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Going beyond the LMS logs. The complexity of analyzing learning evidences

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Abstract

The analysis of students' learning evidences is a key issue in the assessment process. This analysis has become more affordable because educational institutions use Learning Management Systems that track what students are doing. However, evaluation of students learning is much more complex than just presenting or summarizing some of their results; it requires to consider issues such as the context, the type of activities carried out, the learning objectives to achieve or the students' interactions. This paper presents this situation and a sample of how to deal with Learning Analytics for the evaluation of teamwork competence. In order to do this, first we explore the issues related with complexity in LA approaches, later on explore how to assess teamwork competence and present a case study at the University of León, that describe how teamwork assessment was carried out along several academic years.

Keywords

Learning Analytics, Learning Evidences, Interactions analysis, Instant messaging tools, Complexity.

1. Introduction

Educational processes have never been simple and one of the most complex activities could be assessment. Assessment, whether summative or formative, requires evaluating evidence of what students have learned. For some time now, not only the assessment of learning outcomes has been considered, but also the assessment of process followed to achieve these outcomes. This needs attending to the learning process and all the activities that students develop on it. This, in many cases, is done through observation, but it is not always enough specially because not all the phases of the learning process are done in the institutional environments and because in many cases, especially with large students' groups observation can be really complex [1].

With the emergence of online learning activities all the educational institutions have installed a Learning Management System (LMS). This type of platforms can be seen as an environment to manage course, contents, activities and tools for the teachers; and such as a fire camp for students, where they have their courses, contents, tests and so on [2]. Any of these stakeholders are going to leave evidence of what they have been doing in the platform. That is, if they have logged in, if they have accessed to a resource, the time they spend using it, the grade on a test, etc. The LMSs are going to provide us with reports with such kind of data; however, they are not enough to understand how to improve students learning, which is one of the key issues of Learning Analytics (LA).

LA can be defined as *"the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs"* [3]. By applying LA, it is going to be possible to obtain more knowledge about what our students are doing and how they are learning. But at this point, it is important to be aware that not all the available data could be processed and analyzed, and this is a quite complex process.

Where is the complexity on LA analysis? It may depend on several issues such as:

- The context. This a critical issue for the application of LA because the context can constrain the way in which the data exploration or the analysis is done. It is necessary to address the issues such: 1) the learning modality, quantity and type of data are different in contexts

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where learning is carried out only online vs those where classes are blended; 2) the technological systems employed, LMSs, videoconference tools, etc.; 3) the LA tools available for teachers and managers; and 4) the institutional LA policy, if any, and if the LA strategy is based on approaches closer to academic analytics, to learning analytics or both; the possibility to install or not new tools, etc.

- The data access policy. Other important issue when considering applying an LA approach is to know how accessible data is. In this case we should consider the data protection law to be applied that can be defined at different levels: institutional, regional, national, European, etc. In addition, it is necessary to know if it is possible to access to all the data stored in the LMS or only to some parts and if it is possible to access to the logs of activities carried out in external tools employed by the institution.
- Ethical policy. Sometimes, it is not considered ethical to use students' information or track what they are doing. This should be defined at an institutional level. If some of the data could not be used because of ethical reasons this should be considered, specially at the beginning of the application of LA.
- The application scope. At what level LA will be applied. The information required by the institution cannot be the same as that required by the teachers. It is not the same trying to gather information about students of several courses and exploring the results in a specific activity. Depending on this, metrics should be defined.
- The metrics. What data do we need to explore and analyze to obtain certain knowledge? What would we like to assess? These are questions that could help us to evaluate the data, but the definition of the proper metrics is not so straightforward. It requires considering the previous mentioned factors and taking into account existing works in the literature.
- Experts support. It is convenient to know if there is some technical team that can support the teacher in accessing the data, generating reports, or installing LA tools. In addition, it is desirable to have a team with a data science background that can help the teachers to understand which the best way is to explore the data.

This paper is going to present a case study related to the analysis of the individual acquisition of teamwork competence TWC. We are going to describe each of the previous defined factors and how the LA approach is developed at the University of León. In order to do so the rest of the paper is structured as follows: in section 2 we will present a brief description of the adopted LA approach. Later on, we will describe how it was applied taking into to account each of the previously described items. After it, we will comment some of the results and tools employed and finally some conclusions are posed.

2. Teamwork competence assessment LA approach

One of the main aims of universities is preparing students to succeed in labor market. In order to do so, learners should achieve competences that later would need as professionals. Among them a relevant competence to acquire is Teamwork Competence. It is a highly demanded competence by companies [4], so it is very important to facilitate developing it in education institutions.

This type of competence can be developed by applying active methodologies such as Project Based Learning [5] or Challenge based learning [6] that in most cases require working in groups, very popular and especially useful in our actual learning contexts. However, although teamwork can be developed more or less easily the evaluation of the acquisition of such competence is quite hard. The common way to proceed in many cases is to do a summative assessment, that is, to evaluate the final outcome submitted by each of the groups. However, this is not enough to know if students are working properly in teams. It is necessary to check the final result, but also the intermediate results and how each of the students work together as a group while addressing the projects or challenges. This can be time-consuming, especially because it is necessary to track what each group member is doing [1]. One of the advantages of LMS and other institutional tools is that we can access to logs about what each student has done and use them during the evaluation, but it is necessary to apply LA tools and techniques that make this evaluation affordable in time [7, 8].

At the University of León teamwork competence acquisition has been evaluating in several subjects. Since 2015 a methodology known as CTMTC (Comprehensive Training Model of the Teamwork Competence) [9] has been applied. This methodology has been adapted from IPMA method for project management [10]. These projects are addressed in groups by using different Information and Communication Technologies (ICT). CTMTC comprises several stages that produce different outcomes and require a formative and a summative evaluation. As the students use ICT to complete the activities and to interact between them, their activity is logged in the systems and can be later analyzed. To carry out the analysis several ad-hoc defined LA tools were developed. These tools extract data from Moodle and other contexts. Such data is analyzed and presented to the teachers to facilitate the assessment process. In the next sections we will present some of the applications of LA that have been used at the university in several academic courses of 5 subjects with a total of more than 600 students [1, 11-16].

3. Case study of the application of LA at the university of León

In this section we will present how the application of LA at the university of León has been, a description from the first years of application up to now, the methodology flexibility and the different tools used. First of all, it is important to introduce the case study focusing on the factors stated in the introduction:

- Context. The University of León is a Spanish public educational institution located at the north-west of Spain with 10.152 students in 2021/2022 academic year [17]. Most of the classes are face to face with a small percentage of online learning.
  Both for face-to-face classes and for online learning the LMS employed by the University of León is Moodle. It has a log system that tracks many of students' activities. Some external tools are also provided by the institution, such as Google Suite, Office 365, AVIP Videoconference System, Turnitin, etc. Teachers can use other tools for educational activities. Regarding the LA tools, the teachers can use Moodle reports. However, although they are quite varied, they provide too much data and not so useful information. The university does not allow the installation of external plugins just by teacher request, they require a further study by the university ICT team. In 2021 the university acquired an Intelliboard Learning Analytic system, but it is not available for all the teachers. Although at the university different teachers use LA techniques and tools there is not a specific and public policy about this topic.
- The data access policy. The university has a data access policy [18] that follows the Spanish Regulation and the EU-GDPR. As in any educational institution, teachers can access to their students' data and to the grades, but students' data must be maintained in the institutional environments where the university is in charge of personal data security and confidentiality. In addition, when a research activity involves students' data, the ethical commission of the university must approve it. With this consent data can be used anonymously and as aggregated numbers. In this case we have to follow the rules applied by the institution and also we purse the ethical policy. We should point out that with external tools the data does not belong to the institution, so the companies or institutions in charge of such tools are which define the data access policy.
- Ethical policy. The university has an ethical committee that is in charge of all the ethical initiatives. There is not a specific protocol for ethics related to Learning Analytics, but the regional, national, European and international rules and recommendations are adhered to. In addition, each activity will explicitly publish what it is going to do with data, so the students can decline to participate. In the years of application of LA zero students declined to complete the activity in which we apply the tools and techniques.
- The application scope. The university has neither published LA initiatives for the whole institution, nor it has been applied at Faculty, Degree or Course level. The ones carried out were done in the context of a subject or an activity of a subject. For instance, the CTMTC case has been applied in several subjects of Computer Science Degree, in each of them differently. For instance, in Operating Systems it is applied to a project that students should solve in teams and

that has a weight of the 42,25% of the final grade. Other subjects, such as Computer Animation, applied the same methodology from the beginning of the subject to all the practical parts.

- The metrics. When it comes to the metrics, they are based on the methodology. It is possible to have metrics for different types and degrees of analysis. In the case of CTMTC application the most time-consuming part of the evaluation was to measure the interaction among students. It requires reading a lot of posts or messages to know which student was working more and how many of them less, check logs about reads and so on. To help measuring students' interaction, a rubric was defined and employed [15]. It focuses on the issues such as responsibility and engagement (that can be measured considering the messages and if they are short or long), tracking what the team members are doing (visits to the threads or messages read), interaction (messages answering other or providing peers feedback about something), leadership (conversations started, problem solving, first and last messages about something, decisions made). The metrics depend on the data available, the type of data, the analysis techniques available and what you would like to explore. For instance, decision making is something difficult to measure based just on the number of messages, or the length of them. It requires, among other things, knowing what is written in the messages. To analyze this, it is possible to apply natural language processing and look for patterns [19, 20], sentiment analysis [21, 22] or dialog acts [23]. For the case study presented, the previous mentioned rubric was used; however, it has been evolving with the application of new LA tools.
- Experts support. For this case study the teachers are also experts on programming, so the technical part was not a problem, however, sometimes it was necessary the help of data scientists to know what data meant. For instance, to know if some kind of intervention can be associated to an improvement in students' grades, something that is shown in Fidalgo et al. work [1].

4. Solutions adopted

After we have described the complexity of the case study, we are going to comment how it was carried out. As it was developed throughout several academic years and in different subjects it is important also to attend to how the application of LA has evolved in the context.

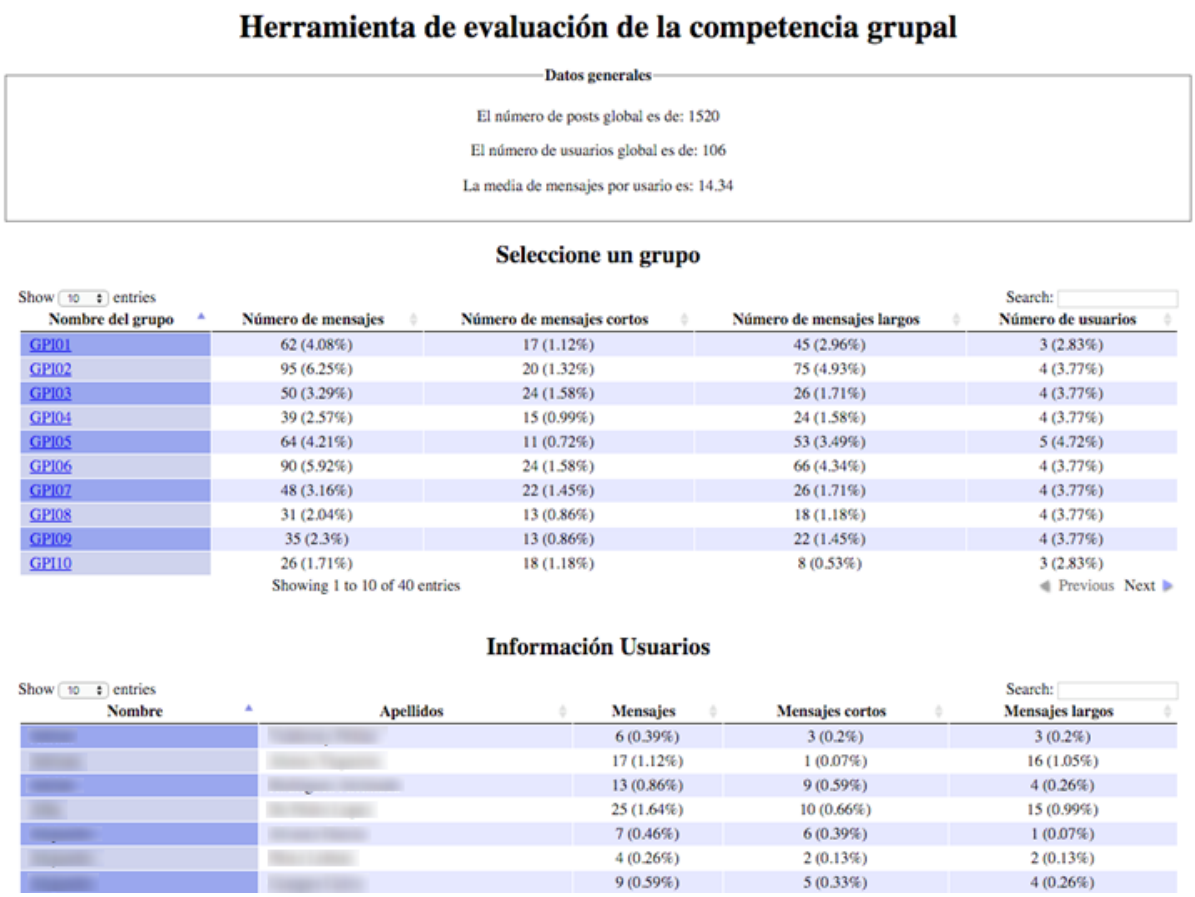
4.1. The subjects

The LA approach was carried out initially in Operating Systems, a second subject of Computer Science Degree Course. Within it, the CTMTC methodology and the LA tools were applied to a project development that has a weight of about 22% of the subject grade. After this first application, other subjects began to use the LA approach. More specifically six more subjects were involved, so it was possible to check the flexibility of the methodology and the tools as their contexts were very varied. For instance: the weight of the assessed activities goes from a 10% to a 60% of the final grade, students from 8 to 144, the way in which the students were divided into groups was is different, etc. In most of them the students interaction was carried out in Moodle forums and the intermediate results were described through a Moodle Wiki [11]. This application was maintained in the subjects during two academic years, after that only Operating Systems, Accessibility and Computer Animation maintained it. The rest continued with other kind of analytics approaches [24-27].

