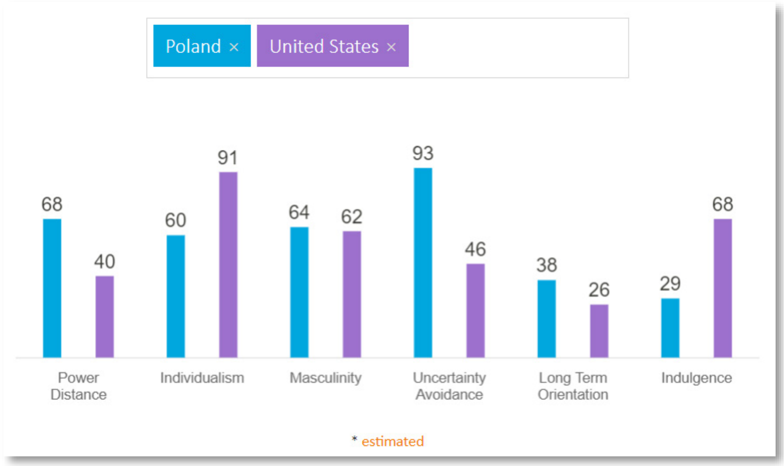

Fig. 8. Poland vs. U.S. (by the scores on the Hofstede's culture model)

Lukosch, Kurapati, Groen, and Verbraeck [22] studied the game performance of different countries in playing the Yard Crane Scheduler game. There are 42 Dutch, 39 Chinese, 37 American, and 16 German participating in the gameplay. The statistical results show that Dutch and German participants have significantly higher scores of game performance than their American participants. However, there are no significant differences between other countries (including German vs. Dutch, American vs. Chinese, Chinese vs. German, or Chinese vs. Dutch). According to the design of the Yard Crane Scheduler game, it is a single-player game and applying flexible planning strategies is the key tip to get more points and win the game. They may imply that Dutch and German participants significantly applied flexible planning strategies better than American. The flexible planning strategies is able to be connected to the dimension of the uncertainty avoidance in the Hofstede's culture model. Low uncertainty avoidance tends to adapt uncertain risk or high fluctuation easily and prefer flexible management or strategies. In contrast, high uncertainty avoidance tends to follow rules or regulations and cannot easily adapt or accept unexpected changes. Therefore, according to the results made by Lukosch, Kurapati, Groen, and Verbraeck [22], Dutch and German should have lower scores of uncertainty avoidance than that of U.S. However, this speculation is inconsistent with the scores of uncertainty avoidance in the Hofstede's culture model (Score of U.S.: 46; Score of Netherlands: 53; Score of Germany: 65, see Figure 9) [14], which shows that U.S. has the lower uncertainty avoidance than Germany and Netherlands.

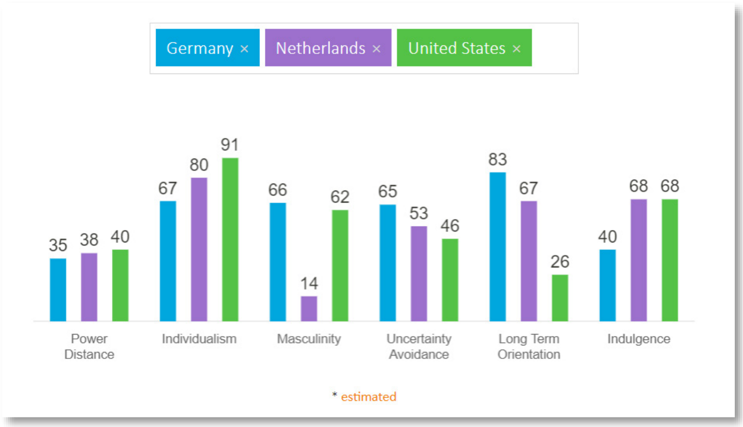

Fig. 9. Germany vs. Netherlands vs. U.S. (by the scores on the Hofstede's culture model)

The summarized review information and inferred results of the selected papers are listed in Table 3. In the selected papers, their research factors or components can be inferred or corresponded to one or more culture dimensions based on the information provided. There are four culture dimensions (including Masculinity, Individualism, Uncertainty Avoidance, and Indulgence) found. Masculinity dimension is the most common analytic characteristic revealed in the selected papers (see Figure 10). However, there is no clear evidence or characteristic to determine Power Distance and Long/Short Term Orientation. With respect to Masculinity, approximately 71.4% (5 out of 7) of the items is consistent with the relative scores of the Hofstede's culture model. Moreover, 33.3% (1 out of 3) of the Uncertainty Avoidance items is consistent with the relative scores of the Hofstede's culture model. However, all of the items regarding Individualism and Indulgence are opposed to the information provided by the Hofstede's culture model.

According to the reviews summaries and statistics (see Table 3 and Figure 10), it appears that the Hofstede's culture model may not be very suitable criteria for game developers to adopt in the process of game design for cross-cultural audiences. However, because not all of the papers emphasized on studying the comparisons of cultural differences, the information provided by these papers is limited and may be not enough to improve the accuracy of inferences. There may be bias when the researchers matched the culture dimensions. Furthermore, the limited numbers of research papers and their experimental design and sampling probably cannot represent or interpret the population from different countries. In addition to the difficulty of cross-culture data collection and classification, a variety of game genre including new types of game continues to be improved and created, which greatly increases the uncertainty and difficulty of relevant research. Moreover, a globalization may lead to the disappearance of cultural boundary. Even so, how to appropriately define and classify an innovative cultural model for game design and development is still an important and valuable challenge in the future.

Table 3. Overview of the results of the analysis of the selected papers

Authors	**Countries for Comparison**	**Participants/Materials**	**Research Factor(s)**	**Mapping Cultural Dimension(s)**	**Consistent with the Hofstede's culture model?**
Cirnu & Tuncay [5]	Romania & Turkey	181 Romanian students & 220 Cypriot students	Game genre preference	Masculinity	yes
			Frequency of playing games	Indulgence	No
Colwell & Kato [27]	United Kingdom & Japan	204 British adolescents & 305 Japanese adolescents	Self-esteem	Masculinity	No
			Preference of aggressive games	Masculinity	No
Ćwil & Howe [33]	Poland & U.S.	99 participants from Poland & 119 participants from the United States	Game genre preference	Masculinity	yes
				Individualism	No
			Hours of gameplay	Uncertainty Avoidance	No
Hou [8]	U.S. & Taiwan	71 avatars (from U.S. games) & 63 avatars (from the Taiwanese games)	Types of facial expressions	Masculinity	yes
		48 male avatars (from U.S. games) & 32 male avatars (from the Taiwanese games)	Degree of androgyny	Masculinity	yes
			Degree of masculinity	Masculinity	yes
James [30]	U.S. & Japan	Top 10 video games in U.S. & Japan respectively	Sales of multiplayers games	Individualism	no
Lukosch, Kurapati, Groen, & Verbraeck [22]	Dutch, Chinese, American, & German	42 Dutch, 39 Chinese, 37 American, & 16 German	Performance in playing the computer game	Uncertainty Avoidance	no
Shadid, Krahmer, & Swerts [41]	Netherlands & Pakistan	48 Dutch children & 48 Pakistani children	Ability of expression in the playing computer game	Uncertainty Avoidance	yes
Wohn & Lee [43]	Asian & Caucasian (located in the Colombia)	253 respondents (Caucasian: 51.2%; Asian: 42%)	Report of social expected outcomes in Facebook games	Individualism	no

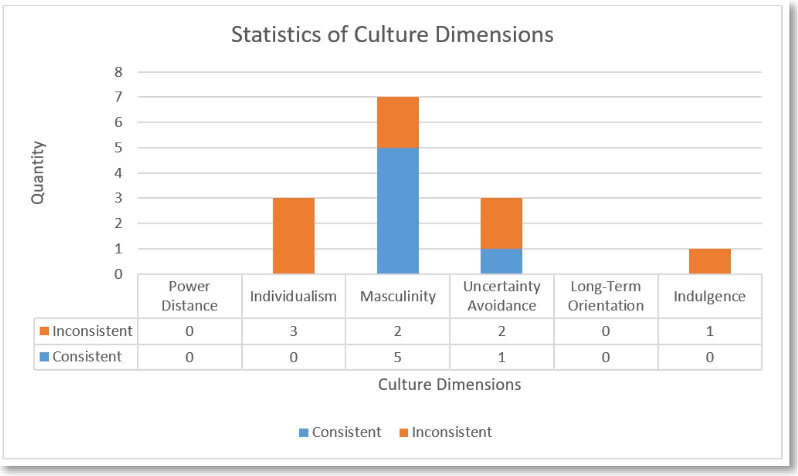

Fig. 10. Statistics of culture dimension inferences from the selected papers

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Case Study on the Evolution of Learners' Learning in the MOOC

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Abstract—Tracking the evolution of learners' learning in a MOOC supports the E-learning operation and allows teachers to easily manage the massive number of learners enrolled in a distance learning course. In this work we started with a study where we were interested in identifying the common parameters that allow us to have a vision on the evolution of learners through the use of SPSS statistical software. This operation allowed us to determine the level of the learners, classify them and group them into homogeneous groups that facilitated their orientation towards courses that meet the characteristics of their profiles. On the basis of our case study, we were able to develop a computer system approach based on K-means learning software and data preprocessing means, for data mining with the aim of analyzing and revealing the parameters that have a great positive impact on the learners' learning, the system uses the identified parameters to classify and group the learners according to their profiles. This type of system is characterized by its autonomy and the ability to process a large amount of data. On the basis of the data used in our case study, we carried out experimental tests on the proposed system which showed its performance in solving our problem.

Keywords—learning, MOOC, teacher, learners, classify, clustering, profiles, artificial intelligence, machine learning

1 Introduction

Monitoring the learning progress of learners in a MOOC seems a necessity given the high rate of overload in tutoring and activities offered in distance learning and especially with the arrival of the Covid pandemic, universities have undergone great changes [1], such as distance learning which has become a necessity to limit the spread of the virus. It is necessary that learners accept the new teaching reform, respect the training schedules and increase their responsiveness since they have real autonomy in this type of learning [2], [3], [4]. As for teachers, they must develop content and personalize teaching resources according to the characteristics of each learner profile in order to increase interactivity between them and the tutors to eliminate any sense of isolation reported among them.

The use of exchange places such as: forum, wiki, chat favors supportive relationships between learners as they exchange and share information with each other, but also to remind certain activities to those who have missed something as it is the place where the learner can ask about any difficulty encountered. However, despite the massiveness of enrollees, the participants within the forums represent a relatively small percentage of the number of enrollees [5], [6].

Asynchronous tools also allow learners to interact on specific issues and establish exchanges with their tutors, which supports the functioning of E-learning and allows teachers to easily manage learners enrolled in a distance course.

Thus, the purpose of this study was to present an approach based on intelligent neural networks that will allow teachers of distance learning courses to easily monitor the learning progress of their learners and to facilitate the interaction between them and their learners through a case study to identify learners by a set of parameters: grades in the following three subjects: communication, mathematics, computer science and the results of: pre-tests, formative tests at the end of each chapter and the scores of the summative test at the end of the MOOC, using SPSS statistical software to perform the analysis of the results obtained in the tests. Based on the parameters deduced from the case study, a K-means classification algorithm was used to classify the learners into three groups: Group A: advanced learners, Group B: average learners and Group C: struggling learners.

2 Literature review

At present, distance learning is seen as an alternative to face-to-face teaching. The transition to this type of teaching requires facilitating contact between the teacher and his learners in order to ensure continuity of the learning process even if it is virtual, as well as enabling the teacher to determine the needs of these learners [7].

Monitoring the learning progress of E-learning learners is a central task as shown by the work of [8], which states that the shift from face-to-face to fully or partially distance learning has raised the problem of the learner's sense of isolation from the machine, leading the learner to no longer feel isolated in front of the computer in distance learning [9]. Certainly, the method of classifying and grouping learners into homogeneous groups is an effective method that facilitates the choice of courses and activities by teachers according to the behavior of each user [10].

Some researchers have proposed several works on effective methods to facilitate the tracking of learners' learning in a distance course, the majority of which like [11], [12], [13], and others have chosen to work on the analysis of the notion of traceability to study the MOOCs. This method refers to different practices that change according to the disciplinary affiliation of the researchers.

Some of them consider the traceability of learners as all the messages and comments left by them on the discussion forums and the different exchange spaces. For others, it is the analysis of all the digital traces of learners. There is also work that uses both approaches, either by offering personalized digital materials to tailor the training to the learner, or by using information about what the learner has already done with the content or by exploiting a representation of the learner's skills [14].

For example, [11] have focused their work on identifying any traces left by learners in MOOCs discussion forums, such as: wiki and chat to test the degree of learner engagement by comparing them with the frequency of exchanges that each learner has carried out. The problem with this study is that it is the analysis of textual data which in most cases concerns learners who consume just part of the course and who do not participate because they do not need a certificate.

For its part, [12] conducted a study on non-certified learners based on the analysis of their traces during the consultation of the pedagogical videos proposed by the latter [12]. The objective of this study, is to encourage passive participants and to improve their learning without the need for a certificate. The limitation of this study is that [12] limited its work to the analysis of the use of videos by non-certified passive learners.

And for [13], they set out to conduct a qualitative survey of 34 learners pursuing two different MOOCs to see: how they work? How much time they spend on their work? This study has a limit related to the minimum number of the sample chosen to be studied. For [15], [16], their work is based on the follow-up of learners' traces from their learning path via the analysis of the temporal evolution of learners in relation to the course they are pursuing. But the works of [15], [16], have reported limits because the analysis did not take into account all the learners given the massiveness of the data. For his part [17], proposed in his work a remediation, or feedback in the sense of providing methodological assistance to learners to improve their learning and encourage them to continue the MOOC until the end but the number of certified learners is minimum in relation to the number of registrants. Some works based on artificial intelligence, in particular the improvement of the sum map, have shown their performance in classifying and grouping learners into homogeneous groups with the same profiles [18].

The originality of our study, compared to the literature review presented above, lies in the fact that it to seek the answers for the below-mentioned questions:

1. How can we develop an intelligent computer-based method to enhance learners' learning in a MOOC?
2. How to better manage massive learner data?

3 Case study

3.1 Research framework and context

The study is conducted on 109 students, whom I have chosen because I teach them and have access to their transcripts, and personal information to ensure the certainty of the information, they will enter in the platform of the institution where I work when they register in the MOOC. They are continuing their studies in the first year of the MIPC in the academic year 2021 /2022. The course started on 01/09/2021 for a duration of 4 weeks. Among the objectives of this course, is to introduce the students to the basic elements of algorithmic and C programming and to deduce the elements that influence the improvement of their learning. The content of the course was structured in 5 main sessions, corresponding to 3 weeks of classes and one week for a summative test, on the platform of the polydesciplinary faculty of Larache according to the following schedule:

Table 1. MOOC schedule

Week:1	Week:2	Week:3	Week:4	Week:5
September/October From :27 to 04.	October From :05 to 11	October From:12 to 18	October From :19 to 25	October/November From: 26 to 01
Pre-test of positioning.	Chapter:1	Chapter:2	Chapter:2	Summative test
Getting to know the platform.	Formative test	Formative test	Formative test	

For the purpose of this study, the common parameters that allow the evolution of learners' learning in terms of knowledge, skills and attitudes at the end of a course are determined. In order to determine these parameters, we will take into consideration a set of traces that will be useful to measure this change based on their grades in three subjects: communication, computer science and mathematics, and secondly the results of: pre-test positioning, formative evaluations and summative evaluation.

3.2 Organization of the MOOC

Students are asked to fill in the MOOC registration form and are asked to mention their grades in communication, mathematics and computer science. Then they are invited to take a diagnostic test which is conducted before the MOOC in order to provide a status of the students' achievements and to enlighten the teacher on what the learners already know and what mistakes they need to correct. After each chapter, the students are asked to take a formative test which has the function of encouraging the progression of learning and providing information on the learners' achievements in order to evaluate the degree of understanding of the content. So, that those who have not achieved the average can benefit from immediate remediation. At the end of the MOOC, the learners will complete the training with a summative or certificate test which has the function of attestation or recognition of learning to certify the degree of mastery of learning at the end of the MOOC. All of this, is done with the aim of classifying them and grouping them into homogeneous groups, according to their prerequisites, their levels and the knowledge acquired during the MOOC.

3.3 Analysis of the data

Using SPSS software, we were able to identify the numbers of each parameter and organize them into diagrams in order to classify and group learners into homogeneous groups, with the same prerequisites and level of learning, as well as to follow their evolution during the MOOC until the end, in order to deduce the factors that positively influence the improvement of their learning.

3.4 The average of the three subjects

The average of the three subjects: mathematics, computer science and communication were calculated using SPSS software, to facilitate the determination of the learners' prerequisites. Figure 1, below, shows the diagram of the average numbers obtained.

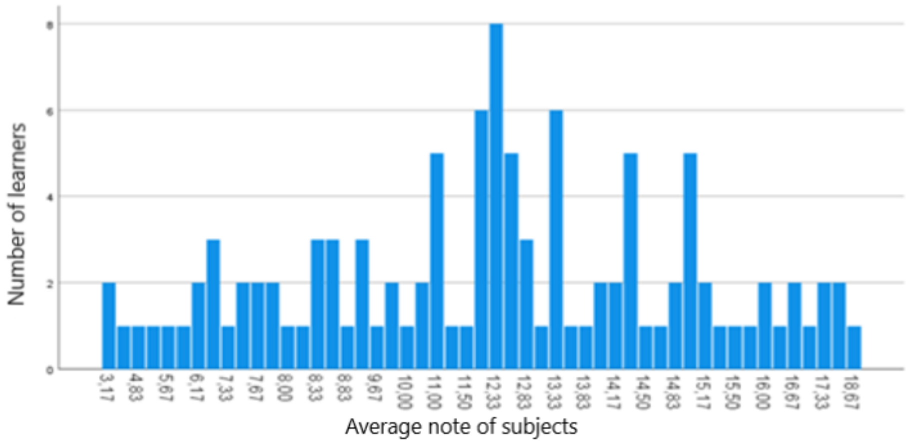

Fig. 1. The staffing diagram of the average of the three subjects: computer science, mathematics and communication

According to the diagram above, we can already see that we have a workforce of 74 learners who have above the average and 35 learners who have not had the average.

And to check the validity and the certainty of the level of the learners in these three subjects, they were given a pre-test which relates to questions which are related to the necessary prerequisites that the learners who are registered in the algorithmic and programming module must have. in C language, which allowed us to have the following results in (Figure 2).

3.5 The results of the pre-test

After taking the pre-test, it was found that learners with above-average scores in the three subjects of communication, computer science and mathematics were able to score well in the pre-test, which was related to the necessary prerequisites for learners enrolled in the algorithmic and programming module. Learners who scored below average in all three subjects were not able to pass the pre-test (see Figure 2, below).

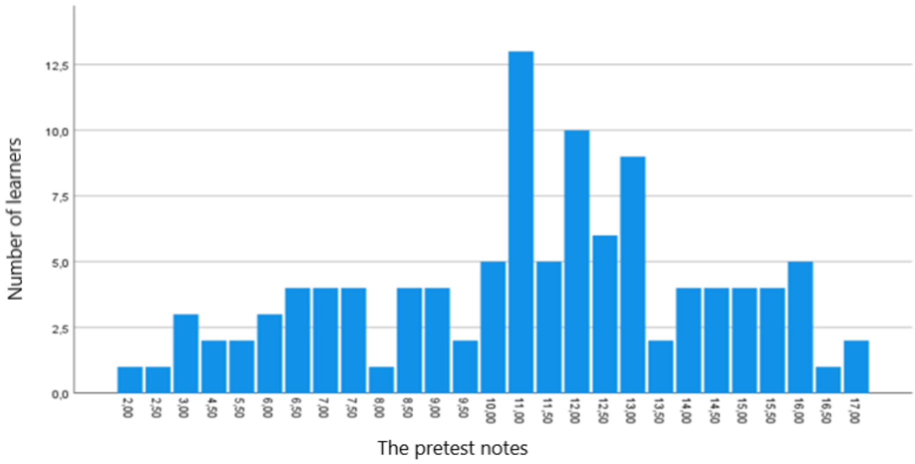

Fig. 2. The staffing diagram of the pre-test notes

According to the analysis of the diagram above, we see that we had the same results as we had in (Figure 1), a workforce of 74 learners had above the average and 35 learners did not. did not have the average. So, we see that the average in the three subjects: mathematics, computer science and communication as well as the passage of a pre-test, are mandatory factors for determining the prerequisites of learners in this MOOC.

From the results obtained, it was possible to classify and group the learners into homogeneous groups having the same prerequisites based on the mark obtained in the three subjects and the marks of the pretest. (Table 2), shows the number of learners in each group.

Table 2. Classification and grouping of learners according to their notes

	Group A 13 ≤N ≤20	Group B 13 ≤N ≤20	Group C N<10
Numbers of the average of the three subjects.	44	30	35
Pre-test enrolment.	35	39	35
The number of learners in each group	≈ 40	≈ 35	35

According to the results of the table below, the learners have been classified and grouped according to the average of the three subjects and the result of the pretest according to 3 groups:

- Group A (advanced learners): with a score between 13 and 20.
- Group B (average learners): with a score between 10 and 13.
- Group C (learners in difficulty): with a score below 10.

According to the results obtained in the table, it was found that for category A and B there is a difference of 9 numbers between the passing of the average of the three subjects and the result of the pre-test and that is normal. than the disparity between the averages of each subject. And for category C we obtained the same number of learners, which shows that the average of the three subjects: (communication, mathematics, computer science and) has a great influence on the results of the pretest.