In the three subjects that continue with the methodology, some changes were also carried out. These changes are mostly based on experience. In Operating Systems the first change was the weight of the activity in which the LA approach was used, passing from a 22% to other activity that has a 42.25%. There were also changes in Accessibility subject regarding the group formation, at the beginning students were divided into groups by the teacher and later the students could decide on the team members. In Computer Animation, in which the methodology was applied twice, the one for parts of the project development in groups of about 6 persons and the other in the integration of such parts with groups of 20 participants, it finally changed to small groups and just one application.

4.2. The approach

As in most of the subjects, at least at the beginning, the approach was similar to what we are describing here. CTMTC in any of the subjects was applied to a practical work that usually implies carrying out a project in groups. The groups were formed by the students or the teachers; it depends on the subject. Once the groups have been formed, the students should conceive the project following the methodology stages. Stages such as group forming, planning, development are carried out using ICT tools, such as Moodle Forum, Moodle Wiki, Moodle Assignment Module, Google Drive, Control Version Systems, etc. When assessing the acquisition of teamwork competences, individual and group evidences were evaluated following the rubric previously commented [15]. The evaluation of the interaction between peers is an important issue in CTMTC, in order to facilitate this we used the LA tool defined [1]. It provides information about the group and about the team-members, as shown in Figure 1.



Herramienta de evaluación de la competencia grupal

Datos generales

El número de posts global es de: 1520

El número de usuarios global es de: 106

La media de mensajes por usario es: 14.34

Seleccione un grupo

Show 10 entries — Search:

Nombre del grupo	Número de mensajes	Número de mensajes cortos	Número de mensajes largos	Número de usuarios
GPI01	62 (4.08%)	17 (1.12%)	45 (2.96%)	3 (2.83%)
GPI02	95 (6.25%)	20 (1.32%)	75 (4.93%)	4 (3.77%)
GPI03	50 (3.29%)	24 (1.58%)	26 (1.71%)	4 (3.77%)
GPI04	39 (2.57%)	15 (0.99%)	24 (1.58%)	4 (3.77%)
GPI05	64 (4.21%)	11 (0.72%)	53 (3.49%)	5 (4.72%)
GPI06	90 (5.92%)	24 (1.58%)	66 (4.34%)	4 (3.77%)
GPI07	48 (3.16%)	22 (1.45%)	26 (1.71%)	4 (3.77%)
GPI08	31 (2.04%)	13 (0.86%)	18 (1.18%)	4 (3.77%)
GPI09	35 (2.3%)	13 (0.86%)	22 (1.45%)	4 (3.77%)
GPI10	26 (1.71%)	18 (1.18%)	8 (0.53%)	3 (2.83%)

Showing 1 to 10 of 40 entries — Previous Next

Información Usuarios

Show 10 entries — Search:

Nombre	Apellidos	Mensajes	Mensajes cortos	Mensajes largos
[redacted]	[redacted]	6 (0.39%)	3 (0.2%)	3 (0.2%)
[redacted]	[redacted]	17 (1.12%)	1 (0.07%)	16 (1.05%)
[redacted]	[redacted]	13 (0.86%)	9 (0.59%)	4 (0.26%)
[redacted]	[redacted]	25 (1.64%)	10 (0.66%)	15 (0.99%)
[redacted]	[redacted]	7 (0.46%)	6 (0.39%)	1 (0.07%)
[redacted]	[redacted]	4 (0.26%)	2 (0.13%)	2 (0.13%)
[redacted]	[redacted]	9 (0.59%)	5 (0.33%)	4 (0.26%)

Figure 1: General information and user information [16]

The application of CTMTC showed an improvement when it comes to the grades in those subject parts where it was used [15, 16]. However, one of the problems detected was that students do not use forums for their interaction - they use other tools and specially instant messaging tools [28]. If the interaction is carried out in these tools, it is necessary to take into account that the activity is developed beyond the institutional environment which requires changes in the methodology, the evaluation rubric and of course the tool [29].

The methodology was adapted to gather all students' interaction in just one chat group instead of managing each stage in different threads. The rubric should reconsider how interaction is carried out, for instance, it is important to take into account when a message belongs to a conversation, what a reply is, what an emoji means, what can be considered long and short in this new context. The LA tool then requires an adaption. It needs to be adapted not only to show the information employed by the new rubric, but also to require facilitating students to upload their conversations. The teacher creates a

WhatsApp activity in the platform and the students can upload a text file with their conversations, although as each message is associated to a phone number it is necessary to preprocess the file to replace each phone number or contact name with an ID [30] (Figure 2).

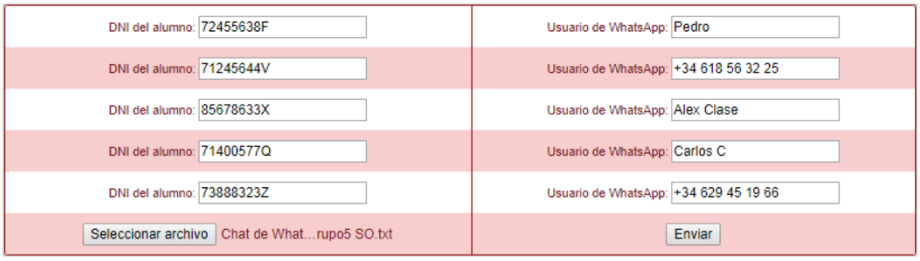


Figure 2: Preprocessing functionality for the LA tool, the personal id is in the left column and the phone number or contact name is on the right [30]

CTMTC adaption to WhatsApp was successful, the number of messages increased, and grades were improved. However, not all students were happy using a proprietary tool and having to do the preprocessing. This meant to look for a new adaption, in this case to Telegram Instant Messaging Tool. The methodology remained the same, but the tool needed to change. In this case Telegram API provided much more information, such as the number of emojis, replies, etc; obtaining results quite useful for the review. A sample of the use of this new approach can be found at [31] and some screenshots of the new dashboard are seen in Figure 3.

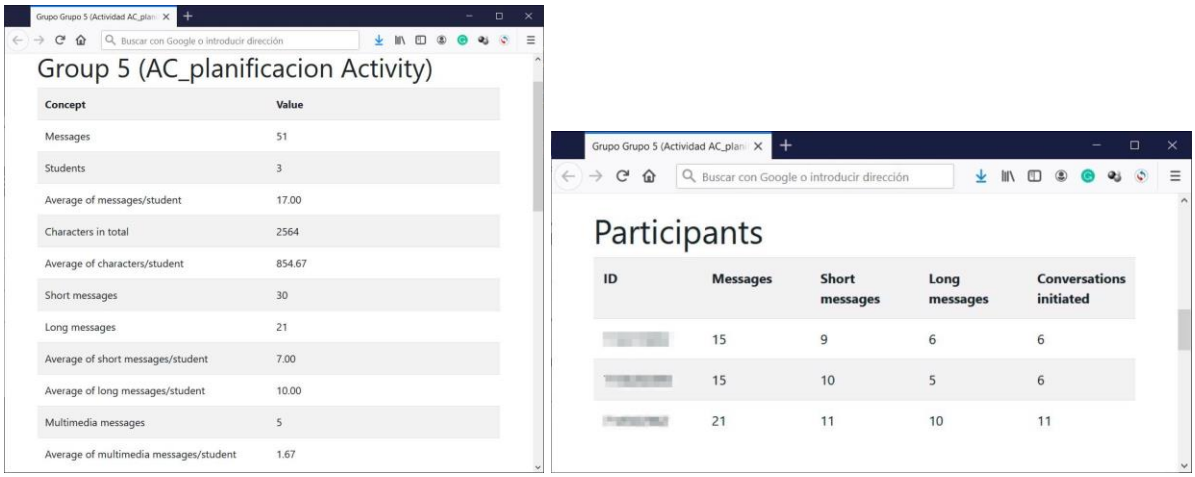


Figure 3: Individual and group information for Telegram Dashboard [32].

Following all these experiments the teachers involved pointed out that it was very interesting to explore not only the number of messages but also the content of such messages, in this way it would be possible to explore issues such as teamwork behavior, leadership, sentimental analysis. In order to do so Natural Language Processing [33] approaches were used; the tool was improved including a complete new dashboard (Figure 4) and providing other metrics [34].

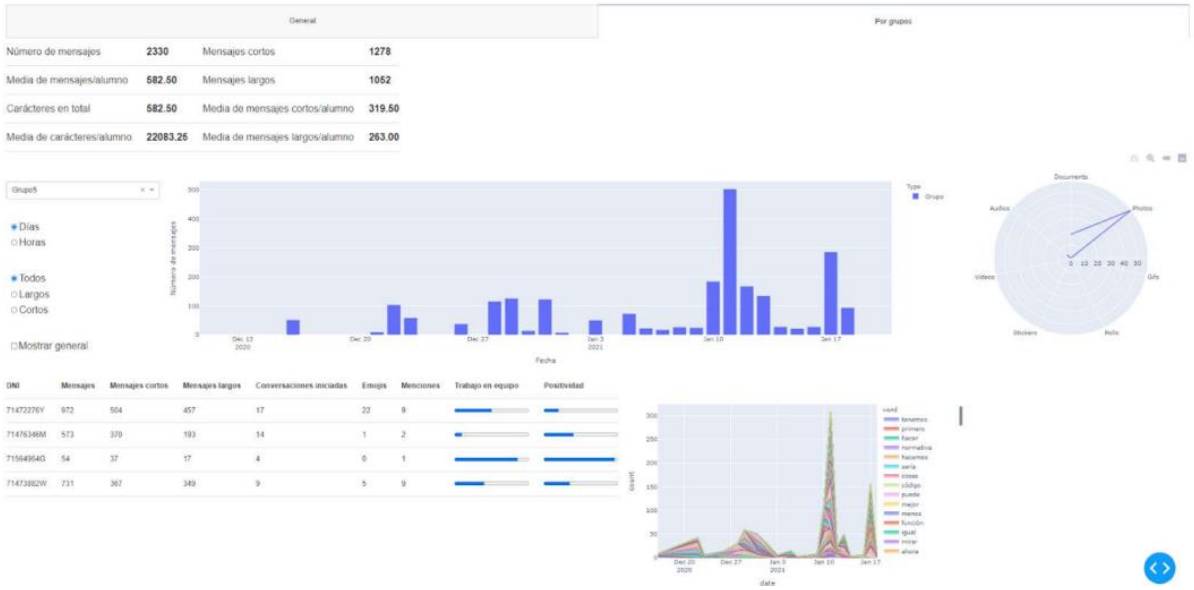


Figure 4: Group information in the PNL Telegram dashboard [34].

It was applied just one academic year so it is early to make conclusions about the performance of the new approach.

5. Conclusions

LA is a powerful discipline with the final aim to improve students' learning. However, LA application requires a deep study Acknowledgment of the context where it is applied, the data nature, the institutional policies and, last but not least, to have a clear idea about what to study and how to assess it. The process is quite complex, but the results are really interesting.

In this paper, we have presented several issues that should be taken into account when applying LA and the case study that shows how a methodology was applied during several academic years and how this application and the associated LA tools have been evolving. From these experiments it is possible to see how important it is to learn from experience and refine the process, the success of the application could depend on several factors, but it is essential to consider opinions of all the involved stakeholders and explore the literature looking for the best solutions.

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Using descriptive and predictive learning analytics to understand student behavior at LMS Moodle

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Abstract

Learning analytics is a data-centric field that applies machine learning algorithms in the educational domain to analyze e-Learning environment data. This study employs descriptive and predictive learning analytics approaches in order to develop descriptive and predictive models of student behavior and success. Cluster analysis, unsupervised machine learning algorithm, and decision tree, supervised machine learning algorithm, are applied on the data from a Learning Management System (LMS) Moodle. Research results indicated: (i) groups of students with similar patterns in behavior at LMS, (ii) student activities at LMS that lead to successful course completion. Such results serve as guidelines for teachers when developing courses and students when enrolling in the course. Descriptive and predictive learning analytics is an innovative approach in education that can enhance teachers and students and improve learning outcomes.

Keywords

Learning analytics, educational data mining, LMS data, machine learning.

1. Introduction

Implementation of learning management systems (LMS) has grown exponentially during COVID-19 crisis. There are numerous LMS-s developed, such as Moodle, Edmodo and Blackboard. These systems generate a huge amount of data about students' activities. Such data are a valuable source of information for students, teachers and faculty management. In order to obtain knowledge from raw data, data mining should be conducted on structured data from LMS. The use of data mining is shown to give promising results in this area [1]. Educational data mining and learning analytics are subfields designed especially for knowledge extraction from educational data. Both fields are focused on detecting patterns in educational datasets. A list of data mining and learning analytics tasks includes statistics, clustering, classification, prediction or subgroup discovery, among others [2]. In this paper clustering and prediction are combined on the Moodle LMS data set. Previous research papers showed that Moodle is LMS which is mostly used [3], [4].

The data about students' activities at the LMS invokes numerous questions regarding prediction. In this paper, we present a study on the effectiveness of descriptive and predictive learning analytics to describe student activities at LMS and predict students' success in the course. Whereas various works have used these techniques to analyze students' LMS activity, our study combines two approaches.

This paper is structured as follows. Section 2 reviews related work on the given topic. Section 3 explains data and methodology. Section 4 gives research results along with their explanation and interpretation. Section 5 concludes the paper, discusses research limitations, and gives guidelines for future research in this domain.

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2. Related work

Students` success prediction was the subject of numerous research papers so far. Recent work in the educational scientific community strives to exploit the potential of learning management system data to develop accurate and reliable prediction models. Hereinafter, we provide an overview of existing research papers close to our approach.

In the recently published study of Feldman-Maggor et. al. [5] focus was on the characterization of students based on their learning patterns and the authors strived to identify indicators for students' success prediction in an online environment. On the data from undergraduate online chemistry courses, logistic regression and a decision tree algorithm were applied. Assignment submission and the students' video viewing are the most significant predictors. The authors emphasized the importance of students' choices they make regarding their learning process.