3.6 Analysis of the results of the formative tests

At the end of each chapter, learners are asked to take a formative test to check whether they have acquired the necessary knowledge and information, for those who validate the chapter, they go directly to the next chapter and so on. And for those who have not validated the chapter, they automatically benefit from a remediation to remedy their deficiencies.

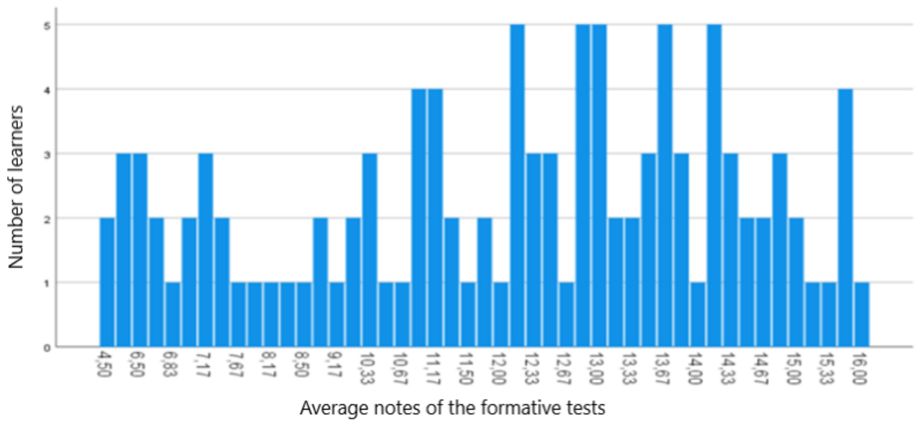

Fig. 3. Plot of the average notes of the three formative tests.

According to the results obtained in the diagram above, we see that a workforce of 81 learners were able to validate the three formative tests, which means an improvement of 7 learners from the results of the pre-test. This reflects their commitment to monitoring the MOOC and the remediation they received, which subsequently enabled them to validate the formative test 2 and 3.

To close the MOOC, learners are asked to take a summative test, to check the overall knowledge of their achievements during the MOOC. (Figure 4) shows the results obtained.

3.7 Analysis of the summative test

Learners who passed the pre-test and the formative tests were able to pass the summative test (see Figure 4 below).

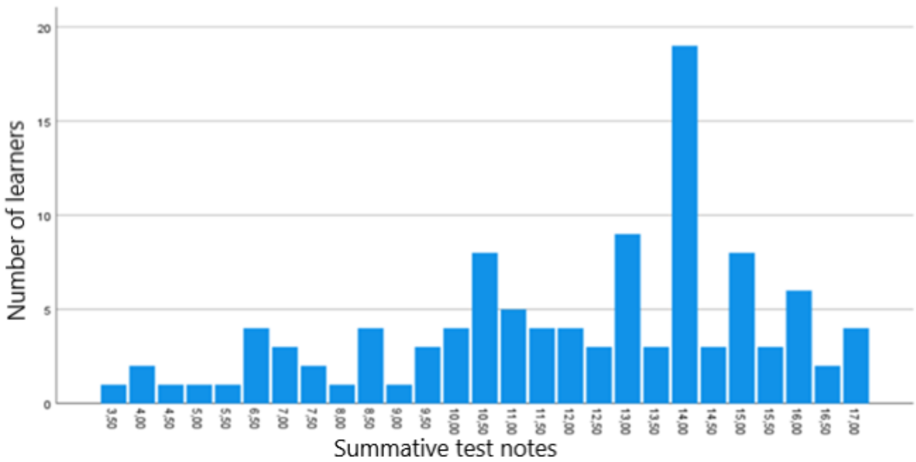

Fig. 4. Summative test notes chart

According to the results obtained in the diagram above, we see that 85 learners were able to validate the summative test and 24 did not. So, an improvement of 4 learners was reported between passing the formative tests and the summative test.

3.8 Comparison table of results

Table 3. Monitoring the progress of learners' learning by comparing the results obtained.

	Group A $13 \leq N \leq 20$	**Group B** $13 \leq N \leq 20$	**Group C** $N<10$
Learner numbers according to grades in the 3 subjects and the pre-test.	40	35	35
Learner numbers according to the results of the three formative tests	45 (+5)	36 (+1)	28 (-6)
The number of learners according to the results of the summative test.	58 (+13)	27 (-9)	24 (-4)

4 Approach to an intelligent learner monitoring and organization system

4.1 Definition of the objective approach

In our case study, we were able to group the objects into three homogeneous groups based on two criteria: the average of the three subjects (communication, mathematics and computer science) and the pre-test score. In this part of the work, we used the result obtained in the case study, to build our objective approach to define the objective function of the proposed system. The idea, is to find a computational solution based on artificial intelligence means to classify, group and subsequently determine the membership of learners to profiles. For the simulation of this function, we used the Manhattan distance to calculate the distance between two objects in a space (see formula below).

$$d_{xy} = \left|X_{ik} - X_{jk}\right| \tag{1}$$

In the first step, we calculated the distance between the objects representing the learners and the starting point of frame O (see formula below).

$$d_{xo} = \sum_{i=1}^{n} |x_i| \tag{2}$$

The distance is divided by 2 for the scaling of the calculated distance values (possible value of the score). Using these distances, we grouped the learners in three clusters (groups), respecting the objective determined in the case study, so for each cluster we determined the centroid distance, which is equal to the average distance of the distances calculated for each cluster, in the table below we present the results obtained.

Table 4. Result of the simulation of the objective function

Type of class:	The distance Manhattan/2	The distance of the centroids
Group A: 13 ≤Note ≤20	Maximum value: 17,33	15,25
	Minimum value: 13,17	
Group B: 10≤ Note<13	Maximum value: 12,92	11,50
	Minimum value: 10,08	
Group C: Note<10	Maximum value: 09,83	6,28
	Minimum value: 02,58	

After determining the centroid distance, we could choose the object (the learner) that represents the center class of each cluster and with the help of the obtained parameters, we calculated for each cluster the membership distance of the different objects. To determine the membership of a learner object to a cluster, we use the following formula.

$$d_{jk} = \sum_{i=1}^{n} \left|x_{ji} - x_{ki}\right| \leq d_{\exists} \tag{3}$$

Where: *n*: the object length.
djk: the *distance* between the center of cluster *k* and object *i.*
d: distance of cluster membership (group).

4.2 Presentation and working description of the proposed approach

Following our case study and the results obtained, as well as the need imposed by distance learning and the platforms dedicated to this type of learning, it is essential to develop intelligent computer means, that facilitate and help the teacher to well organize and manage his course, while respecting the categorization of the learners' profiles. In the figure below, we present the diagram of our approach with its blocks and their operating principle.

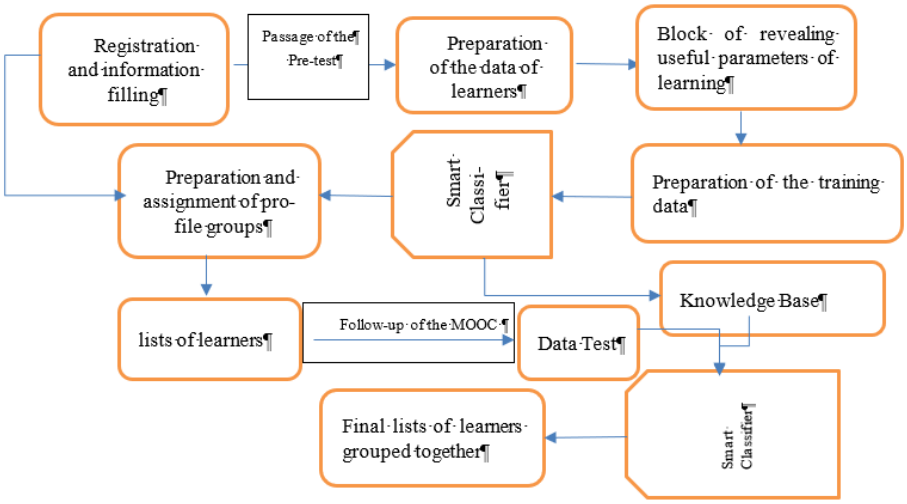

Fig. 5. The representation of our intelligent approach

Our system starts with the registration of the learners, who are led to fill in the registration form in the platform before starting the MOOC, to have their personal information and especially their averages in the three subjects: communication, mathematics, computer science. Once the list of learners is ready, they are given a pre-test to check their prerequisites and the validity of the information they have entered in the platform. Based on the results obtained in the three subjects and the results of the pre-test, our system began to prepare the learners' data, for processing via the data processing block in order to reveal the useful learning parameters that positively influence the evolution of the learners' learning. So, that they will be classified later in the form of classes that respond to the characteristics of their profiles.

After identifying and studying the parameters, we start preparing the learning data, which contains the parameters already chosen and predefined by the system during the preparation of the learning data, using one of the intelligent classifiers that will deliver the classes and the membership of each learner. Using the list of learners, we have obtained, we assign each student to the group that corresponds to the characteristics of his profile. So, we already have homogeneous groups that we have named the lists of learners who will follow the MOOC. The profile groups will follow the MOOC, take the three formative tests and the summative test at the end. The results obtained will form the test data, where each parameter represents the stimulus of a concrete learner which will be used with the knowledge base by the intelligent classifier to define the class to which the learner belongs. In the final phase, we will obtain a list that determines the group to which each learner belongs, according to their prerequisites and level.

4.3 Example of the realization of the proposed system

In order to carry out the operating steps of the proposed system indicated in the different blocks, we will rely on the packages and models provided by Python. It is the most usable language for the development and testing of the intelligent system, as it has enough artificial intelligence algorithms that are characterized by learning, adaptation and generation that seem necessary for our system. In this work, we have exploited and compared different algorithms for the realization of the system based on the proposed approach.

Data visualization for revealing useful parameters. After the preparation of the data obtained during the case study carried out on a sample of 109 learners, these data were made into a global matrix that contains all the scores that allowed us to classify and group them. The multitude prepared will be the basis for all the operations that will be carried out later to demonstrate the functionality of the proposed system. In this step, our objective is to demonstrate how the system will visualize the information on the set of learner data parameters to the teacher so that he can select the most useful parameters for grouping the learners, according to their prerequisites and level. In our example, we used methods based on the correlation coefficient. (Figure 6) represents the set of functions used to illustrate the relationship between all the variables in the data set.

```
# display the correlations between each Feature
correlation_Matrix = df.corr()
top_corr_features = correlation_Matrix.index
plt.figure(figsize=(20,20))
#plot The correlation Matrix as a heat map
g=sns.heatmap(df[top_corr_features].corr(),annot=True,cmap="RdYlGn")
```

Fig. 6. Code Show correlation matrix

This program code allowed us to illustrate the plotting of the correlation matrix in the form of a heat map shown in (Figure 7).