Gašević et. al. [6] presume that instructional conditions influence the prediction of academic success. They performed research in nine undergraduate courses offered in a blended learning model. The study illustrates the differences in predictive power and significant predictors between course-specific models and generalized predictive models. The results suggest that it is imperative for learning analytics research to account for the diverse ways technology is adopted and applied in different courses and in different domains. The authors conclude that differences in how students use the learning management system require further research examinations.

Costa et. al. [7] evaluated various educational data mining techniques for the prediction of students' failure in programming courses. Authors strived to investigate the effectiveness of these techniques in the prediction of students failing to take actions that decrease the failure rate. They evaluated four techniques (Naive Bayes, decision tree, neural network and Support Vector Machines) on two data sets from programming courses at Brazilian Public University. One dataset is from distance education and the second one is from on-campus.

Cerezo et. al. [8] examined students' learning process patterns using Moodle logs data. The authors grouped students according to similar behaviors regarding effort and time spent working. Different patterns of students' behavior at the LMS were clustered and the relationships between patterns and students' grades were analyzed. 140 undergraduate students enrolled in Moodle 2.0 course were included in the research. Results indicated variables predicting students` results. Their results could serve as a basis for the improvement of students' achievement in LMS.

Conijin et al. [9] analyzed blended courses in one institution using LMS Moodle. The authors predicted student achievement from LMS variables using multi-level and standard regressions. Their results showed that predictors vary significantly across different courses. The generalization of such prediction models is low.

Macfadyen et al. [10] used LMS tracking data to explore which student online activities could predict academic success. Their analysis from a Blackboard Vista identified variables correlated with student grades. Regression was applied in data analysis resulting in a predictive model for this course which identified variables such as a number of messages posted and number of completed assessments as variables explaining the most variation in student grades. The logistic regression approach showed an accuracy of 81%. These results are useful for the extraction and visualization of LMS data on student engagement and the likelihood of success.

Matcha et. al. investigated students` learning strategies [11]. Among others, clustering was used to detect and interpret learning tactics and strategies. Recently, Saqr and Lopez-Penas [12] examined online engagement by applying clustering to reveal the clusters of students' learning strategies and engagement patterns in the courses.

Based upon previous research papers, hereinafter, we are combining descriptive and predictive analysis of LMS Moodle log data from one course taught through two generations of information technology students.

3. Research methodology

The goals of the research are:

(i) to identify the most important predictors of students' success among LMS Moodle logs data,
(ii) to group students of similar LMS behavior patterns,
(iii) to identify the relationship between students' clusters and student's success

To achieve the goals of this research, we address the following research questions:

(i) Which of the variables extracted from the LMS Moodle logs have the highest impact on the student's performance?
(ii) Can we create good student clusters based on their usage of the LMS?
(iii) Is there any correlation between students' clusters and students' success?

3.1. Data description

Data are collected from the course Knowledge discovery in data taught at the University of Zagreb, Faculty of Organization and Informatics. Dataset consists of two generations of students. The course was taught as an elective at the undergraduate study level. It was implemented as a blended course: lectures and lab exercises were held in the classroom combined with LMS Moodle usage. Data were extracted from Moodle for two generations of students, thus creating a sample of 83 students. Extracted variables considered a number of logs at specific resource and activity: File, Forum, Student Report, Folder, Choice, File submission, Overview report, Page, System, Test, and Assignment. Overall grade at the course was included in data analysis as a dependent variable.

3.2. Machine learning algorithms

Two machine learning algorithms were applied in data analysis: unsupervised machine learning algorithm cluster analysis and supervised machine learning algorithm decision tree. Clustering is an unsupervised machine learning algorithm used for grouping objects into clusters of similar objects [13]. In the e-learning context, clustering has been used for: finding clusters of students with similar learning characteristics [14]; discovering patterns reflecting user behaviors [15], or grouping students according to their characteristics to give them personalized learning approaches [16]. K-means clustering algorithm is applied because it is the mostly used clustering algorithm [17].

A decision tree is a supervised machine learning algorithm belonging to the information-based group of algorithms. Those algorithms develop predictive models by determining the most informative attributes for the prediction of a given task. In the e-learning context, classification and prediction have been used for: predicting students` success in the course [18], predicting students' performance and their final grade [19] as well as predicting the students' achievement along with discovering the relevance of the attributes [20].

For the prediction of student success based on the LMS activity, in this research supervised machine learning algorithm of the decision tree is used. Decision tree approach is simple to understand and interpret the results. Furthermore, previous research papers shown decision tree superiority when comparing with other approaches [21]. Finally, we study a model to analyze the influence of the LMS variables on the student's final grade in the course. Students` clusters are built within the same dataset, and finally, we investigate clusters and their correlation with students' final grades.

4. Research results

Data analysis consists of two parts. First, descriptive models were developed followed by predictive models. Table 1 reports CCC value (Cubic Clustering Criterion) for three different groups: 2, 3 and 4. Three clusters are optimal for a given dataset since CCC value is the lowest.

Table 1. Descriptive model evaluation

Number of clusters	CCC
2	-3.802982345
3	-1.666896309
4	-2.510022785

Three groups of students are identified. Cluster 1 consists of 42 students, cluster 2 of 4 students, and cluster 3 of 37 students. Characteristics of each group are given in tables 2 and 3 as mean values for the groups.

Table 2. Students clusters characteristics

Cluster	File	Forum	Student report	Folder	Choice
Cluster 1	43	39	6	3	5
Cluster 2	101	130	14	8	6
Cluster 3	60	92	16	6	5

Table 3. Students clusters characteristics

Cluster	File submission	Overview report	Page	System	Test	Assignment
Cluster 1	5	6	4	76	19	30
Cluster 2	24	7	9	387	33	122
Cluster 3	7	9	7	147	26	49

Cluster 1 consists of students with the lowest overall activity at Moodle. Average view values for all resources and activities except files are the lowest. Cluster 2 consists of students with the highest overall activity at Moodle. Average view values for all resources and activities except student reports and view reports are the highest. Student report and view report are the highest for students in cluster 3, whereas other values are between clusters 1 and 2.

Following descriptive models, predictive models were developed for clusters 1 and 3. A decision tree algorithm is applied for predictive models' development. Evaluation of two models is given in table 4 in terms of RSquare values (metric for model reliability) and RASE (metric for model error).

Table 4. Predictive model evaluation

Model	RSquare	RASE
A predictive model for Cluster 1	0.547	0.969
A predictive model for Cluster 3	0.425	0.973

Both models indicate good quality results. Results interpretability assumes conducting sensitivity analysis. Figures 1 and 2 show sensitivity analysis results for models of cluster 1 (figure 1) and cluster 3 (figure 2).

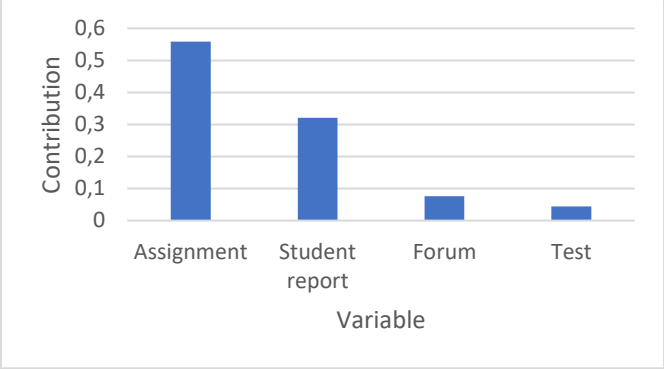

Figure 1: Sensitivity analysis for Cluster 1

Assignments and student report views are the most important predictors of grade for cluster 1. Choice and test logs are the most important predictors of grade for cluster 3.

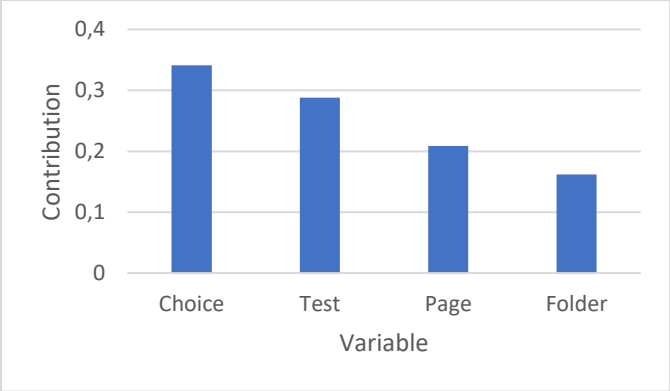

Figure 2: Sensitivity analysis for Cluster 3

We can see that there are differences in student success predictors among groups of students with different levels of activities at LMS. That's why it is justified to combine descriptive and predictive learning analytics approaches and hybrid approaches to provide complete information.

One of the advantages of decision tree application is that decision tree results can be presented in the form of rules. Prediction rules for cluster 1 are given in table 5 and prediction rules for cluster 3 in table 6.

Table 5. Prediction rules for Cluster 1

Leaf report	Average grade
Assignment<31&Student report<4	1.5
Assignment<31&Student report>=4&Assignment>=26	2.2857142857
Assignment<31&Student report>=4&Assignment<26&Assignment<21	3.4
Assignment<31&Student report>=4&Assignment<26&Assignment>=21	4.2
Assignment>=31&Forum>=17&Test<22	3.1666666667
Assignment>=31&Forum>=17&Test>=22	4
Assignment>=31&Forum<17	4.6

Table 7. Prediction rules for Cluster 3

Leaf report	Average grade
Choice<2	1.6
Choice>=2&Page>=7&Folder<7	2
Choice>=2&Page>=7&Folder>=7	3.2
Choice>=2&Page<7&Test<23	2.4
Choice>=2&Page<7&Test>=23&Test>=28	3.375
Choice>=2&Page<7&Test>=23&Test<28	4
Choice<2	1.6
Choice>=2&Page>=7&Folder<7	2

To answer the third research question, correlation analysis was performed. The correlation coefficient of $r = 0.2037$ indicates there is no relationship between students' grades and grouping based on Moodle activity.

5. Conclusion

Earlier research papers have demonstrated that higher education institutions could use the predictive power of LMS data in combination with machine learning algorithms to develop models' tools that identify successful students and at-risk students and allow interventions. In this paper, we have proved that a combination of unsupervised and supervised machine learning algorithms on LMS data results in useful models for explaining and predicting students' behavior at LMS.

To achieve the goals of this research, we have answered the following research questions:

(i) Which of the variables extracted from the LMS Moodle logs have the highest impact on the student's performance?

Assignments and student report views have the highest impact on grades for students with lower LMS activity. Choice and test logs have the highest impact on grades for students with higher LMS activity.

(ii) Can we create good student clusters based on their usage of the LMS?
Based on the CCC value, we can conclude that good student clusters are created.

(iii) Is there any correlation between students' clusters and students' success?
There is no correlation between students' clusters and students' success.

Research results contribute to the personalization of learning and teaching approach, especially for online environment. In future research, we will upgrade the study with the following aspects. First, more courses will be included in the analysis, and students of different study programs. Secondly, different machine learning algorithms will be applied to the LMS data and compared to see if are there differences in performance between different algorithms.

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Evaluation of STEAM Methodologies in Undergraduate Applied Mathematics Courses

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Abstract

In recent years, STEAM practices have become very popular, especially in higher education. The shift from STEM (Sciences, Technology, Engineering and Mathematics) to STEAM, which includes Arts, added a new paradigm to education, with the goal to emphasize students' creativity and intellectual curiosity. In this paper, the case study within the ERASMUS+ project FUTUREMATH is presented. This case study includes analysis of implemented STEAM methods in four undergraduate courses. The paper focuses on analyzing both students' satisfaction in the adoption of STEAM methodologies, and the role of this approach for their better understanding of complex mathematical topics. The findings of this research lead to the conclusions that students accepted the new approaches very well, and that STEAM approach helped them in relating calculus topics with the topics in their academic majors. This work outlines good STEAM practices in working with students, as well as it addresses future needed improvements.

Keywords

Higher education, STEAM approaches, STEAM methodologies evaluation

1. Introduction

STEAM is an educational model which acronym stands for science, technology, engineering, arts and mathematics, and as such it serves as access points for guiding student inquiry, dialogue, and critical thinking [1]. With the expansion of science, technology, engineering and mathematics (STEM) job market, there is a hope that with STEAM initiatives students will gain more than high-tech skills and that with integration of the arts part into STEM, STEAM will provide pathways for personal-meaning making and self-motivation [3].

In STEM fields, it has been a challenge for many years to reduce attrition rates, typically caused by dropping out of the academic programs or university [4]. Traditional methods of teaching, in the modern educational environment, have become methods that do not produce sufficiently good learning results. One of the considered approaches to mitigating this effect is by introducing technology along with innovative teaching practices.

Implementation of STEAM methodologies in the classroom has its benefits, but also its challenges. In order to have an effective integration of STEAM methodologies in the curriculum, teachers have to have detailed knowledge about STEAM concepts and to participate in continuing education [5]. In other words, teachers have to be very familiar with the content, but they often have to teach outside their "comfort area" of speciality [6].

Advanced mathematical topics such as calculus for undergraduate studies received significant attention, especially when technologies with innovative teaching and learning approaches are applied [7]. Calculus is often regarded as one of the foundational courses for most STEM majors; therefore, noteworthy efforts have been investigated in order to introduce technologies for innovative teaching practices. Although the majority of students do recognize topics in mathematics as an important subject, in practice, very few students properly recognize the value of mathematics [8, 9]. In order to improve student engagement and overall learning outcomes, it can often be beneficial to apply those

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mathematical concepts to real-world examples and situations, which in turn aids the students to find math problems easier and less abstract to identify with [10]. It is fortunate that a significant crossover potential with science, technology, engineering, and the arts exists, making the goal of student engagement an achievable one [11]. Current, emerging and disruptive technologies can drive the necessary and hence inevitable change throughout the educational landscape, especially in higher education, leading to the redefinition and reshaping of both teaching and learning, in accordance with the principles underlying the interdisciplinary STEAM approach, particularly by designing interactive, collaborative, and inquiry-based learning environments [12].

This paper presents part of the Erasmus+ FUTUREMATH project, dealing with implementation of STEAM methodologies in teaching calculus topics in the curriculum of courses taught in three undergraduate academic majors: software engineering, information technologies and game development. Calculus topics were presented through the application in the "real world" problems that are related to the topics and future courses needed for these groups of students. STEAM methodologies and their teaching/learning content was developed for four different courses and relating to the following lesson topics:

1. Big O notation,
2. Recurrence relations,
3. Elliptic curve cryptography,
4. Classification in machine learning, and
5. Implementation of numerical integration methods using the Java programming language.