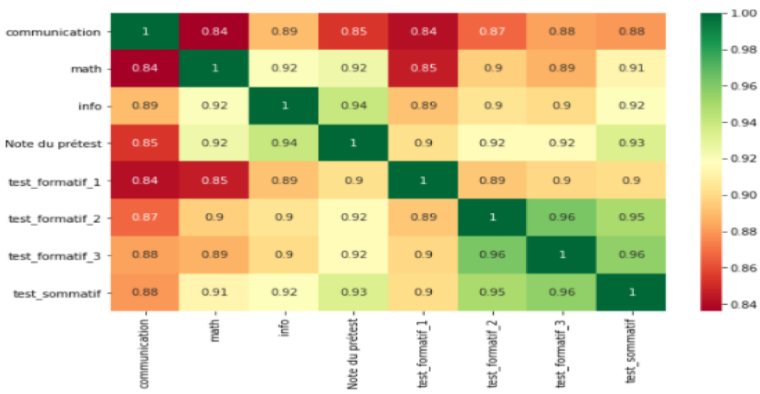

Fig. 7. Correlation matrix graph

The figure above, represents the correlation matrix (graph) with each cell filled in color according to the correlation coefficient of the pair it represents. In the next step, after obtaining the correlation matrix, we used the *describe ()* function which generates descriptive statistics by summarizing the number of distinct values, dispersion, mean, minimum and maximum and the shape of the distribution of a data set for the given series object. (Figure 8), illustrates the values obtained by the function.

```
# Display Infos About The Data
df.describe().T
```

	count	mean	std	min	25%	50%	75%	max
communication	109.0	12.798165	4.473750	2.0	10.00	14.0	16.0	20.0
Math	109.0	10.944954	3.985122	2.0	9.00	10.0	14.0	19.0
info	109.0	11.449541	3.502608	3.0	9.50	12.0	14.0	20.0
pretest	109.0	10.903670	3.533227	2.0	8.50	11.5	13.0	17.0
test_formatif_1	107.0	11.191589	3.064284	2.0	9.25	12.0	13.5	16.0
test_formatif_2	109.0	12.041284	3.209598	4.5	10.00	12.5	14.0	17.0
test_formatif_3	109.0	11.766055	3.289693	4.0	10.00	12.5	14.0	17.0
test_sommatif	109.0	12.009174	3.296309	3.5	10.00	13.0	14.0	17.0

Fig. 8. Display of data information

The analysis of the graphical correlation matrix, as well as the results obtained in (Figure 8), easily allowed us to identify the most useful parameters for grouping learners with the same prerequisites and learning levels, which are: communication, mathematics, computer science, pre-test, formative test and summative test. This function of our proposed system will give a huge solution to manage and monitor learners' learning.

Classification and grouping of learners. After identifying the parameters in the previous step, the system moves to the classification and grouping of learners. There are several ways of doing this, but in our case, we have opted to use k-means for classification and regression for prediction. Following the study and analysis of the data set, it is possible to divide the learners into three groups:

- Group A (The most advanced): these are the students who have an excellent background in mathematics, computer science and communication which allowed them to easily understand the chapters and to pass the formative tests at the end of each chapter. This group of learners, showed their seriousness and strong will and interest in following the MOOC to the end, this is what the pedagogical team noticed because they showed their commitments, especially when carrying out the activities requested by their teacher and the time, they spent connected on the platform following the courses and videos as well as their interactions in the forum.
- Group B (Average learners): already those who have an average level in mathematics, computer science and communication had average grades with the evolution of some elements.
- Group C (learners in difficulty): are those who have gaps in mathematics, computer science and communication. Those, who are close to the average were able to progress and validate some formative tests thanks, also to the remediation proposed at the end of each formative test.

In (Figure 9) and (Figure 10), the K-means application code and the results obtained are illustrated.

```
#Visualising the clusters
plt.scatter(x[y_pred == 0, 0], x[y_pred == 0, 1], s = 100, c = 'red', label = 'Class A')
plt.scatter(x[y_pred == 1, 0], x[y_pred == 1, 1], s = 100, c = 'blue', label = 'Class B')
plt.scatter(x[y_pred == 2, 0], x[y_pred == 2, 1], s = 100, c = 'green', label = 'Class C')

#Plotting the centroids of the clusters
plt.scatter(kmeans.cluster_centers_[:, 0], kmeans.cluster_centers_[:,1], s = 100, c = 'yellow', label = 'Centroids')

plt.legend()
```

Fig. 9. The k-means application code

According to the figure above, the code produces three scatter plots, it displays the students according to their classes. Class A (advanced learners) in red, Class (B) average learners in blue and Class (C) in green (struggling learners). In (Figure 10), we have graphically visualized our dataset to observe the clusters formed.

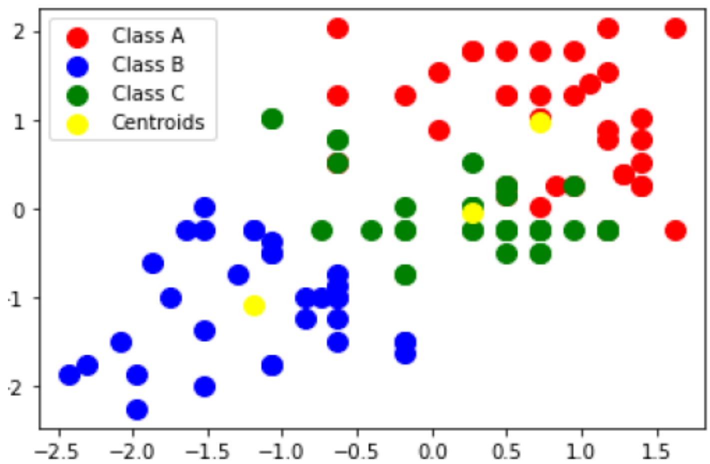

Fig. 10. Visualization of learners' classes

The figure above shows the result of the classification and grouping of the learners using the K-means algorithm, the objects are displayed as scatter plots, each cluster is presented by a color and each class of individual by a point, and the centers of the clusters are presented in yellow. Individuals with the same characteristics that belong to one of the clusters have the same colors. According to the arrangement of the points in the clouds, we can qualify the quality of the classification and clustering we have obtained, since we have a grouping of each class in a separate side from the other class, then we can say that it is a good classification and clustering.

5 Discussion

The results of the study confirm that improving learner learning in a MOOC is considered useful to improve their learning and ensure their commitment to the MOOC from start to finish. This result is consistent with the work of [19], [20].

In this regard, the results of our study provide a starting point for our university to identify the needs of students during a distance learning course in order to help them follow the MOOC from start to finish without any interruption.

The use of distance learning processes has become an obligation especially with the circumstances that the world has experienced (covid 19 and the war in Ukraine), as well as its improvement has become a necessity, in order to ensure good conditions of work for teachers and learners.

In this study, students engaged in the MOOC from start to finish because they felt truly supported during the MOOC. And according to the time the learners have been connected in the platform as well as the traces left by them in the forum, we can see that the participants have spent enough time learning and sharing their knowledge with the learners who have difficulties to help them) learn quickly and remedy its shortcomings via the notion of sharing which is very useful to help learners [21], [22].

In higher education, the integration of high-performance computer tools makes it possible to develop teachers' attitudes towards their students, in order to easily identify their needs for a better improvement of their teaching practices which influence the degree of commitment of learners and c This is what we obtained according to our study since 109 registrants committed to follow the MOOC from the beginning to the end.

On the one hand, the results obtained show that nearly 78% of the registrants were able to complete the MOOC with an improvement in learning of 68.57% for learners in group C and an improvement of 77% for learners in group B, which engenders that it is essential to consider the monitoring of learners' learning as a potential factor in the development of MOOCs.

On the other hand, this study did not encounter any difficulty in analyzing a massive amount of learner data, even though it may be difficult for most teachers [23].

Also, working according to groups of profiles with the same learning needs, levels and interests is essential to apply to future teachers [24], because it facilitates their work of monitoring and supervising learners and encourages them to better adapt courses to the characteristics of each group of profiles, to respect their learning rhythms and to eliminate any feeling of isolation, which in most cases leads to the multiplication of MOOCs by learners [25].

Our system adopted in our study has shown its performance in the analysis of numerical data but no performance has yet been reported in the analysis of qualitative data. The resolution of this ambiguity will be the prospect of our future work.

6 Conclusion

Distance learning requires the use of new computerized technologies, to improve the conditions of this type of education, as well as to facilitate the teachers' operations of monitoring and supervision of their learners. This is why in our work, we started with a case study, to reveal all the information concerning the prerequisites and the levels of the learners in order to classify them in profile groups, with the same characteristics and learning pace, in order to allow the teacher to work with each profile group according to its learning pace. Taking the tests and following, the MOOC until the end allowed us to identify a set of factors that positively influence the improvement of learners' learning.

Subsequently, we developed an approach to an intelligent system, capable of learning to classify learners into appropriate classes, according to the parameters determined in our case study. The system is equipped with the means to reveal and visualize the most useful parameters for proper user interpretation and preparation of learning data. Thanks, to our use of the K-means algorithm as a suitable method we were able to generate three adequate cluster groups and meet the result obtained in the case study. This new method, will lead to a good prediction of the factors that can improve learners' learning in a MOOC.

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Big Data-Based Behavior Analysis of Autonomous English Learning in Distance Education

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Abstract—Distance English education platforms like ABC360 and Rocky English provides a new learning model, which facilitates the autonomous English learning. This study aims to clarify the relationship between learning process and learning efficiency of distance English education, and provide personalized services for distance English teaching. To this end, we carried out a big data analysis on the behavior of autonomous English learning in distance education, in a bid to reveal the learning law and behavior pattern of the learners. Section 2 provides the research strategy for the motivation and behavior of autonomous English learning in distance education, and establishes a research model for such motivation and behavior. Section 3 constructs a behavior analysis model for autonomous English learning in distance education, computes the correlation between the target autonomous learning resources (ALRs) and the series of clicked ALRs, and calculates the probability for autonomous English learners in distance education to click on new resources. The proposed network model can handle a massive amount of learning behavior data, i.e., boast a certain ability to process the big data. The three parts of the model were introduced in details. The effectiveness of the model was demonstrated through experiments.

Keywords—distance education, autonomous English learning, big data analysis, attention mechanism

1 Introduction

English learning is a learning process integrating various psychological activities, such as observation, simulation, cognition, reflection, and memorization [1-4]. From learning words, memorizing words, understanding grammar, to situational application, fragmented and personalized learning models enable students to establish conditional reflection to English sentences and contexts [5-10]. Distance English education platforms like ABC360 and Rocky English provides a new learning model, which facilitates the autonomous English learning [11-16]. Given a computer or smartphone with Internet access, students can learn English autonomously anytime, anywhere, including applied oral English like English for overseas studies and workplaces [17-24]. With students as the subjects, the autonomous English learning is immune to the interference from any people or things. Through autonomous learning, the students can continuously improve their English proficiency, through reading, listening, speaking, research, observation, and practice. This novel learning model emphasizes the cultivation of active and conscious learning, and pays attention to students' learning preferences. To a certain extent, the learning activities of autonomous learners are stochastic and uncertain. Thus, it is difficult to analyze their learning behaviors.