For the purpose of this study, a student survey was designed and distributed, with the aim of determining student level of satisfaction with the new way of teaching.

The paper is organized as follows. Section 2 describes implemented STEAM models and principles. Section 3 represents research methodology used for data collection and analysis in four different pilot courses. Section 4 presents results and discussion. Section 5 concludes the paper.

2. Implemented lesson format

The STEAM model implemented in the case studies analyzed in this paper, was inspired by the active learning strategies used both in online and in-class settings. In the pilot lessons, similar principles were implemented. Online content of the lesson follows designed lesson plans and typically contains: learning objectives, previous knowledge assumed, description of the practical problem ("real world" problem/application), student project or problem assignment, theoretical/instructional content, lesson video, activating exercises, discussion, self-evaluation with feedback, assessment, and student homework assignment. The lesson starts with clearly stating the learning outcomes and objectives of the lessons, which highlights the expectations that students should have from learning the lesson. This is followed by the "interest catcher" used to introduce students where students will be able to apply calculus topics in "real world" problems. In our case, all the students that participated in the pilot lessons, were students from the academic majors relating to the computing disciplines, and most of the "real world" applications relate to that. Table 1 gives examples of interest catcher for pilot lessons.

Table 1
Examples of interest catchers for pilot lessons.

Lesson title	Interest catcher with "real world" problems/applications
Recurrence relations	Examples of recursion in programming, A mathematical example of recursion is the definition of factorials, The tower of Hanoi
Big O	How are programs analyzed and how they behave during scaling?
Classification in machine learning	Classification of Iris dataset using Bayesian classifier.
Definite integrals solving in Java	Software implementation of integration methods
Elliptic curve cryptography	How can blockchain use less processing (and therefore electrical) power?

Once the student's interest has been caught and clear expectations in learning outcomes and lesson objectives have been set, students can approach the instructional part of the lesson. Given that STEAM methodology relies on active learning strategies, lessons represent a combination of instructional material, along with assigned projects, problems, videos, assessments, etc. Each lesson contains assessments, which are designed to assess learning outcomes. These assessments are used in different formats and with different purposes. While some are self-assessment tests designed for students to receive instant feedback on their understanding, the others are used to assess and grade student knowledge. The used assessments were in different formats: quizzes, tests, discussion, self-reflection.

Two types of videos (clips) were used:

1. Introduction to the lesson – short 3–5-minute videos used for teachers to introduce learning outcomes, objectives and expectations. This video can be used to introduce an interest catcher.
2. Lecture video – video that is no longer than 10 minutes with the goal to introduce students with main concepts through instructions and explanations.

The lessons were built on the practical problems and projects assigned to students (based on problem-based or project-based learning methods), closely related to calculus topics. The online content was made to engage students to be more motivated in their learning. The developed lessons were then published on a learning management system so that students can either access content, either interactively or download it in PDF format. By making the lesson available online to students, their progress and activity could be followed.

3. Methodology

This paper investigates the student satisfaction with the lessons developed and implemented using STEAM methodologies and principles. Pilot lessons were implemented in four different undergraduate courses by applying different calculus topics for undergraduate students in three different academic majors: Software engineering, Information technology and Video game development. The lessons were implemented both in the classroom and in online learning environments.

The purpose of this analysis is to show the impact of STEAM approaches in understanding calculus topics in students' mathematics and non-mathematics classes. In each class, student motivation and problems were related to one or more calculus topics with the "real world problem". In non-mathematics courses, these problems were relating to the main topics and goals of the course itself. The underlying assumption was that relation to the "real world problems" would help not only improve their motivation, but also tune their interest and keep their attention to the calculus topic, by trying to solve the defined problem.

The pilot course lessons were attended by a total of 108 undergraduate students. A total of four courses with five lessons covering calculus topics were taught:

(i) Discrete structures (with lessons Big O notation and Recurrence relations),
(ii) Introduction to object-oriented programming (with lesson Definite integrals in Java),
(iii) Blockchain technology in data protection (with lesson Elliptic Curve Cryptography), and
(iv) Artificial intelligence (with lesson Classification in Machine Learning). Discrete structures and Introduction to object-oriented programming were taught to first- and second-year students, while courses Blockchain technology in data protection and Artificial intelligence were taught to third-year and fourth-year students.

After the lesson piloting, the students were asked to fill out the survey with the goal to analyze students' satisfaction with introduced mathematics topics and methodologies used. There are nine single-answer multiple-choice questions in the survey. For the questions one to eight, 5-point Likert scale was used with five offered answers: I agree, I partially agree, I neither agree nor disagree, I partially disagree, and I disagree. The Likert scale was chosen as it is very efficient for classroom lectures evaluation [13]. The ninth question was the question with only two offered answers. Although 108 students attended pilot lectures, totally 79 students completed the survey. The survey addressed the following issues:

- How satisfied are students with new methodologies?
- What can be improved so that students could easier understand complex mathematical problems and their application in real world problems?
- How important is inclusion of various additional materials in different formats to keep students interested in the given topics and motivated to be active during and after classes?

Given the exploratory nature of this study, as this study was part of the larger sample within the FUTUREMATH project, responses from individual course surveys were combined. The intent of this analysis is not only to investigate satisfaction of students with new STEAM methodologies in their classes, but also to use the results for the improvement of lesson content from the perspective of the teaching and learning. The results were analyzed using descriptive statistics (frequency, mean, standard deviation and median). In order to be able to address future improvements and better increase student motivation to study calculus related topics, dependence between all parameters was analyzed using correlation matrix with Pearson's coefficients that included statistical significance [14]. This approach gave a good understanding of significant relationships between collected answers and helped in analysis of implemented STEAM technologies in students' understanding of calculus topics in pilot lectures.

In order to perform defined analysis, student answers were scaled according to Likert scale, where the answers were transformed as follows: 5 - I agree, 4 - I partially agree, 3 - I neither agree nor disagree, 2 - I partially disagree and 1 - I disagree. The last question (Teaching material is available in the form: printed or electronic) with two possible answers were transformed as follows: 1 – Electronic and 0 – Printed. Obtained results and discussion follows in the next section.

4. Results and Discussion

The results' analysis is divided into two parts: (i) the analysis of student satisfaction with newly implemented STEAM methodologies, and (ii) the analysis of correlation between the questions about students' satisfaction in order to address the future improvements of teaching and learning design for the teaching of calculus topics for STEM student majors.

4.1. Analysis of Student Satisfaction

Table 2 shows the survey answers for all five pilot lessons, filled out by 79 of the 108 students in the pilot courses, while Table 3 shows the mean, standard deviation and median of the survey answers.

Based on the analyzed students' answers, the students were most positive about the organization of the lesson 4.86±0.38. 87.34% of students agreed, 11.39% of students partially agreed, while only 1 student (1.27%) neither agreed nor disagreed. When it comes to perception whether the computer environment helped them with visualization of mathematics concepts (4.57±0.73) in total 69.62% of students agreed, while 18.99% partially agreed, 10.13% neither agreed nor disagreed, and only 1 student (1.27%) partially disagreed. It should be noted that in all courses, computer environments were used in different ways. While all lessons were presented to students using university's LMS, the assigned tasks and problems required using different software tools. The least additional software tools were used in the course Discrete structures, and this is where all the "I neither agree nor disagree" answers came from.

Four out of five lessons were taught live at the University's campuses, while the fifth lesson was taught via Zoom platform. In each lesson the presenter had a visual aid, such as power projector, screen, speakers, etc. All lessons were accompanied by a presentation, assigned tasks and problems, assigned tests and other learning materials relevant to the lesson. In total, 75.95% of students agreed that visualization helped them to acquire knowledge more easily, a total of 22.78% partially agreed, and only 1.27% neither agreed nor disagreed. Based on the averages on the survey results students were positive regarding the perceived help from the visualization in their learning, 4.75±0.47.

All planned lessons were presented with a reflection on contemporary "real world" problems, mainly relating to computing disciplines. Some of the students did not actively participate in the reflection; however, most of the students were excited to join in the conversation and work on assigned tasks. In total, 62.03% found teaching contents to be interesting, 25.32% partially agreed, 7.59% neither agreed nor disagreed, and only 5.06% partially disagreed, with the averages being 4.44±0.84.

While some of the topics were too abstract for some students, the presenters gave multiple real-world scenarios in which the solutions deriving from the topics presented could be applied. After presenting "real world" applications, students were more eager to follow the lesson. In total, 59.49% of students agreed that the lessons topics are applicable in everyday life, 24.05% partially agreed, 13.92% neither agreed nor disagreed, 1.27% partially disagreed, and only 1.27% disagreed. With the averages of 4.39±0.87, this question has the smallest grade and we can conclude the following: when teaching to first year students, when fundamentals are necessary to be covered for more advanced topics, it is challenging to relate mathematics to the full extent, other than mentioning how these principles will be later applied in their courses and field of study.

In addition to the full lesson content published on university's LMS, students were given additional useful literature that can be used to further expand their knowledge. In total, 68.35% of students agreed, 24.05% partially agreed, 5.06% neither agreed nor disagreed, 2.53% partially disagreed, while 0% disagreed, with the averages 4.58±0.71. Similar to the previous question, first-year students can have difficulties learning from undergraduate-level textbooks, especially if they are accustomed to high-school curricula.

An improvement that we propose is the addition of so-called "hand-on" textbooks or "cookbooks" for first-year students, which focus more on examples and real-world applications. Furthermore, STEAM methodologies should be incorporated from the beginning of studies whenever possible, with the goal of getting students accustomed to these principles and practices. Certainly, the approach of implementing STEAM methodologies would require additional effort and a level of creativity from the teachers themselves.

Table 2
Survey answers for the five taught lessons.

Questions	I agree	I partially agree	I neither agree nor disagree	I partially disagree	I disagree
Q1: The lesson was well organized	69	9	1	0	0
Q2: Computer environment helped me to get visual approach of mathematics contents	55	15	8	1	0
Q3: Visualization helped me to acquire knowledge more easily	60	18	1	0	0
Q4: Teaching contents are interesting	49	20	6	4	0
Q5: Teaching contents are applicable in everyday life	47	19	11	1	1
Q6: Teaching contents are applicable in sciences	48	18	7	4	1
Q7: Literature is adequate for understanding the teaching contents	54	19	4	2	0
Q8: The communication with the teacher helped me to acquire knowledge more easily	67	7	2	0	3
Q9: Teaching material is available in the form: printed or electronic	77 (Electronic)	-	-	-	2 (Printed)

Table 3
Survey questions for implementing STEAM methodologies.

Questions	Mean±	Standard deviation	Median
Q1: The lesson was well organized	4.86	0.38	5.00
Q2: Computer environment helped me to get visual approach of mathematics contents	4.57	0.73	5.00
Q3: Visualization helped me to acquire knowledge more easily	4.75	0.47	5.00
Q4: Teaching contents are interesting	4.44	0.84	5.00
Q5: Teaching contents are applicable in everyday life	4.39	0.87	5.00
Q6: Teaching contents are applicable in sciences	4.39	0.94	5.00
Q7: Literature is adequate for understanding the teaching contents	4.58	0.71	5.00
Q8: The communication with the teacher helped me to acquire knowledge more easily	4.71	0.85	5.00
Q9: Teaching material is available in the form: printed or electronic	0.97	0.16	1.00

4.2. Analysis of correlation between the questions

Table 4 shows a correlation matrix between the answers, which emphasizes a strong positive correlation between most questions. The degree of correlation was classified as small (0.10 - 0.29), moderate (0.30 - 0.49), and high (0.50 - 1). We have found that the strongest correlation exists between the applications of teaching contents. Namely, students strongly agreed that the teaching contents are applicable both in everyday life and in sciences (Q5 and Q6, $p < 0.001$), Furthermore, in both applications students found the teaching contents to be interesting, with a moderate positive correlation (Q4 and Q5, $p < 0.001$; Q4 and Q6, $p < 0.001$).

In addition, good course organization, as well as teacher communication is reflected with teacher's literature recommendations (Q1 and Q8, $p < 0.001$; Q7 and Q8, $p < 0.001$). Students who thought the lesson was well organized strongly agreed that visual aids and communication with the teacher helped them to acquire knowledge more easily (Q1 and Q3, $p < 0.001$; Q1 and Q7, $p < 0.001$), and also thought that the teaching contents were interesting (Q1 and Q4, $p < 0.001$).

Students who agreed that computer environment helped them to get a visual approach to mathematics had a moderate positive correlation with finding the lessons more interesting (Q3 and Q4, $p < 0.001$), adequate literature (Q3 and Q7, $p < 0.001$) and communicating with the teacher (Q3 and Q8, $p < 0.001$).

However, the strong correlation between communication with the teacher and application to sciences (Q6 and Q8, $p < 0.001$) suggest that teachers may have a more scholarly approach to teaching in their classes. These results are backed up by the small correlation between Q1 and Q5, showing that, although lessons are well planned, they still lack more examples from everyday life compared to those in sciences. Similarly, a moderate correlation between application in sciences and adequate literature exists (Q6 and Q7, $p < 0.001$), which agreed with our previous conclusions that textbooks are not always aimed at practical, real-world examples.

Table 4
Correlation coefficient matrix of the survey answers

Questions	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1	1.0***	0.24*	0.52***	0.51***	0.17	0.22*	0.4***	0.54***
Q2		1.0***	0.17	0.27*	0.41***	0.21	0.37***	0.38***
Q3			1.0***	0.42***	0.12	0.11	0.22	0.3**
Q4				1.0***	0.42***	0.44***	0.27*	0.43***
Q5					1.0***	0.74***	0.27*	0.38***
Q6						1.0***	0.46***	0.55***
Q7							1.0***	0.54***
Q8								1.0***

*** - $p < 0.001$, ** - $p < 0.01$, * - $p < 0.05$

5. Conclusions

This paper presented the implementation of STEAM methodologies in the undergraduate curriculum of academic majors relating to the computing disciplines. The intent of this work was to do an exploratory study on the sample of students from one university, in order to identify through the student satisfaction analysis how satisfied the students with new implemented STEAM methodologies were, and their perception of contribution of STEAM methodologies in their learning. In addition, this study was used to address future improvements that can be used in teaching and learning design using STEAM methods in teaching calculus topics in mathematics and non-mathematics courses.