During the Covid-19 epidemic, Cui and Yang [25] surveyed the self-regulation of college English learners in online learning. The survey was carried out in a presentation-assimilation-discussion (PAD) classroom in a local college of China. During the online learning, PAD classroom was implemented for a semester. After that, the learners' self-regulation ability was tested through a questionnaire survey in three dimensions: self-preparation, self-management, and self-evaluation. The teaching effect of English listening courses in Chinese colleges is generally unsatisfactory. Zhou [26] designed an autonomous learning platform based on artificial intelligence (AI), which attempts to improve the listening ability of students with the aid of AI. The design concept and operation process of AI-based learning platforms originate from the current application of AI-assisted English listening platforms. Weng [27] surveyed how college students use self-access center (SAC) to learn English autonomously, summarized the current state of their ability of autonomous English learning, and provided feasible suggestions on cultivating their autonomous English learning in the presence of computers and the Internet. Wei [28] hailed Internet-based autonomous learning as an important learning model. Internet support comes from four key areas: knowledge internalization, task, peers, and society. The four supportive areas affect the autonomous English learning in colleges very differently. English learners can utilize different areas of Internet support to enhance their autonomous learning ability. Hence, different teaching strategies should be applied to different learners. Kamsa-Ard and Danvivaht [29] carried out a survey on the online resources utilized by students to improve their oral English, the way these resources are utilized, and whether these resources affect the students' fluency of spoken English. The respondents were Grade 3 English majors in Khon Kaen University. Three sets of data were collected via pre- and post-tests, questionnaire surveys, and semi-structured interviews. The collected data were subjected to frequency analysis.

To sum up, the existing studies have not sufficiently introduced the external factors affecting the learning pattern, and the analysis approaches for learning pattern. Moreover, the correlation between learning pattern and learning efficiency has not been deeply analyzed. This study aims to clarify the relationship between learning process and learning efficiency of distance English education, and provide personalized services for distance English teaching. To this end, we carried out a big data analysis on the behavior of autonomous English learning in distance education, in a bid to reveal the learning law and behavior pattern of the learners. Section 2 provides the research strategy for the motivation and behavior of autonomous English learning in distance education, and establishes a research model for such motivation and behavior. Section 3 constructs a behavior analysis model for autonomous English learning in distance education, computes the correlation between the target autonomous learning resources (ALRs) and the series of clicked ALRs, and calculates the probability for autonomous English learners in distance education to click on new resources. The proposed network model can handle a massive amount of learning behavior data, i.e., boast a certain ability to process the big data. The three parts of the model were introduced in details. The effectiveness of the model was demonstrated through experiments.

2 Research strategy

When the demand of a student for distance English learning is not satisfied, he/she will generate internal stimuli for autonomous learning, which pressurize the student to compete with other students, and motivate him/her to learn autonomously. Then, the student will prepare an autonomous learning plan and determine the target behavior, aiming to satisfy the learning demand. Once the demand is satisfied, the English learning effect is improved, and the motivation for autonomous learning is further enhanced. In this case, the student will produce new demand and engage in new activities of distance learning. The entire process is shown in Figure 1.

Figure 2 displays the research model of distance English learning motivation and behavior. It can be clicked that: statistical behavior features, learning preferences, and learning motivation directly act on the students' motivation of using distance English education platform, which in turn affects the learning activities. The learning time and learning location are important factors of distance education. With the proliferation of the Internet technology and smart terminals (e.g., laptop, smartphone, and tablet computer), distance education transcends the geographical limitation, and facilitates fragmented learning. Under distance education, the students differ significantly in learning time, and their learning locations vary greatly.

To model the long-term behavior of autonomous English learning in distance education, this paper builds up a stratification model for behavior series, which illustrates the long-distance dependence amidst the behavior series on autonomous English learning in distance education. In this way, the dynamic preference variation is clearly characterized. This novel modeling algorithm divides the behavior series into multiple layers based on the time windows. Different attention models were established, and applied separately inside and between time windows, in order to characterize the preferences of autonomous English learners in distance education.

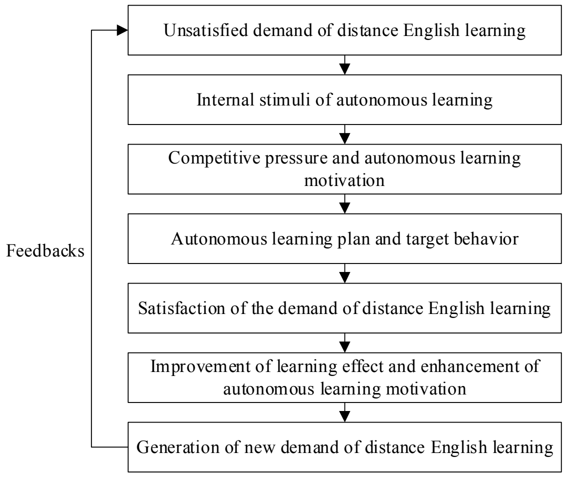


Fig. 1. Relationship between motivation and behavior of distance English learning

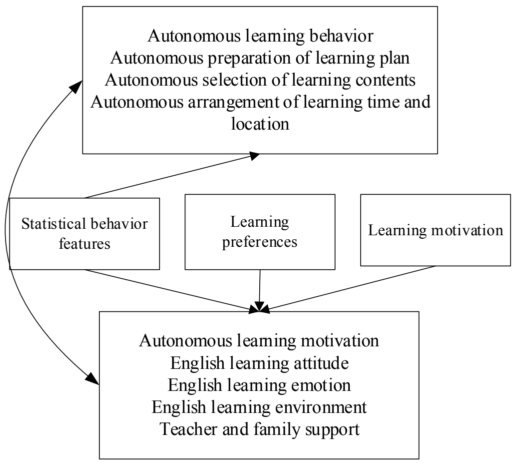


Fig. 2. Research model of distance English learning motivation and behavior

3 Behavior analysis model

The cold start problem is a prominent issue in ALR recommendation. This paper computes the correlation between the target ALRs and the series of clicked ALRs, before solving the probability for autonomous English learners in distance education to click on new resources. The traditional content-based filtering methods often ignore the sequential information among autonomous English learning behavior in distance education. In this study, the ALRs clicked by autonomous English learners in distance education are innovatively modeled as a series, in the order of the interaction time.

The resources of autonomous English learning take different forms, namely, audios, videos, and text files. Our network model needs to handle a massive amount of data on learning behavior, i.e., acquire the ability to process the big data. Our model consists of three parts: the feature space for ALR mapping, which is responsible for obtaining the eigenvector corresponding to each resource; the sequential stratified attention model; the prediction module of the click rate of a given new ALR. The three parts are detailed as follows:

To obtain the eigenvector corresponding to each ALR, this study embeds the ARL in an e-dimensional space. For an autonomous English learner in distance education, the series of clicked ALRs is denoted by $\{p_1,p_2,...,p_m\}$, and mapped into a eigenvector series of learning resources $\{a_1,a_2,...,a_m\}$, where $a_i \in R^e$. Here, Inception-v3 model is pretrained on ImageNet, and then applied to extract the eigenvector p_i^g of each autonomous learning behavior from the collected dataset of such behaviors. The high-dimensional eigenvector p_i^g is dimensionally reduced by learning an embedded matrix D_g. Let $g_i \in R^e{}_g$ be the eigenvector of autonomous learning behavior; $p^z{}_i$ be the class of ALR p_i. Then, we have:

$$g_i = D_g p_i^g \tag{1}$$

Since each ALR has and only has one class, the learning resource class can be characterized as a one-hot vector. Let $p^z{}_i$ be the class of ALR p_i; $z_i \in R^e{}_z$ be the eigenvector of the class. Similarly, the class eigenvector can be dimensionally reduced by learning D_z:

$$z_i = D_z p_i^z \tag{2}$$

After dimensionality reduction, the eigenvector of autonomous learning behavior is stitched by the class eigenvector. Let [*] denote the stitching operation. Then, we have $a_i[g_i;d_i]$. As a result, $a_i \in R^e$, where $e=e_g+e_z$.

If the behavior series is very long for an autonomous English learning in distance education, the ALR eigenvector series $\{a_1,a_2,...,a_m\}$ needs to be modeled by a recurrent neural network (RNN), and extended to multiple scales, using the sequential stratified attention mechanism. These moves aim to better depict the long-distance dependence of learning behavior, and reduce the computational complexity of the model.

In this paper, the behavior series of autonomous English learning in distance education is split into n time windows, each of which contains l ALRs: $n \times l = m$. To extract the local short-term preference features of autonomous English learning in distance education from each time window, this paper establishes an attention model based on the class level and entry level of ALRs. Next, the forward multi-head self-attention model is called to mine the correlation between time windows, such as to obtain the global preferences of autonomous learners from the 1st to the i-th time window. After that, the local preference features are combined with the global preference features, and normalized to obtain the final preference features of each time window, concerning the autonomous English learning in distance education.