Based on this study, it can be concluded that integrating STEAM principles into STEM studies can be very beneficial for keeping the interest and motivation among students, to better understand mathematics fundamentals that they need and will need in their profession. This approach does acquire additional effort from teachers and a level of creativity when introducing active learning methodologies

and STEAM principles. When appropriate, students should be taught with STEAM principles from their beginning of studies, to get them acquainted with the principles as well, so that later they would be accustomed to this type of learning.

The major strengths of this teaching methodology can be summarized as follows. Firstly, "real world" problems can be easily implemented as examples during classes, making the topics easier for students to understand. Secondly, the inclusion of various additional materials in different formats allows students to be interested in the given topics. Finally, more abstract and complex mathematical problems can be presented in a manner that keeps students active during and after classes.

For future work, we intend to extend the pilot lessons to complete courses at all years of undergraduate studies, which would be taught during the whole semester. We also plan to improve the surveys by increasing the number and type of questions. After completing the pilot courses, a detailed course evaluation analysis will be performed, with the goal of examining students' adoption of STEAM methodologies.

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Prediction of student academic performance using machine learning algorithms

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Abstract

Educational data mining (EDM) can be used to identify students' activities, progress, achievements, and overall success in learning. EDM has become very popular in recent years as a convergence of learning, analysis, visualization, and recommendation which makes the learning process persistent and visible. In this paper, an EDM approach was conducted in order to classify and predict student performance with machine learning techniques. Based on the history educational dataset collected in Learning Management System (LMS) and Educational Management System (EMS), a model for the classification of student performance was conducted. A model is trained and evaluated on data from four different courses. Machine learning algorithms such as Logistic Regression (LR), Linear Discriminant Analysis (LDA), K-Nearest Neighbor (KNN), Decision Trees (DT), Naive Bayes (NB), and Support Vector Machine (SVM) are analyzed. Support Vector Machine (SVM) classifier was finally selected for model training and evaluation. Although the proposed model gave quite good results, there is room for improvement in future work, which is discussed in the paper

Keywords

elearning, student academic performance prediction, educational data mining, machine learning

1. Introduction

Wide usage of online educational learning and management systems led to a large amount of stored data. The educational experience such as students' interactions with forums, lectures, and online assessments in the form of homework, projects, tests, etc. provide the possibility to discover valuable and significant knowledge about student specifics and their further achievements [1].

Students' performance is a term used for measuring not only students' achievements but also the quality of educational institutions. While some authors define student performance as a value obtained from measuring a particular student learning assessment compared with study curriculum, grade point average (GPA), or final grades, others define student academic performance only as the possibility of gaining a long-term goal such as graduation or potential for future job prospects [2]–[4].

Analyzing collected data and predicting student performance has great importance for the efficiency of educational institutions and can help in identifying students with low academic achievements at the early stages of studying, tackling academic underachievement, increased university dropout rates, graduation delays, etc.[5]. For educational institutions, it is very important to understand the potential of using collected data in order to improve learning efficacy and academic achievements of individuals and institutions [6].

Educational data mining (EDM) is one approach that educational organizations can use to uncover the patterns hidden in educational data, extend their knowledge or make predictions about further student achievements [6]. While EDM is used for discovering knowledge from data, machine learning (ML) algorithms provide tools for that purpose.

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EDM uses a broad range of data features, metrics, and prediction methods. In order to make conclusions or predictions on students' academic performance, features like cumulative grade point average (CGPA) and performance on online assessments (i.e. assessment scores, quizzes, attendance) have been used most frequently [7]–[10]. A prior academic achievement (i.e. high school data) can also help in understanding students' performance [11]–[14]. Some authors include university entrance tests as an important attribute as well [11]. Additionally, students' demographics such as gender, age, socioeconomic status, family background, and disability can also have an impact on students' success [8], [15], [16]. Learning in online learning environments means that the data recorded in the system, such as the number of access to lessons, time spent in learning, and participation in forums, play an important role and represent significant attributes in researching adequate metrics for addressing student performance [8]. Psychological attributes such as motivation, student interests, and personality type are usually interesting for research and are listed as important, but their qualitative nature sometimes makes them difficult for analysis [17], [18].

The large number of features that have been found in different research bring with them different prediction models to discover students' performance. The prediction of students' academic performance consists in estimating the unknown score or grade usually obtained by using different classification and regression techniques such as Decision Trees, Artificial Neural Networks, Naive Bayes, K-Nearest Neighbor, and Support Vector Machines [19]. Object Oriented Programming course data obtained from Politehnica University Timisoara was used for developing a model that could help in the identification of students at risk by predicting student academic performance. Their dataset included attributes such as student membership to the advanced study groups, number of credits earned in the previous year, average activity mark, number of attendances in practical activity meetings, average examination mark, and number of final exam attempts, with the conclusion that the Logistic Regression (LR) classifier produced the best accuracy for prediction students' academic performance [20]. In training small dataset size in order to predict students' academic performance, Support Vector Machine (SVM) and Learning Discriminant Analysis (LDA) algorithms showed the best accuracy [21]. A dataset from the University of Minho in Portugal with 395 samples was used to predict students' academic success using SVM and KNN. The performance of both algorithms was compared, and it was discovered that SVM performed better than KNN [22]. Review papers on machine learning-based student academic performance prediction show that Neural Network has the highest prediction accuracy (98%), followed by Decision Tree (91%), Support Vector Machine (83%), K-Nearest Neighbor (83%), and Naive Bayes (76%) [7].

In this paper, we focus on predicting students' academic performance by using historical data collected at Belgrade Metropolitan University with the aim to identify a model suitable to predict students' success in a course. Data used in this work represent educational data collected in two Object-oriented programming courses and two Information Technology based courses, gathered from academic year 2017/18 to 2021/22. The collected data set contains students' high school average grade, grades on tests, homework, projects, and class participation, as well as student class attendance, number of failed attempts to pass the final exam and final grade. Final grades are classified in two categories – those who passed the course and those who failed it. This work provides comparative analysis on different machine learning algorithms such as Logistic Regression (LR)[23], Linear Discriminant Analysis (LDA) [24], K-Nearest Neighbor (KNN) [25], Decision Trees (DT) [26], Naive Bayes (NB) [27], and Support Vector Machine (SVM) [28].

This paper is organized as follows. Section 2 presents short overview of the Educational Data Mining techniques. Section 3 describes used methodology for data collection and analyses. Section 4 presents and discusses obtained results. Finally, Section 5 concludes the paper.

2. Educational data mining

EDM develops and adopts different methods that are used in order to gain valuable knowledge hidden in educational data from educational settings. EDM uses different statistical, machine learning, and data-mining methods with the aim to better understand students and to try to predict patterns that characterize students' behaviors and performances [29], [30]. Education, statistics, and informatics represent the main areas of EDM where overlaps of these areas lead to coupling of EDM with machine

learning, data mining, learning analytics, and computer-based education [31]. The goal of the EDM is to transform raw data with a large number of attributes into meaningful data-driven decisions. EDM can also lead to more accurate predictions of student knowledge, dropouts, and student motivational state as it is based on different data, which in return provides a broader understanding of specific groups of students [32], [33]. EDM can be classified in five main categories: (i) prediction, (ii) clustering, (iii) relationship mining, (iv) distillation of data for human judgment, and (v) discovery with models [34]

Prediction - Develops a model that calculates assumptions for certain events and are made based on available processed data. In data mining, independent variables are attributes that are already known, and response factors are what needs to be predicted. Three main categories of prediction are classification, regression, and density estimation [35].

Clustering - Identifies data that grouped together, respond to a similar logic and observations. In online learning, an example of clustering would be grouping students based on their learning patterns which allows one to further gain meaningful conclusions [36].

Relationship mining - Discovers relationships between numerous variables in a dataset and can provide information on variables that are strongly associated with another variable. Additionally, relationship mining can discover the strongest relationships between some variables. Four main categories of relationship mining are: (i) association rule mining, (ii) correlation mining, (iii) sequential pattern mining, and (iv) causal data mining [30].

Distillation of data for human judgment - Develops methods for appropriate presentation and visualization of data for easier human judgment [37]. Presenting the data in different ways can help in discovering new knowledge in order to achieve classification and/or identification. Data distillation for classification can be used as a preparation stage for further prediction, while identification aims to display data such that it is easily identifiable via well-known patterns [38].

Discovery with models - entails using previously defined models based on clustering, prediction, or knowledge engineering using human reasoning rather than automated methods [34].

ML uses techniques that allow machines to learn and make accurate predictions from past observations. In recent years coupling of ML with EDM has received high attention in research. Various techniques and algorithms such as Clustering, Classification, Regression, Neural Networks, Association Rules, Genetic Algorithms, Decision tree, etc. are used for knowledge discovery from databases [31].

3. Methodology

Methodology used to build a student performance prediction model is presented in Figure 1. Methodology consists of three stages: (i) Data collection and integration, (ii) Data preprocessing, and (iii) Model building and evaluation. In the *Data collection and integration* stage data is collected during the student learning process. *Data preprocessing* stage includes tasks such as: (i) handling missing values, (ii) solving inconsistency, (iii) removing redundancy, (iv) feature selection, and (v) normalization. An output from this stage is a transformed dataset which is converted into a normalized dataset. In the *Model building and evaluation* stage normalized data is divided into two sets: training dataset (consists of 80% of received normalized data) and testing dataset (20%).

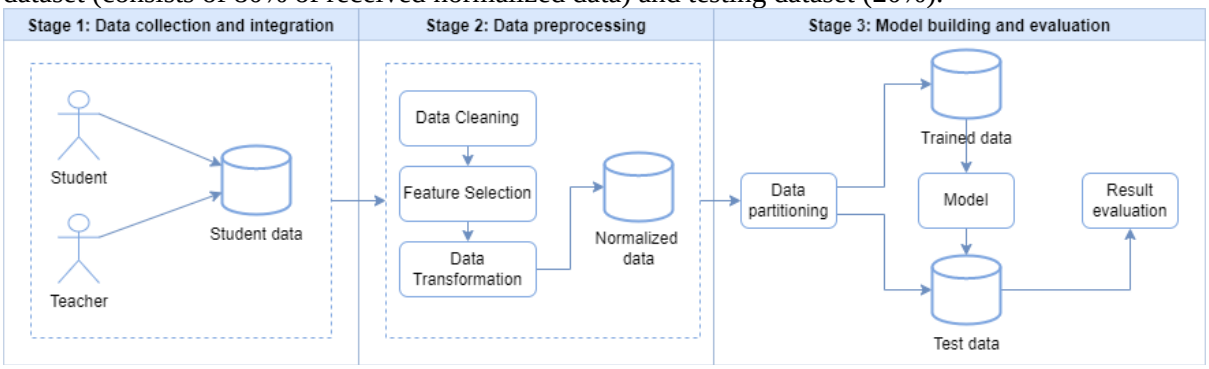


Figure 1. Student performance prediction methodology

In this study, the data were taken from Belgrade Metropolitan University's EMS and LMS, where all student records are stored. This dataset includes data collection from academic year 2017/18 to

2021/22. Data were narrowed down to four courses: (i) Introduction to object oriented programming (ii) Objects and data abstraction, (iii) Introduction to information technologies, and (iv) Information technology systems. The dataset included records for 1696 students.

In the first stage, the raw dataset was collected and after that dataset was preprocessed by removing outliers, missing and noise values. Null, empty or negative values were removed from the dataset. Students' data used in this work includes: (i) homework assignments grades, (ii) online test grades, (iii) project assignments grades, (iv) class participation grade, (v) number of failed attempts to pass the final exam, (vi) class attendance, and (vii) high school average grade. In the selected courses, students had assigned with weekly homework assignments, online assessments every three weeks, and one project assignment per course. Student class attendance was taken each week. Besides the assigned grades, EMS and LMS collected additional data about student learning such as time spent on the LMS, forum participation, time when students submitted their assignments, etc.

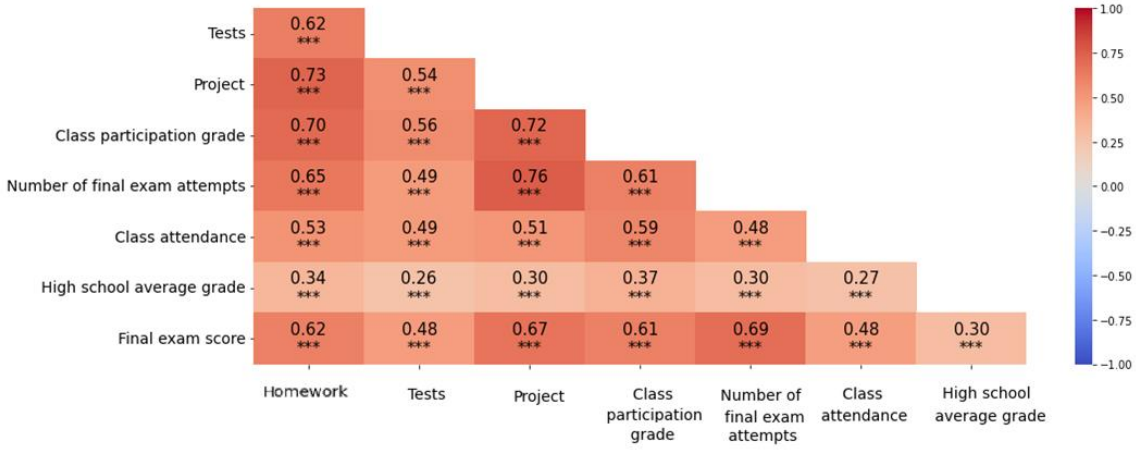
The syllabus of each course defines a different number of assignments and their portion of the final grade. Homework assignments, tests, projects and class participation grades represent 70% of the final grade for the course. Final exam represents 30% of the grade.

The collected dataset was normalized using min-max normalization which performs a linear transformation on the original data and scales the data in the range (0, 1). The numeric values of the final exam score are classified into the categorical variables fail/pass (946 were classified with *fail* and 750 with *pass*). The *fail* class includes students who earned less than 50% of the exam score, while the *pass* class includes those who successfully passed the exam and achieved 50% or more on the exam score.

Exploratory data analysis was conducted in order to select suitable features. Correctness of feature selection was ensured with Pearson's correlation finding and correlation between the variables in data set was explored. Six machine learning algorithms were applied for model validation. Selected ML techniques were utilized for this purpose: (i) Logistic Regression (LR), (ii) Linear Discriminant Analysis (LDA), (iii) K-Nearest Neighbor (KNN), (iv) Decision Trees (DT), (v) Naive Bayes (NB) and (vi) Support Vector Machine (SVM). Evaluation of the built model was done on testing dataset with SVM classifier. To undertake the classification of ML techniques Python programming language and Google Colab Environment were used. Obtained results are presented using accuracy and confusion matrix as metrics.

4. Results and Discussion

In order to perform feature selection and analyze correlation between variables, correlation matrix with Pearson's coefficient was calculated. Figure 2 illustrates the correlation heatmap graph of the input dataset provided by using the Python Pandas library. Correlation degree was classified as follows: low (below 0.29), moderate (from 0.3 to 0.49) and high (from 0.5 to 1). Based on the obtained results, we can see the presence of moderate and high correlation degrees among all variables.



*** - p < 0.001, ** - p < 0.01, * - p < 0.05

Figure 2. Correlation HeatMap

It was of interest to analyze whether the correlation exists between all of the parameters. For instance, it is interesting to see that homework is in high correlation with tests (0.62), projects (0.73), class participation grade (0.70), number of final exam attempts (0.65), and class attendance (0.53). One of the possible explanations is that attending class regularly helps with completing homework successfully, and in return being ready for the project. Similarly, the project has a high correlation with class participation grade (0.72), number of final exam attempts (0.76), and final exam scores (0.67). However, the focus was placed on the correlation between the final exam grade and other parameters. Based on the correlation matrix, it can be seen that the highest correlation is between the project and number of attempts the final exam was taken (0.76). Additionally, a high level of correlation is shown between the final exam score and projects' grade (0.67) and homework (0.62).

Courses that were taken into consideration for our dataset, are similar not only in the structure of the final grade, but also in the type of assessments. For instance, all of the courses are part of the computing curricula, and have a high degree of practical assignments, and even assessments are based on problem solving that is mainly relating to programming or some sort of technology (hands on) assignment. Hence, this is the reason why it is expected to see correlation between the final exam scores and homework and projects, as the final exam questions are similar to homework and project assignments. It should also be noted that students' class participation grade have a high correlation with the final exam score (0.61) because that grade in itself carries information about how actively and regularly the student studied during the semester, which indicates student's preparation for the exam. Poor correlation is found between high school average grades and final score exams (0.3). That shows that differences in high schools from which the students come do not have a great influence on the passing of the course. This value reflects differences in the type of high schools the students attended or the level of knowledge they acquired there. Moderate correlation is shown for the correlation with class attendance and tests. Being present in the class does not necessarily mean that the student is active and participating. This is the reason why there is a high correlation between the final exam scores and class participation grade (0.61), but only moderate correlation between the final exam scores and class attendance (0.48). Similarly, there is a moderate correlation between the final exam scores and grades received on tests (0.48). This is interesting, as most of the tests are multiple choice questions, including the covered theoretical work, where the class final exam questions contain both theoretical and practical problems. Also, we can see moderate and high correlation degree levels between features and the target variables (final exam score), so all features are kept in the dataset.

In order to choose a classifier for predicting the final exam outcome (whether the course was passed or failed), a 10-fold cross-validation approach was conducted. Cross validation approach splits the training dataset into 10 groups of approximately equal size, trains the model on nine groups and tests the model on the tenth group in ten iterations. The outcomes of the experiments are summarized using classifier accuracy that was calculated as the average accuracy after ten cross validation iterations. Six ML algorithms were applied for validation of the model. Classifier accuracy for all ten iterations is presented with boxplots in Figure 3.

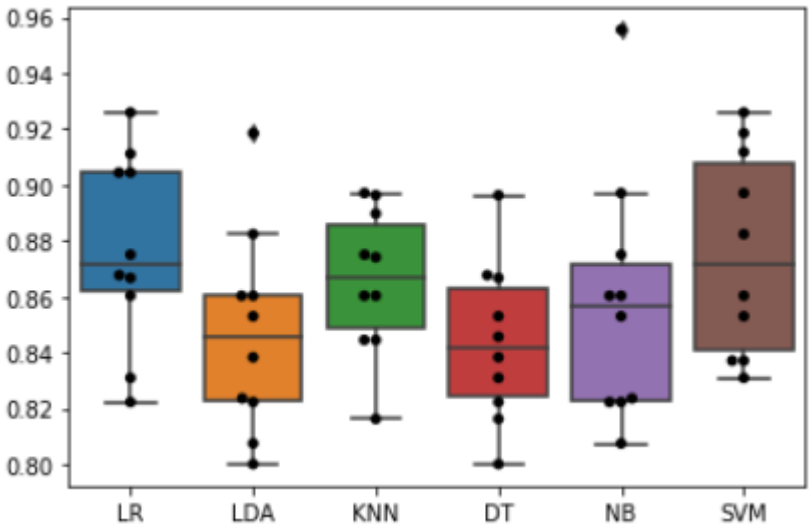


Figure 3. Boxplots with accuracy after 10 iterations of cross validation for six different classifiers

SVM shows the best results with choosing the classifier in all ten iterations with the average accuracy of 88.5%. Other examined algorithms show the average accuracy of LR (87.6%), LDA (84.6%), KNN (86.5%), DT (84.4%), and NB (85.7%). Obtained results are in accordance with conclusions in [20] that show that SVM performs well with small dataset size. As a supervised learning algorithm for classification problems, SVM has the best performances when the class boundaries are nonlinear because it is focused only on the class boundaries, while points that are anyway easily classified are skipped [39].

Once the model was trained, it was tested on the collected dataset. The proposed model for predicting students' academic performance based on SVM shows 90.3% accuracy after model evaluation on testing dataset. Chosen model performance was additionally assessed using a confusion matrix. The confusion matrix summarizes the selected model's overall performance as shown in Figure 4.

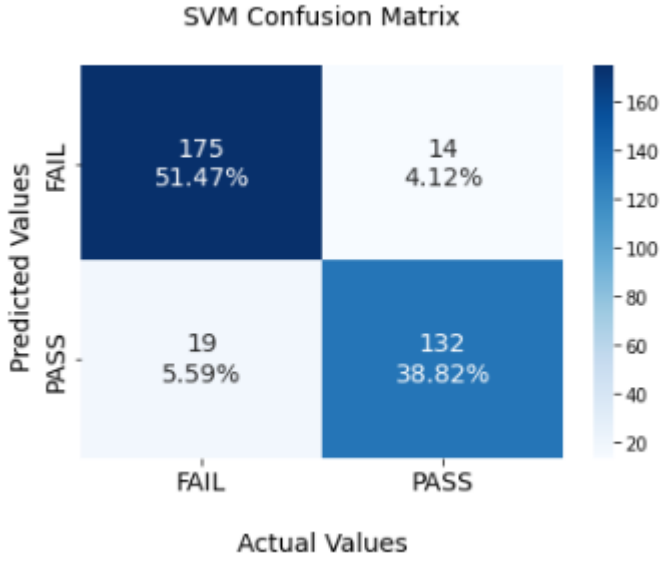


Figure 4. Confusion matrix of SVM proposed model

Based on Figure 4, we can conclude that the model predicts that 175 students from our dataset will fail the exam and that 132 students will pass the exam. This is compared to 189 students who actually failed the exam, and 151 students that passed. This means that model does not work perfectly and there are present type I and type II errors. Model classifies 14 students that passed the course in the failing

group, and 19 students that failed the course are classified in the passing group. Also, the model predicts that 132 students will pass the exam, out of 151 students who actually passed the exam. The model does not work perfectly and there are present type I and type II errors. Model classifies 14 students that passed the course in the failing group, and 19 students that failed the course are classified in the passing group.

Evaluated SVM model performance is presented through precision and recall as shown in Table 1.

Table 1. Models performance

	Precision (%)	Recall (%)
FAIL	93%	93%
PASS	90%	87%

Based on the precision, we can see that from all "fail" predictions, 93% really failed the exam, while from all "pass" predictions, 90% passed the exam. On the other hand, based on recall we can see that from an overall number of students that actually failed the exam, the model predicted 93% successfully, and from an overall number of students that actually passed the exam the model predicted 87% successfully. These metrics confirmed that the chosen model gives very satisfactory results in predicting the final exam outcome. The results show that the selected model can be used to predict the final exam outcome (whether the course was passed or failed) with sufficiently high accuracy. This is important for early identification of at-risk students, which can help in addressing their problems and challenges early on.

5. Conclusion

Student academic performance is one of the important quality indicators for every university. Being able to anticipate identification of at risk students at an early stage of student academic life, provides an opportunity to improve the learning process and also reduce the dropout rates. In this work we have examined the accuracy of six different machine learning algorithms in order to predict students' passing or failing the final exam. The six ML algorithms that were investigated were NB, LDA, LR, DT, KNN, and SVM. For the analysis of the proposed model, dataset for four different courses was used. Algorithms were evaluated based on characteristics such as accuracy and precision rate. SVM showed as the most accurate in classifying a data set of student academic performance, and in predicting students' final exam outcome. Future work will analyze a larger number of ML algorithms and try to include additional features in order to gain more accurate model for the prediction of student academic performance and support the entire process of learning.

Acknowledgment

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Artificial intelligence brings opportunities for the university's spin-off companies

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Abstract

Creating high-technology spin-offs has been a long-term goal for many research universities. Recently, the EuroHPC Joint Undertaking (JU) funded the project EuroCC NCC (National Competence Centres) to establish a European network of 33 countries in the field of high performance computing (HPC), high performance data analytics (HPDA) and artificial intelligence (AI). The Sofia University St. Kliment Ohridski (SU) is a pillar of the Bulgarian Competence Centre (EuroCC BCC) partnering with the University of National and World Economy and the Institute of Information and Communication Technologies at the Bulgarian Academy of Sciences (IICT-BAS).

In the near future the SU is expected to create spin-offs in the sector of information technologies as a result of consolidated efforts of the researchers involved in the project EuroCC NCC and the newly established Institute for Computer Science, Artificial Intelligence and Technology (INSAIT) at the SU focusing on PhD education and research. Digital transformation of university teaching and research that is ongoing facilitates the spin-offs creation. The short life-times of the most spin-offs prevents most of the student to adopt a spin-off as a possible career path. Hence, the parent university needs a strategy to increase the survival time. A modern tool for labor market intelligence is the artificial intelligence that brings opportunities to find out what can be done to increase the life-time. Possible solutions were discussed in the fall of 2021 during the 2nd ASEF Higher Education Innovation Laboratory - a platform for university managers, administrators and academics to exchange good practices. One solution was to increase the period of time used by the professors after the spin-offs creation until the students develop complementary skills necessary to run the spin-offs by them self. Another solution was to expand the e-skills with a special focus on AI implementation in research of labor and trade market.[1]

Keywords

E-skills, Digital Transformation, Artificial Intelligence, high-tech spin-offs life-time

1. Introduction

The research universities have developed various strategies to increase their competitiveness in the last decades. Because students have a vast amount of learning options to choose from, nowadays the universities accept digital transformation to maintain a competitive edge. *Digital transformation* was defined in [1] as "a series of deep and coordinated workforce, culture, and technology shifts that enable new educational and operating models and transform an institution's operations, strategic directions, and value proposition". A strategic direction of the university transformation has been the support of creation of high-technology spin-offs since late eighties of the last century, [2]. While this is widely explored strategy, there is a problem, which needs deep understanding for finding a proper solution: the problem is that most of the university spin-offs have very short life time - they decay before a useful product for the society is delivered.

The spin-off process is one approach to transfer technological innovations to industry. The ongoing debate on the impact of these spin-offs on the economy and society reveals both pros and cons. On one

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side, there are positive actions undertaken by universities to commercialise their research, which include patenting and industry-academia partnership. The spin-offs contribute to technology transfer through their commercial ties to industrial customers and partners, introducing innovation and science-based technologies in industry and thus facilitating economic growth. On the other side, in many cases the relationship between the spin-offs and parent institutions becomes unstable shortly after the spin-off creation - the university staff is put aside by the spin-offs, which diminishes the interest of the university staff in the future creation and tend to apply all their resources to their core business (education and research). Such a disengagement becomes a threat for the whole process.

There has been a change of international entrepreneurial strategy - now the formal control in the organisations is replaced by internalisation of certain competences. Having in mind that a spin-off requires advanced planning across a number of disciplines, incorporating elements of capital markets, tax, finance, intellectual property, this new entrepreneurial strategy imposes specific conditions for the success of the spin-offs.

The research question of the present study is: what are the factors that affect creation and survival of academic spin-offs? This short article identifies some considerations based on meta-analysis of existing data, which universities may wish to take into account to help ensure a successful spin-off.

2. State of the art - observations, findings, meta-analysis

The good relationships of academic spin-offs with their parent university is expected to positively influence their ability to attract funding for innovation activities. A sample of 100 firms analysed in [3] clarifies whether and how the relationship with the university increases the ability of the spin-offs in attracting funding for research and development. A relationship tended to be beneficial if it was not rather strong or complex. Another finding of the study is that the ability to acquire funding tended to increase if the spin-offs develop a well-connected network of university and non-university contacts.

There is mixed evidence about spin-off's performances, especially compared to those of other innovative start-up companies [4,5]. It is found that venture-backed university spin-offs are concentrated in the biotechnology and information technology industries. Moreover, a spin-off tends to stay close to the university, suggesting that technology transfer through spin-offs is largely a local phenomenon [6]. It seems that the university spin-offs have a longer life-time but are not significantly different from other start-ups in terms of the probability of completing an initial public offering.