The following explains how to realize the attention model based on the class level and entry level of ALRs. Let p_{ij} be the j-th ALR in the i-th time window (i=1,2,...,n,

j=1,2,...,l); $Q_z \in R^{ez\times ez}$, $Q_1 \in R^{ez\times ez}$, and $Q_2 \in R^{ez\times eg}$ be the parameter matrices to be learned; φ_1 and φ_2 are e_z-dimensional bias vectors; $\varepsilon(*)$ be the activation function. Then, the class level attention score can be calculated by:

$$\beta_z\left(z_{ij}\right)=Q_z\varepsilon\left(Q_1 z_{ij}+Q_2 g_{ij}+\phi_1\right)+\phi_2 \tag{3}$$

The above score can be normalized by:

$$\tilde{\beta}_z\left(z_{ij}\right)=\frac{exp\left(\beta_z\left(z_{ij}\right)\right)}{\sum_{j=1}^{l} exp\left(\beta_z\left(z_{ij}\right)\right)} \tag{4}$$

Finally, the class information of the ALRs in the i-th time window are merged to represent the coarseness preference of autonomous English learners in distance education. Let ⊕ be the elementwise multiplication. Then, the merge process can be defined as:

$$k_i^z=\sum_{j=l}^{l}\tilde{\beta}_z\left(z_{ij}\right)\oplus z_{ij} \tag{5}$$

Similarly, the entry-level attention score can be calculated by:

$$\beta_g\left(g_{ij}\right)=Q_g\varepsilon\left(Q_1' z_{ij}+Q_2' g_{ij}+\phi_1'\right)+\phi_2' \tag{6}$$

Let $Q_g \in R^{eg\times eg}$, $Q'_1 \in R^{eg\times ez}$, $Q'_2 \in R^{eg\times eg}$, $\varphi'_1 \in R^{eg}$, and $\varphi'_2 \in R^{eg}$ be the parameters to be learned; k^z_i and k^g_i be the merged preferences of the autonomous English learners in distance education in the i-th time window ($k_i \in R^e$). In the current time window, the ALR information can be merged based on the normalized attention weight:

$$k_i^g=\sum_{j=k}^{l}\tilde{\beta}_g\left(g_{ij}\right)\oplus g_{ij} \tag{7}$$

To capture the sequential changes in the preferences of autonomous English learners in distance education, this paper introduces the multi-head self-attention model to limit the unidirectional flow of the model information (Figure 3). Firstly, the local preference map $\{k_i, i=1,2,\ldots,n\}$ is duplicated three times. The results are denoted as $\{w_i\}$, $\{l_i\}$, and $\{u_i\}$. Based on $\{w_i\}$ and $\{l_i\}$, the attention score is calculated, and then subjected to weighted aggregation with $\{u_i\}$, producing the global preference map $\{h_i, i=1,2,...,n\}$. Specifically, w_i, l_i, and u_i are linearly mapped f times to an ef-dimensional space, using different projection matrices (ef=e/f). Suppose o=1,2,...,f; the parameters of projection matrices are denoted as $Q^w_o \in R^{ef\times e}$, and $Q^l_o \in R^{ef\times}$; the bias vector is denoted as $\varphi_o \in R^{ef}$. Then, the attention tensor can be expressed as $F \in R^{ef\times n\times n\times f}$. Thus, the attention score of the O-th mapping can be calculated based on w_i and l_i:

$$F_{i,j}^{(o)}=Q_o\varepsilon\left(Q_o^w w_i+Q_o^l l_j+\phi_o\right) \tag{8}$$

To capture the long-distance dependence of the behavior series, the above attention tensors are superimposed with a directed mask N. Then, the element can be defined as:

$$N_{i,j}^{(o)} = \begin{cases} 0, if \quad i > f \\ -\infty, otherwise \end{cases} \tag{9}$$

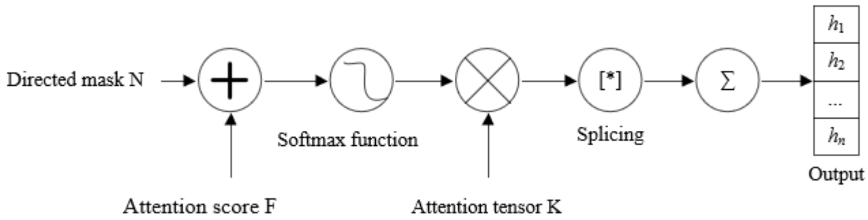


Fig. 3. Multi-head self-attention model

The directed mask N, attention score F, and attention tensor K are illustrated in Figure 4. During the softmax normalization of attention scores, if j is greater than i, then the distance learning location i contributes zero to the distance learning location j. Hence, our attention model only focuses on the scenario of j<i. The corresponding normalized attention weight applies to the $K \in R^{ef \times n \times f}$, where each element is an e_f-dimensional vector. Suppose o=1,...,f, and $Q^{\tau}{}_o$ is the projection matrix parameter. Then, the element can be defined as:

$$K_{i,j}^{(o)} = Q_o^{\tau} \tau_j \tag{10}$$

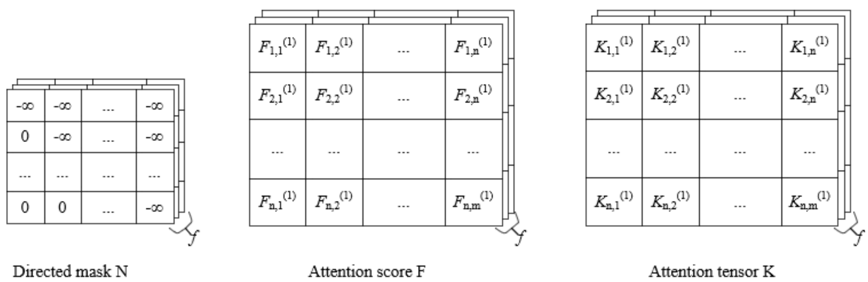


Fig. 4. Illustrations of N, F, and K

Figure 5 shows the acquisition flow of attention tensor K. Since e=e_f×f, tensor $K \in R^{ef \times n \times n \times f}$, after being applied the attention weight, is stitched into $K \in R^{n \times n \times e}$ along the dimension O. Then, superposition is performed along the dimension i, yielding $\{h_1,h_2,..,h_n\}$, with $h_i \in R^e$. Let $\{v_1,...,v_n\}$ denote the final preference series of autonomous English learners in distance education, $v_i \in R^e$; GU denote the normalization process. Then, we have:

$$v_i = GU(k_i + h_i) \tag{11}$$

The next is to predict the probability of an autonomous English learner in distance education to click on a new ALR, based on the preference series $\{v_1,v_2,...,v_n\}$. Here, a new ALR is denoted by an e-dimensional vector a. For a given a, the preference series is aggregated by the attention model. Let $Q_v \in R^{e\times e}$, $Q_3 \in R^{e\times e}$, $Q_4 \in R^{e\times e}$, and $\varphi_3 \in R^e$ be the parameters to be learned; $\varepsilon(*)$ be the activation function. Then, the aggregation function can be given as:

$$\beta_v(v_i) = Q_v \varepsilon(Q_3 v_i + Q_4 a + \phi_3) \tag{12}$$

The attentions score obtained by formula (12) is normalized into $\beta^*_v(v_i)$. Then, weighted aggregation is performed between $\beta^*_v(v_i)$ and v_i, yielding $v^e=\Sigma^n_{i=1}\beta^{\sim}_v(v_i)\oplus v_i$. According to the behavior series of autonomous English learning in distance education, the long short-term dynamic preferences are represented by a vector v^e. To further capture the static preferences, this paper stitches the preference vectors v^e and v^r with the ALR vector a, and then predicts the ALR click rate, using a multilayer perceptron (MLP). Let [*] denote the stitching operation ($v^r \in R^e$, $v^e \in R^e$), and NUG denote the MLP. Then, we have:

$$\hat{\phi} = NUG\left(\left[v^e; v^r; a\right]\right) \tag{13}$$

The training error of the network can be expressed as:

$$E(v,a) = -blog\hat{b} - (1-b)log\left(1-\hat{b}\right) \tag{14}$$

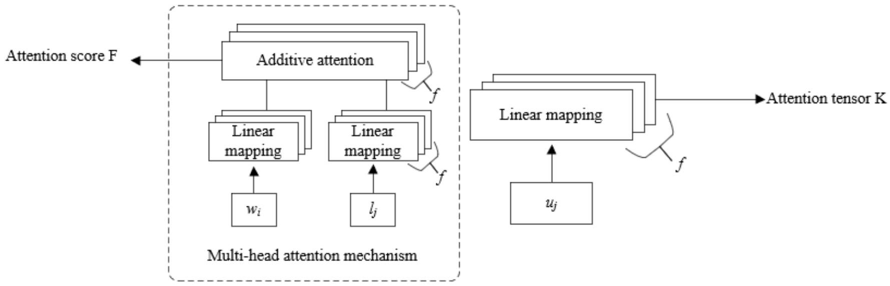


Fig. 5. Acquisition of attention tensor

4 Experiments and results analysis

The authors firstly tested the model performance at different time window sizes. The results in Table 1 show that: when the time window was smaller than 10, our model performed similarly on AUC, GAUC, and DNCG. When the time window was of the size 6, our model reached the best performance. With the gradual increase of the time window, the proposed model performed slightly worse on the three metrics. Overall, the preferences of autonomous English learners in distance education are close to each other, when the time window is relatively small. In this case, the proposed class-level and entry-level attention model can easily emulate the autonomous learning behavior in each time window. If the time window is large, the autonomous learning preferences change significantly in each time window, adding to the difficulty of modeling. In this case, it is difficult for the model to achieve an ideal performance, or control the time cost of training and reasoning. To sum up, the time window size of 6 is the most suitable for our model.

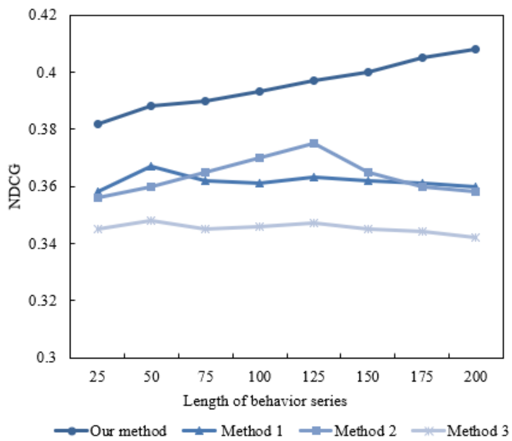
Table 1. Model performance at different time window sizes

Time window size	**2**	**4**	**6**	**8**	**10**
AUC	0.7152	0.7532	0.7786	0.7648	0.7695
GAUC	0.6258	0.6642	0.6859	0.6728	0.6725
NDCG	0.3625	0.3958	0.4142	0.3852	0.3862
Time window size	18	26	34	40	48
AUC	0.7562	0.7495	0.7341	0.7228	0.7115
GAUC	0.6681	0.6695	0.6536	0.6452	0.6401
NDCG	0.3747	0.3785	0.3625	0.3648	0.3547

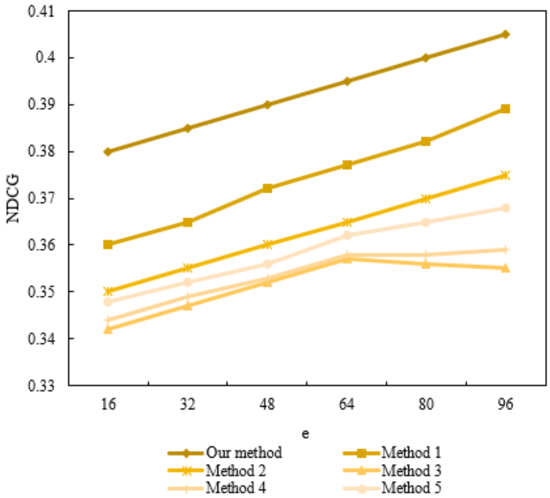
Note: AUC, GAUG, and NDCG are short for area under the curve, generalized area under the curve, and normalized discounted cumulative gain, respectively.

Further, we investigated the influence of behavior series length and embedding dimension e on model performance. The test results are reported in Figures 6-8. The two eigenvectors of ALRs were set to half of the embedding dimension e.

According to the subgraph (a) of Figures 6-8, the proposed model outshined the contrastive models significantly in all three metrices, regardless of the length of the behavior series. The three contrastive models are self-attentive sequential recommendation (SASRec), deep interest evolution network (DIEN), and Caser model. SASRec, DIEN, and Caser are denoted as Models 1-3, respectively.