According to the results of the Carroll Knowledge Foundation survey "Entrepreneurship in academia" students and teachers consider spin-off, value teaching skills and are ready to participate in the company with their universities and research institutions. The participants in the survey were 321 representatives of the academic community from over 20 higher schools and institutes throughout Bulgaria. 40% of the participants were students, 23% - with a doctoral degree, 15% were doctoral students. The rest were associate professors, professors and other representatives of the academia. A surprising 92% of respondents say they have considered or are considering in one way or another their own business, and 81% have participated for a limited period of time in a spin-off with the university or institute where they work. The question: "are entrepreneurial thinking and skills necessary during higher education" was answered **YES by 75%** of respondents. This high percentage is detected also on a global scale. The positive attitude towards entrepreneurial thinking rapidly penetrates the country.

Just two years ago, in a similar survey, 80% said they **would** "consider this possibility" and **only 10% said a definite "Yes"** to the question: whether academics are considering a spin-off with the university or institution they work in. It is important to note that *the respondents were only PhD students and young scientists working in the field of new materials and technologies, and engineering science*s.

Important observation from these surveys is that the percentage of the academic staff has increased - at least at the readiness level, because the number of spin-offs created in practice by the university is very limited. In Bulgaria the universities' share in the spin off is fixed to a small amount of money, which limits the universities' interest. It is obvious that there is a need to change the legislation in Bulgaria in order to speed-up the process of creation of spin-offs by the universities if the new strategy is to be implemented. Efforts in this direction by the Bulgarian government, business organisations and the European Commission will be presented at the forthcoming first edition of Spinoff Bulgaria Conference, 1-2 September 2022 in the city of Burgass. The organising committee provides an

opportunity for business, academia, investors, healthcare and government stakeholders to get together and discuss the future of innovation in the country and the region, [7].

2.1. Are there barriers to set up academic spin-offs?

The criteria for classifying a spin-off as an academic one is the "transfer effect" that corresponds to exploitation of **the knowledge created at universities** by the spin-off, [8]. Academic spin-offs are companies that gain a licence to use a university's intellectual property.

Here arises the question: what about the knowledge owned by other investigators (external intellectual property rights, IPR? In fact, this is the usual IPR situation faced during the process of commercialisation of the new knowledge that might be generated outside the parent university.

This should not be considered as a hindrance for creating a spin-off but opportunity to encourage the university staff to establish a collaborative network similar to the European Technology Platforms with clear indication how the IPR will be used for benefiting all stakeholders,.

Barriers however do exist in creating academic spin-offs. A case study from Portugal [9] indicated several barriers, which we have also identified in Bulgaria, [10,11]:

1. A wide gap between the knowledge produced by researchers and what is used in practice.
2. Lacking research income from industry to the university.
3. Technology transfer activity is low or completely absent.
4. Difference in metrics: university quality is usually measured by scientific publications and citations while the industry measures quality by the degree of innovation.
5. Gender, age and Faculty influence academic staff's tendency to cooperate with the business sector.
6. Creation and performance of university spin-offs are also dependent on university statutes, location, culture, intermediary agents, experience and university goals.
7. Lack of awards for research; status and prizes are awarded only to holders of knowledge.

2.2. How to overcome these barriers?

The analysis of the barriers, which prevent the creation of academic spin-offs reveals possible paths to overcome them. For example:

Item 1 The gap can be closed by incorporating the Culture of sharing and disseminating information in the university curricula. It takes time but it is a must. The sooner the better.

Item 2 The money flow can be encouraged initially by special governmental incentives for enterprises that invest in research at the universities. Good practices can be found in the regulation of the framework programme Horizon2020. Many projects, that received grants for scientific research, were completed with one or even two spin-offs created by the participating universities.

Item 3 Increase financial, physical, and human resources in organisations for the transfer of knowledge and encourage users to acquire, adapt and use new knowledge.

Item 4 Evaluate performance and provide incentives to whoever shares knowledge; promotion of transfer awards. The Sofia University financially supports the PhD students who openly share the research data with the other researchers.

Item 5 Knowledge should be easily understood by the receiver, with the use of appropriate, clear, precise and simple language, supported by examples, conceptual models and concrete experiences.

Item 6 The location and ranking of the university should be carefully considered in defining the goals. These considerations can be helped by **artificial intelligence algorithms** designed to analyse the dynamics of the market in order to select a profitable sector, the approaches of hundreds universities that are successful in the process, the methodology of culture alignment with the business requirements.

Item 7 Promotion of transfer awards at the universities, motivating user involvement, early in the research.

It has been already proved that students involvement in research projects at their early stage of education is a winning strategy.

One example: The car design and production attract many students because of the possibility to work in a team of chemists, physicists, computer-, mechanical-, electro- engineers. The design and construction of a car frequently result in patents of innovative products in several fields. These patents are an excellent foundation of spin-offs.

The item 6 is very important for the university staff responsible for defining the goals of knowledge development and its short-term and long-term commercialisation. Since the location of the university is given, the staff should work on the maximum ranking of the university. This activity can take the **opportunity of implementing artificial intelligence algorithms (AIA) for analysing the huge amount of scattered data all over the world to infer the relationship between the successful increase of the university ranking** that involves the university location, selection of the profitable disciplines, attraction of staff experienced in these disciplines, the timing and commercialisation of the knowledge.

The interest is high in how big data analytics (BDA) and (AIA) contribute to sustainability and performance of the universities along the path of innovations. BDA can help the university by extracting valuable information from big data, however if the sustainability is ignored the social impact will be temporary. The AIA impact service design and commercialisation of high tech products being an effective decision-making tool to increase productivity, and gain sustainable competitive advantages.

Previously, AI focused primarily on tools such as artificial neural networks. The last couple of years, due to enormous generation of data (Big Data) that can be analysed with big machines (supercomputers), the convergence of high performance computing (HPC) with AI, big data, BDA and the cloud, is a main innovation driver in the data economy. This trend indicates that the decision-makers at the universities should defined their goals in alignment with the requirements of the wider society. In other words, AI accompanied by the HPC helps understand an ever-changing world and provide decision-makers at the university with the tools to select the most beneficial sector to spin-off the knowledge generated at the university.

To complete the process of creation the findings of the AI need to be promoted via organising workshops on application discovery and customer discovery. The first one identifies different areas of application for a given technology and to assess and elaborate the most promising ones in detail (technology push). The second one teaches researches to explore customer needs and to derive technological solution potential from them. In the beginning of the spin-offs creation the funding sources must be carefully identified also taking into account the sustainability for at least five years

Figure 1: The car HydRU V5 is designed and produced by the students and their professors at the "Angel Kanchev" University of Ruse.

3. The lifetime of the academic spin-offs

The high value of university research and spin-offs potential for regional development was recognised by the governments and policy makers who began to stimulate the spin-offs creation. However, the process of facilitated creation of spin-offs was accompanied by another process: decreasing of the spin-offs lifetime (reduced survival).

Eleven survival factors were investigated within a quantitative survey to understand which had a significant impact on academic spin-offs performance, [12] in Romania. The study has "validated two research hypotheses that the quality of scientific support received from a university or research centre during the development of a product and the competency of a team in accessing government funds were the most important factors having nonlinear influences on" the performance of the academic spin-offs. Pearson's correlation matrix and a Cobb–Douglas nonlinear regression model were implemented to find out these factors. Various factors affect the life-time of a spin-off such as entrepreneurial skills [13], characteristics of the core technology [14], industry characteristics, career experience, research knowledge, and market requirements, [15].

Keeping in mind that the academic spin-offs transfer new technologies in practice it became vital to help the process of spin-offs creation decoupled from the lack of stability since the short lifetime indicates the status of the entity is unstable.

Examples of the incubator program, [16] - accelerator invented at Fraunhofer for funding innovation projects and technology transfer support for five years. It has been found that a new technology, a good business model and a strong, convincing team of founders are the most important factors for winning investors and, thus, for establishing a high-tech spin-off on the market. However, to achieve a longer presence on the market (long life-time) there is a need for properly defined milestones and contractual relationships for sustainable funding. More, the existing team of founders should be supported by external experts in strategy, sales, internationalisation and services like marketing.

4. Conclusion

In order to increase the life-time of the academic spin-offs it is necessary to

- dynamically analyse the labor and trade market (the opportunity is to implement artificial intelligence algorithms capable to take into account the multi-parametric data collected);
- ensure that the spin-off is the direct contractual partner of the director/rector of the university;
- fund the first stage of development;
- select a patented high-technology available at the university or accessible from another IPR owner ready to transfer the ownership.

Acknowledgements

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Machine translation – a shortcut to better language competence in the era of e-learning?

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Abstract

This paper investigates the use of machine translation (MT) among university students learning a second language. With two questionnaires answered by both students learning Slovene as a second language on-line and their teachers, it was found that students use MT (particularly Google Translate) very frequently. They are quite satisfied with it and perceive its impact on their language learning – with some limitations – as positive. On the other hand, teachers are slightly more reluctant and integrate MT only partially into their language teaching.

Keywords

machine translation, Slovene as a second language, university students, language teachers, questionnaire

1. Introduction

In recent years, machine translation (MT) has become a key factor in language learning. Its rapid spread began when it became available as a free on-line service, and it gained further momentum with the appearance of Google Translate[2] in 2005 [1]. Since the Covid 19 pandemic which moved most tertiary-level teaching on-line, the use of MT has been an every-day fact in the university language classroom [2]. For instance, since then the teachers of Slovene as a second language at the University of Ljubljana have been regularly receiving their students' homework assignments, written with much fewer language errors than their authors produce when in class. This is most likely not due to some discrepancy between what students can do at their home computers and what they can do in the classroom, but to the use of MT. In other words, it could be that they write their homework in their first language (L1) or another language they are more fluent in and translate it into Slovene using MT.

How does this affect second language teaching and learning? Does MT cause students to reach better language competence – assuming that that is the objective of most learners – faster or do they rely on digital help too much and learn more slowly? The subject has already been explored, but mostly for languages with a large number of speakers: Bin Dahmash explored it among the Arab learners of English in [2], Clifford et al. among Spanish and other Romance language students in the USA in [3], Case among foreign language teacher at a regional Swedish university in [4], Ata & Debreli among Turkish speaking students learning English in [5], while Ducar & Schocket rethought general issues regarding Google Translate in [6].

This paper focuses on the case of a less widely used language, i. e. Slovene. The findings presented here are the results of two different surveys, one among university students learning Slovene as a second language on-line (described in detail in [7]) and the other one among their language teachers. The main questions that this paper is trying to answer to are: how often do language learners use MT, how does it affect their learning, and do they perceive it as a shortcut or a hindrance to better language competence in the target language?

2. Methodology

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[2] https://translate.google.com/.

In 2021/22 an on-line survey among foreign students who were regularly enrolled to the University of Ljubljana was conducted. They were mostly speakers of Serbian, Bosnian and Macedonian as L1, learning Slovene as a second language for two semesters.[3] Due to the Covid 19 pandemic all the teaching was organised on-line via the Zoom platform and web classrooms. 104 responses to the survey were received, meaning it was answered by a bit more than 50% of students who completed both semesters of the Slovene language course [7]. The attitudes and opinions of teachers of Slovene as a second or foreign language were gathered with a short on-line questionnaire in winter 2022. It was responded by 22 teachers, mostly at various university courses and also other, more commercially oriented courses. Most of them have many years of teaching experience (10 to 20 years of experience or even more). It should be borne in mind that it is hard to generalise this relatively low number of respondents, but this specific teacher population of Slovene as a FL/SL teachers is not large – for example, no more than 50 teachers participated in the training where they received the survey invitation. So, the survey answers do give us some insight into the views of the whole population of teachers.

The questions in both surveys were mainly closed-ended so they were subject to quantitative analysis, while a few open-ended questions required a qualitative approach.

3. Results

3.1. Students' use of MT

As in some of the previous surveys [3,5], for Slovene students and teachers alike MT software almost unambiguously means Google Translate. DeepL,[4] Yandex Translate[5] or even some on-line dictionaries (Glosbe)[6] were also mentioned among the answers, but they are used to a far lesser extent. Of all the features that Google Translate offers, students mostly use the most basic feature Type. It is interesting that the students respondents hardly ever use the Talk feature, which translates audio files – according to the Cypriot research [5], almost one third of Turkish speaking students who learn English are using it. This relatively large difference is probably due to the similarities of my respondents' first and target language as most of them are speakers of South Slavic languages.

While the details of how Google Translate works are kept secret [8], it is speculated that for smaller languages, the text is translated from the source language into English first and then into Slovene [9]. This is apparently known to MT users, as three languages are most often involved in the process: the student's first language, English and Slovene (Figure 1). Since the quality of the results also depends on the direction of translation, it must be stressed that students translate into Slovene more often from English than from Bosnian/Croatian/Montenegrin/Serbian (BCMS), but when translating from Slovene, they choose to translate into BCMS more often than into English. A relatively large part of respondents, particularly speakers of Macedonian, do not include their L1 into MT but rather choose English, possibly due to the quality of translation.

[3] For regularly enrolled foreign students, the University of Ljubljana offers the Year Plus module in which they learn Slovene for free, cf. https://www.uni-lj.si/study/year-plus/.

[4] https://www.deepl.com/translator.

[5] https://translate.yandex.com/.

[6] https://glosbe.com/.

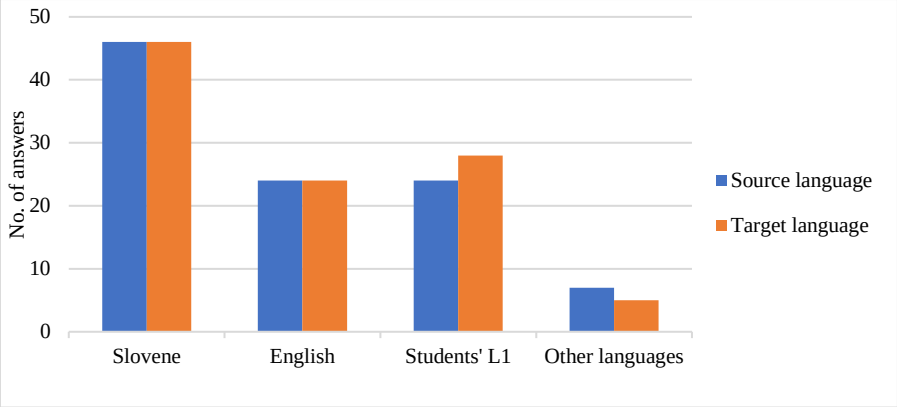

Figure 1: Languages included in the MT process according to the students' answers.