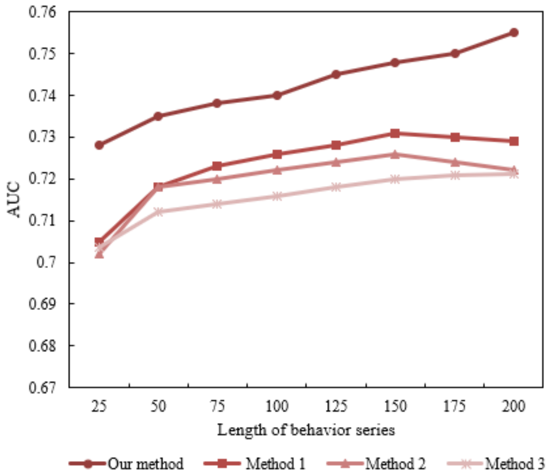


(a)

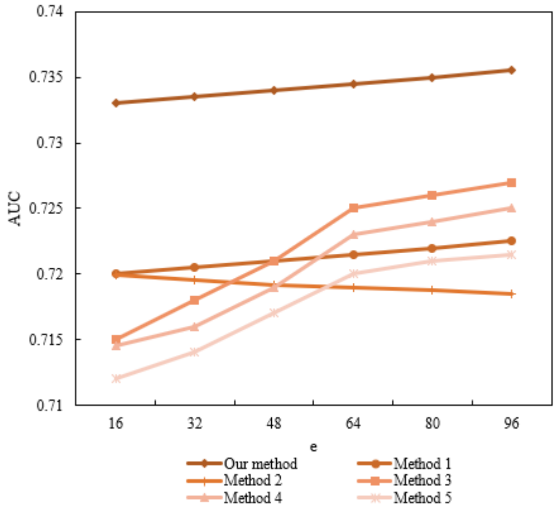


(b)

Fig. 6. Comparison of NDCG performance

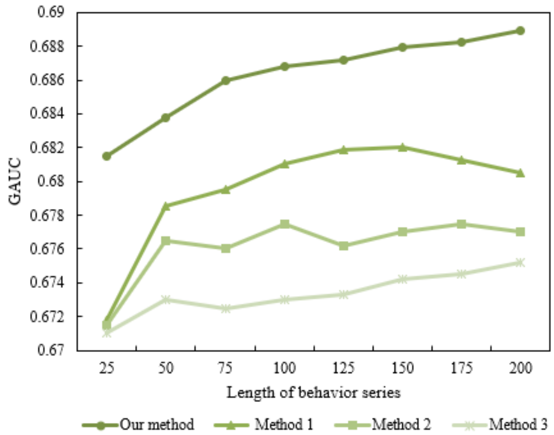


(a)

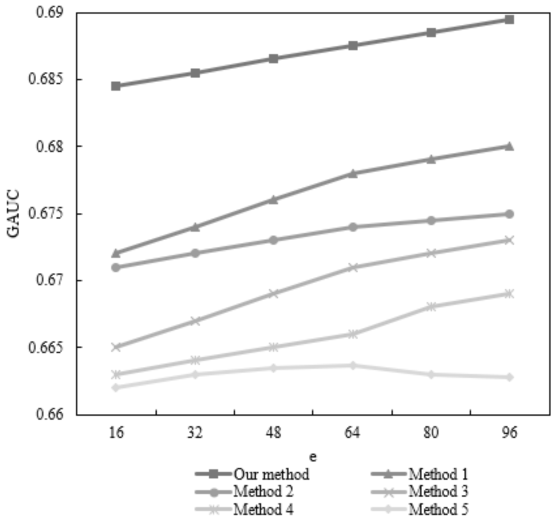


(b)

Fig. 7. Comparison of AUC performance



(a)



(b)

Fig. 8. Comparison of GAUC performance

Among the three metrics, GAUC is obtained by weighting the AUC of each learner. This metric can effectively rank the personalized preferences of autonomous English learners in distance education. That is why our strategy based on the behavior series of autonomous learning outperforms the other models in the ranking of global preferences of learning behavior.

According to the subgraph (b) of Figures 6-8, the proposed model outperformed the contrastive models in all three metrics, regardless of the embedding dimension e. The contrastive models are SASRec, DIEN, Caser, sequential recommendation with bidirectional encoder representations from transformer (BERT4Rec), and behavior sequence transformer (BST). SASRec, DIEN, Caser, BERT4Rec, and BST are denoted as Models 1-5, respectively.

In the behavior series of autonomous English learning in distance education, the ALR feature map can characterize the autonomous learning preferences. When the e is small, the ALR feature map contains limited information, which restrains the expressivity of the behavior series model. With the growth of e, the information volume increases in the ALR feature map. Then, the behavior series model can better illustrate the dynamic preferences of students for autonomous English learning in distance education. Meanwhile, the AUC and GAUC of the contrastive models increased relatively slightly, along with the rise of e. This means, with the increase of e, our model can describe dynamic preferences for autonomous English learning in distance education better than the static preferences.

5 Conclusions

This paper analyzes the autonomous learning behavior in distance English education based on the big data, and reveals the relationship between learning process and learning efficiency. Specifically, we presented the research strategy for the motivation and behavior of autonomous English learning in distance education, devised a research model for such motivation and behavior, and constructed a behavior analysis model for autonomous English learning in distance education. Next, the probability for autonomous English learners in distance education to click on new resources was obtained by solving the correlation between the target ALR and the series of clicked ALRs. The proposed network model can handle a massive amount of learning behavior data, i.e., boast a certain ability to process the big data. The three parts of the model were introduced in details.

In addition, we tested the model performance at different time window sizes, and confirmed that the time window size of 6 is the most suitable for our model. Then, we investigated the influence of behavior series length and embedding dimension e on model performance. The investigation shows that our strategy based on the behavior series of autonomous learning outperforms the other models in the ranking of global preferences of learning behavior. Moreover, with the increase of e, our model can describe dynamic preferences for autonomous English learning in distance education better than the static preferences.

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Enhancing the Reasoning Performance of STEM Students in Modern Physics Courses Using Virtual Simulation in the LMS Platform

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Abstract—The difficulty of tutors in all types of learning (face-to-face and online) is when they teach abstract concepts in modern physics courses, especially to improve students' reasoning skills. We see an opportunity that advances in digital technology can help overcome this problem. This study aims to improve the reasoning performance of STEM students in modern physics courses using virtual simulation integrated with the LMS platform. Experimental design was prepared with one control group (face-to-face learning with expository method). The sample was 54 STEM students at the University of Mataram which was divided into the experimental group (n = 27) and the control group (n = 27). Reasoning skills were measured using an essay test instrument, and the results were analyzed descriptively (analysis of increasing reasoning skills scores) and statistically (analysis of differences in reasoning skills scores between sample groups). The results of this study have clearly shown that the reasoning performance of STEM students in modern physics courses can be improved by learning using virtual simulation on the LMS platform. Descriptive and statistical analysis of the reasoning performance of STEM students shows the advantages of learning using virtual simulation when compared to face-to-face learning that relies on expository methods. We recommend using virtual simulation on the LMS platform to teach abstract concepts that are not limited to modern physics but in science learning in general.

Keywords—reasoning skills, virtual simulation, modern physics courses

1 Introduction

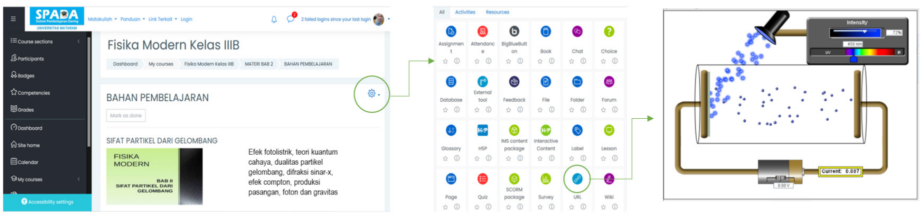
Technology has penetrated all areas of human life, including in education. The use of technology as a form of aggressiveness in all types of activities in the 21st century. Mobile tablets and smartphones provide continuous access for users anywhere and anytime. Accessibility has an impact on the ease of finding information efficiently and has an impact on open social access with other people [1]. Embedding the transformation of learning using technology is a necessity, especially now that its use is increasingly massive in the midst of the Covid-19 pandemic, where technology is no longer a secondary learning tool but has become a primary need in conducting learning materials to students at all levels of education, including higher education.

Technology can provide the right medium for teachers to nurture higher-order thinking in students, a key element of 21st century skills [2], through carefully structured activities [3], [4]. However, most of the time the use of technology in education is used as a source of information rather than as a process-based means to construct knowledge [5]. Therefore, to make a difference to the widespread use of technology, technology must be used as a pedagogical tool for learning and teaching [6], and the pedagogical value of technology is reflected in the level of student involvement and the nature of their participation in learning [7].

Within the framework of STEM education, the fulfillment of new styles of learning is increasingly relevant as technology develops rapidly and this leads to virtual systems [8]. The conduction of learning that utilizes it is not a temporary phenomenon that will last a short time, but the current and future educational formats are likely to continue to utilize technology [9]. One of the uses of technology in learning is a virtual learning system (e-learning). In the design of classroom learning, education providers are encouraged and asked to prepare e-learning to balance the interest in this technology [10]. A long before the Covid-19 Pandemic, many institutional organizations around the world used online systems as an alternative teaching method [11]. In line with the development of online learning technology, a pedagogically effective instructional design is needed to facilitate the achievement of learning objectives, better learning outcomes performance, and create an attractive learning environment so that students do not lose their interest in learning [12].

The interaction and involvement of STEM students in learning is still a problem [13], especially in relation to practicing their reasoning skills [14]. This reasoning ability is an important concern because it is a predictor of student achievement in the STEM field [15]. Reasoning in a more familiar context is called critical thinking [16], [17], this is identified with the attribution of specific abilities such as analysis, inference, evaluation, and decision making [18]–[22]. Acquiring this attribution of critical thinking or reasoning is very important for students [20], it's just that the arguments of previous studies [23] show that effective learning designs to train them are still not well established, especially in supporting STEM student interactivity and engagement. Referring to our experience of teaching physics courses for more than 10 years, there are difficulties in how to teach physics on materials with a high level of abstraction such as modern physics courses. This has an impact on the low reasoning of students, coupled with the interest and motivation to learn students tend to fall. However, we are optimistic about the current massive technological developments that can mediate the teaching of modern physics in more interactive ways and can visualize abstract concepts in physics. Previous studies have recommended the use of virtual simulations in teaching science concepts, and it has resulted in better concept mastery, a better preference for scientific theory, and an increase in students' thinking skills [24].

Teaching with an e-learning system brings students to a virtual environment, visualization of material in many aspects of teaching is found in many formats such as augmented reality, gamification, virtual and remote laboratory, virtual reality, interactive video, and virtual simulation [24], [25]. Focus in the current study is on virtual simulations, where the results of a study by Hassan and colleagues [26] show that student acceptance is very good in its application in the classroom, and has a positive impact on three areas of student learning (knowledge, skills, and attitudes), and conclusively impact on students' better academic performance [27]. The advantages are clear, virtual simulation helps overcome physical and mental limitations in reaching abstract concepts, and helps overcome other problems in learning related to accessibility [28]. Virtual simulations have now developed, in which experimental spaces and designs are prepared students can manipulate experimental parameters according to their needs [29]. In the e-learning system at the university, it is integrated with the Learning Management System (LMS) at the university and its use depends on access permission from the designer (some can be accessed freely or otherwise), they are lecturers as full controllers of the learning system through the LMS. In relation to the current study, we integrated virtual simulation with LMS in modern physics courses to improve the reasoning abilities of STEM students. The learning design in this study is presented in Figure 1.



(a) (b) (c)

Fig. 1. Learning design in modern physics courses using virtual simulation in the LMS platform

The literature on the use of technology in education and learning is mostly directed at cognitive domains, such as knowledge; technology, content, pedagogical, content-pedagogical, technological content, pedagogical-technology, and technological knowledge [1]. In addition, another study highlights the attitude aspect in its use [30]. However, -in our best knowledgement-, the use of technology (virtual simulation) in modern physics lectures to build reasoning abilities of STEM students has not been studied adequately. For the distance learning system, the university has built a learning system infrastructure within the LMS platform.

2 Research methods

2.1 Research design

This study is an experimental study with the randomized pretest-posttest control design [31]. Through a randomization scheme, two sample groups have been determined. They were given treatment as experimental (E) and control (C) groups. The experimental group was given learning treatment using virtual simulation in the LMS (e-learning) platform, while the control group with face-to-face learning used the expository method. Before treatment, both sample groups were observed for their reasoning abilities as pretest (O_1) and posttest (O_2). In simple terms, the research design is as follows.

Experimental group	R	O_1	E	O_2
Control group	R	O_1	C	O_2

The study was carried out on both groups of samples on the same material in modern physics courses, namely the photoelectric effect, quantum theory of light, wave particle duality, x-ray diffraction, Compton effect, pair production, photons and gravity. This material is taught to STEM students in four meetings.

2.2 Research sample

The sample was 54 STEM students at the University of Mataram which was divided into the experimental group (n = 27) and the control group (n = 27). Demographics of the sample is presented in Table 1.

Table 1. The Sample demographics

Characteristics		Exp. group, n = 27		Cont. group, n = 27	
		Quantity	***%***	***Quantity***	***%***
Gender	Female	23	85%	17	63
	Male	4	15%	10	37
Age (year)	< 18	1	4%	0	0
	18 – 19	24	89%	23	85
	> 19	2	7%	4	15

2.3 Research instruments and analysis

The data of reasoning skill (RS) of STEM students according to indicators; reasoning-analysis (RA), reasoning-inference (RI), reasoning-evaluation (RE), and reasoning-decision making (RD) were collected using an essay test instrument. Each indicator consists of two items so that the number of reasoning ability test items is 8 questions. The highest score assigned by each item as the maximum reasoning ability is +4 (descriptor: the answer was correct, and a strong argument supported each reasoning indicator with facts, concepts, and laws), and the lowest is 0 (no answer was provided). Based on this scoring criterion, it is then converted into an equation interval (Prayogi et al., 2018), and the interval category of reasoning ability is summarized in Table 2. Reasoning skill is measured based on parameters of indicator (RSi) and individual (RSs).

Table 2. Criteria for reasoning skills based on parameters of RSi and RSs

Reasoning skills criteria	Score intervals of RSi	Score intervals of RSs
Very good	RSi > 3.21	RSs > 25.60
Good	2.40 < RSi ≤ 3.21	19.20 < RSs ≤ 25.60
Enough	1.60 < RSi ≤ 2.40	12.80 < RSs ≤ 19.20
Less	0.80 < RSi ≤ 1.60	6.41 < RSs ≤ 12.80
Poor	RSi ≤ 0.80	RSs ≤ 6.41

Data analysis of reasoning skills descriptively refers to the criteria in Table 2, and the increase in the score of reasoning skills (n-gain) refers to Hake's formulation [32]. Furthermore, statistical analysis (difference test between sample groups) was carried out to determine the difference in the increase in reasoning skill scores in the two samples ($p < 0.05$). This was preceded by a normality test ($p > 0.05$) using the Shapiro Wilk test (because the sample group members were < 50). Statistical analysis using SPSS 25.0 tool.

3 Results and discussion

The summary of the results of the descriptive analysis of reasoning skills in STEM students is presented in Table 3, this refers to the reasoning skill criteria of each treatment group based on the parameters of the four indicators (RSi).

Table 3. The results of the measurement of each reasoning skill indicator (RSi)

Group	N	Score	Reasoning skill indicator (RSi)				RSi average
			RA	*RI*	*RE*	*RD*	
Experimental	27	Pretest	1.11	1.02	1.13	0.96	1.06
		Posttest	3.04	3.19	3.24	3.20	3.17
		N-gain	0.67	0.73	0.74	0.74	0.72
Control	27	Pretest	1.11	1.04	1.11	1.15	1.10
		Posttest	1.37	1.43	1.39	1.31	1.38
		N-gain	0.09	0.13	0.10	0.06	0.09

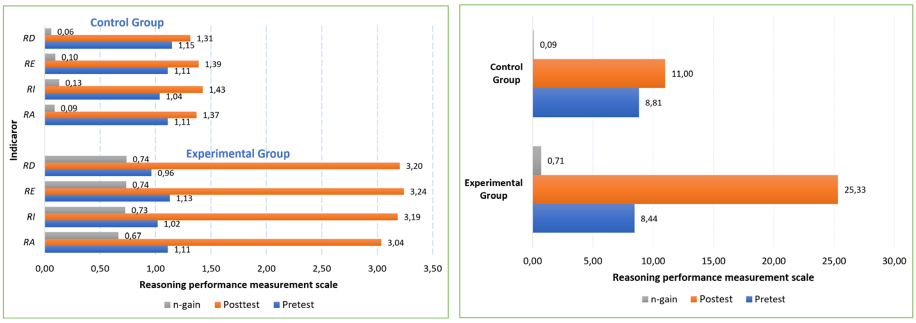
The results in Table 3 show an increase in the pretest to posttest scores according to the RSi criteria for both treatment groups. For the experimental group, the highest increase was found in the RE and RD indicators followed by RI and RA indicators, the average increase in the RSi score for the experimental class was 0.72 with high criteria.

An increase in RSi on the low criteria was found in the control group with an n-gain of 0.09. Furthermore, the performance of the reasoning skills of each treatment group based on the RSs parameter is summarized in Table 4.

Table 4. The results of the measurement of reasoning skills based on the RSs parameter

Group	N	Reasoning skills score and criteria				n-gain	Category
		O_1	***Category***	***O_2***	***Category***		
Experimental	27	8.44	Kurang	25.33	Baik	0.72	High
Control	27	8.81	Kurang	11.00	Kurang	0.09	Low

The summary of the RSs results in Table 4 indicates the good performance of reasoning skills of STEM students in the experimental group, on the contrary, the RSs control group is categorized as poor in pre and posttest. Visualization of the results of the reasoning skills of STEM students based on the RSi and RSs parameters is presented in Figure 2.



(a) (b)

Fig. 2. Reasoning skills of STEM students: a) based on the RSi parameter, and b) based on the RSs parameter

The results in Figure 2 clarify the differences in the performance of STEM students' reasoning skills in the two treatment groups. Based on the RSi parameter in the pretest-posttest, students' reasoning skills increased from 'less' to 'good' and this was different from that found in the control group they remained in the 'less' category. Furthermore, the difference in the increase in reasoning skill scores between the two groups was tested. statistically, this is based on the assumption of normality in both groups. The summary of the results of the normality test is presented in Table 5.

Table 5. Normality test results, $p > 0.05$

Group	Shapiro-Wilk			Data normality
	Statistic	***Df***	***Sig.***	
Experimental	0.947	27	0.184	Normally distributed
Control	0.888	27	0.007	Not normally distributed

One of the two groups of data to be compared is not normally distributed, therefore the difference test of the two data groups uses a non-parametric test (Mann Whitney test). The results are presented in Table 6.

Table 6. Mann Whitney test results, $p < 0.05$

Group	n	Mean Rank	Sum of Ranks	Mann-Whitney	Sig. (2-tailed)
Experimental	27	41.00	1107.00	0.000	0.000
Control	27	14.00	378.00		
Total	54				

The results of the Mann-Whitney test showed sig. <p (0.05), it means that there is a significant difference in the reasoning skills of STEM students between the two treatment groups. Confirming the results of this analysis, it has been explicitly proven that the reasoning skills of STEM students who are treated with learning using virtual simulations in an LMS (e-learning) platform are better than face-to-face learning using the expository method. The results of this study are in accordance with what was found in previous studies, that virtual simulations can improve students' thinking skills [24]. In another study it was found that computer-based simulation had a positive impact on students' reasoning abilities [33].

Virtual simulations allow learners to build visual representations during the learning process, and this has an impact on their critical reasoning [34]. The findings of this study have confirmed that in addition to supporting learning interactivity, virtual simulations have an impact on improving the reasoning performance of STEM students so that it can be used as a cognitive tool in a wider learning context. Visualization of abstract concepts or theories can motivate STEM students in learning and their higher order thinking skills can develop [35]. Although in the context of the current study we did not explicitly observe the learning motivation of STEM students with the application of this virtual simulation, in fact the acceptance or response of STEM students was very good which was marked by the interactivity that was built in learning. It was also found in a previous study [26] that student acceptance was very good in the application of virtual simulations in the classroom, and had a positive impact on the realm of learning in terms of knowledge, skills, and attitudes.

This study has met expectations on the fulfillment of student accessibility in understanding modern physics concepts that are not limited to space and time. When compared to face-to-face learning that relies on expository methods, the reasoning performance of STEM students is superior to learning that uses virtual simulation. The advantages are clear, virtual simulation helps overcome physical and mental limitations in reaching abstract concepts, and helps overcome other problems in learning related to accessibility [28]. Finally, for the continuous learning process we recommend the use of virtual simulation in particular to teach abstract concepts in science, and of course this requires professionalism and serious efforts from stakeholders to achieve better learning goals and outcomes.

4 Conclusion

The results of this study have clearly shown that the reasoning performance of STEM students in modern physics courses can be improved by learning using virtual simulation on the LMS platform. Descriptive and statistical analysis of the reasoning performance of STEM students shows the advantages of learning using virtual simulation when compared to face-to-face learning that relies on expository methods. We recommend using virtual simulation on the LMS platform to teach abstract concepts that are not limited to modern physics but in science learning broadly.

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