Students use MT in various circumstances – they study and thus live in a Slovene environment, so they use it in everyday life as well as in academic contexts. This paper focuses solely on Slovene language courses. Here the use of MT is predominant in the preparation of written assignments (Figure 2), followed by written communication with professors (for instance via e-mail) and in-classroom use (when explaining new vocabulary, writing and reading texts). One teacher commented that in class, he notices that students assign one student to look up words and phrases on the phone. "They are most motivated to get it right if they then have to present the assignment in front of the class."[7] Students use MT more frequently according to their teachers' evaluations than according to their self-assessments. The situation is the opposite only in language exam situations where teachers seem to be a bit (over)confident about their students' non-usage of MT.

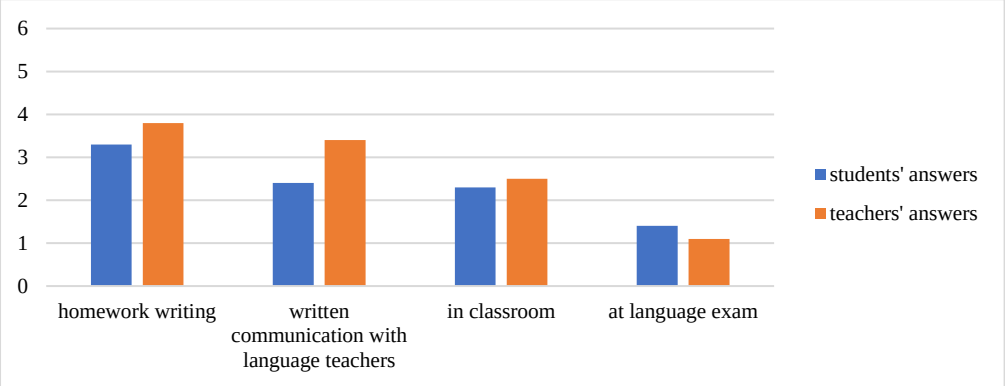

Figure 2: Use of MT at various activities in language courses.[8]

Without a doubt, MT is more widely used when learning the language on-line than in traditional classrooms. The teachers confirmed that, rating their agreement with the statement that students use MT more while distant learning than in traditional classroom on a 6-level scale. 83% of responses were on the positive side of the scale, "I agree" being the most frequent answer (Figure 3).

[7] All comments were originally written in Slovene and translated into English by the author of this paper.

[8] The data were calculated on the basis of ratings on a 6-level scale, with students answering for themselves and teachers rating the behaviour of their students.

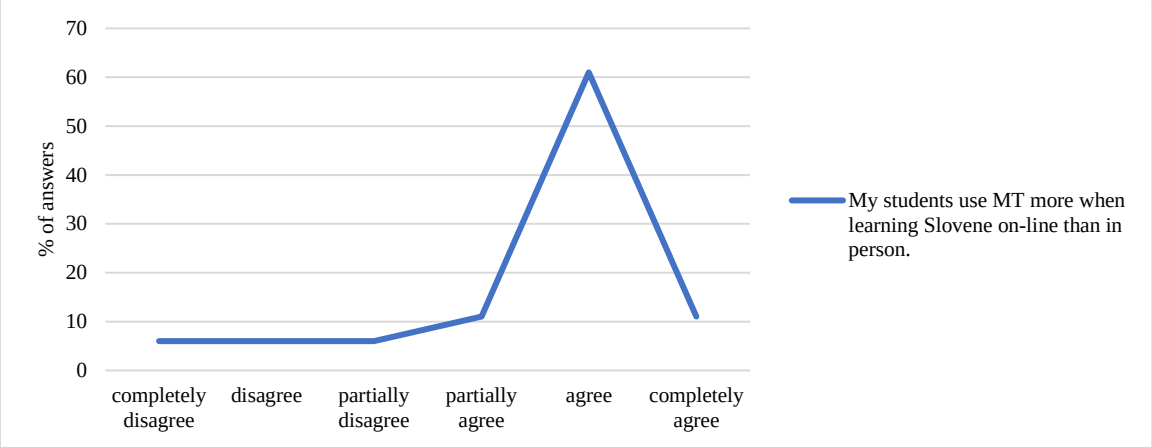

Figure 3: Level of agreement with the statement about the frequency of use of MT when learning the language on-line or in person.

According to various studies [3,5], as well as data from MT providers [10], users most often use MT to translate single words or phrases, less often paragraphs, and least often entire texts. The surveys presented in this paper confirmed that (Figure 4), as their respondents are mostly speakers of closely related languages so they understand Slovene quite well and apparently do not need to translate larger language units. But again, a difference between student and teacher answers can be noticed in the ratings of single word and phrase translation. Perhaps this is due to the fact that teachers encourage their students to translate phrases rather than single words.

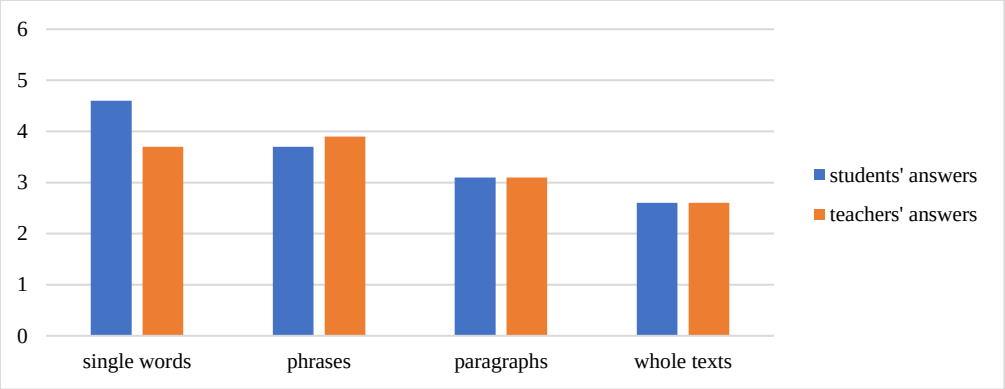

Figure 4: Frequency of machine translation of different language units.[9]

3.2. Satisfaction with MT

In opposition to some other surveys [11], students from the survey presented here are relatively satisfied with the results of MT. Almost needless to say, they are more satisfied with translations of smaller language units (words and phrases) than with translations of whole texts. According to one of the teachers, in MT of full texts "the meaning, cohesion ... was lost. The text was practically incomprehensible." Some of the most frequent translation errors that students state are the use of masculine/feminine forms or the erroneous translations of colloquial expressions. This was also supported by one of the teacher's comments: "The use of masculine form in the past and future tense verbs in texts written by girls – and they themselves are aware of that and say that this is a problem with Google Translate."

The teachers were not asked about their satisfaction with machine translations, but students' and teachers' opinions can be crossed on two statements from both surveys for which they had to rate their agreement with (Figure 5). Of course, both groups are more satisfied with machine translations of

[9] The data were calculated based on ratings on a 6-level scale.

phrases than of full texts, but the difference between students' answers for both statements is smaller than for the teachers' answers.

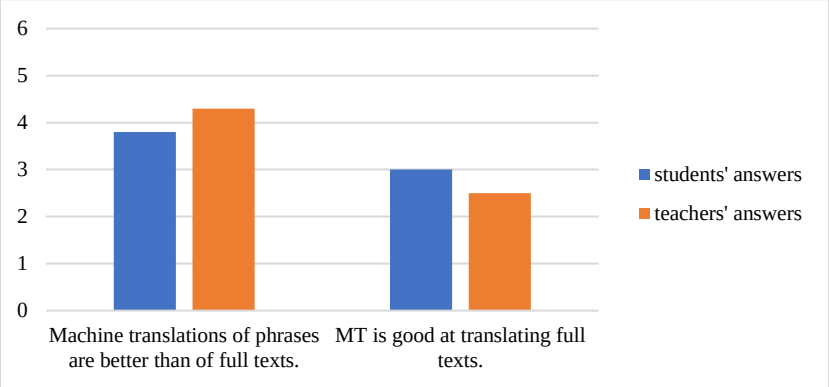

Figure 5: Level of agreement with statements about the quality of machine translations.

3.3. The impact of MT on language acquisition

There is no doubt that MT has an impact on language acquisition, but it is not yet clear whether it is good or bad. On the one hand, there are fears that students become lazy, which is why many teachers even explicitly – though probably not too successfully – forbid its use. On the other hand, MT is supposed to increase linguistic ability and reduce the number of errors in writing [13]. The views of learners worldwide are more or less unanimous. In various surveys it has been found that the vast majority of them find MT translation useful for language learning, especially with regard to vocabulary [3,12]. The respondents presented here were asked about this in the form of statements for which they had to indicate their extent of agreement with them on a 6-level scale. The figures in this section show average results.

A few statements examined the speed and accuracy of learning Slovene (Figure 6). Student respondents were more supportive of the statement that MT makes them learn Slovene faster than teachers who are much more in disagreement (66% of students' and 41% of teachers' responses on the positive side of the scale). Both students and teachers are more reluctant to claim that MT helps them use Slovene more correctly (55% of students', 34% of teachers' responses on the positive side of the scale, with a bigger part of students' responses in the middle of the scale). But both groups rejected the claim that without MT students would be forced to learn Slovene more (38% of students' responses on the positive side of the scale, with a clear preference of the negative answers; 41% of teachers' responses on the positive side of the scale). It can also be observed that for all statements, students' average ratings are slightly higher than teachers' scores (Figure 7), i.e. students are apparently slightly more satisfied with the impact of MT on their language learning.

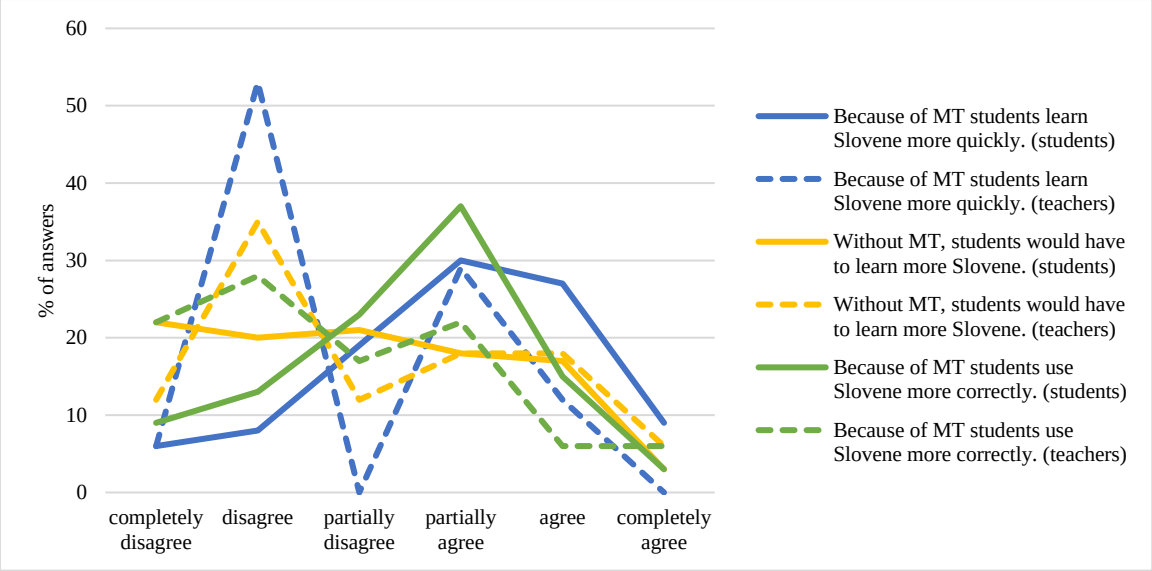

Figure 6: Level of agreement with statements about MT and the speed and accuracy of learning Slovene.

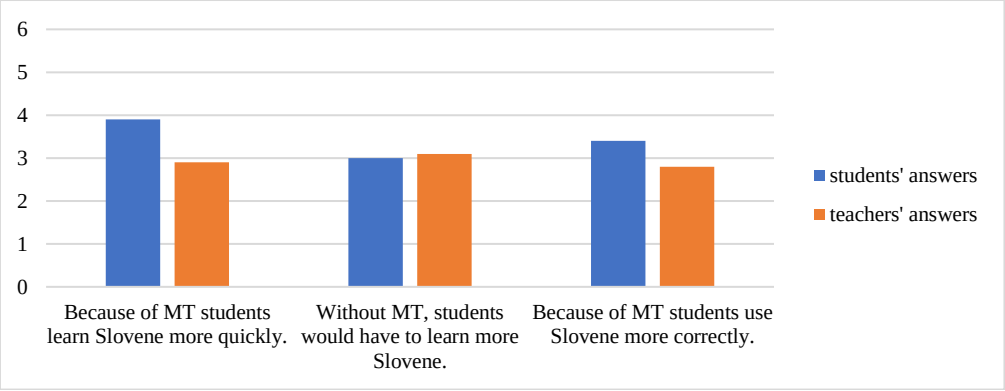

Figure 7: Level of agreement with statements about MT and the speed and accuracy of learning Slovene, average ratings.

Regarding the impact of MT on students' general linguistic performance in the Slovene environment (Figure 8), there are small differences in the results between three statements, although respondents overwhelmingly agree with all of them. As with the statements above, students' average ratings are a bit higher than teachers' for all statements (Figure 9), i.e. students are apparently slightly more satisfied with the impact of MT on their performance in a Slovene speaking environment. Both groups feel that MT makes students understand Slovene texts better (76% of students' and 68% of teachers' responses on the positive side of the scale). When it comes to writing in Slovene, students feel that MT helps them to write better in Slovene while teachers are less in agreement (72% of students' and 60% of teachers' responses on the positive side of the scale, none of the teachers chose "completely agree"). Less strongly do both groups, but teachers in particular, agree with the statement that they find it easier to communicate in Slovene (66% of students', 45% of the teachers' response on the positive side of the scale). Apparently, students and teachers alike feel that MT is not as useful for communicating better in Slovene as it is for some other aspects of language use – and after all, isn't communication one of the goals of second language learning?

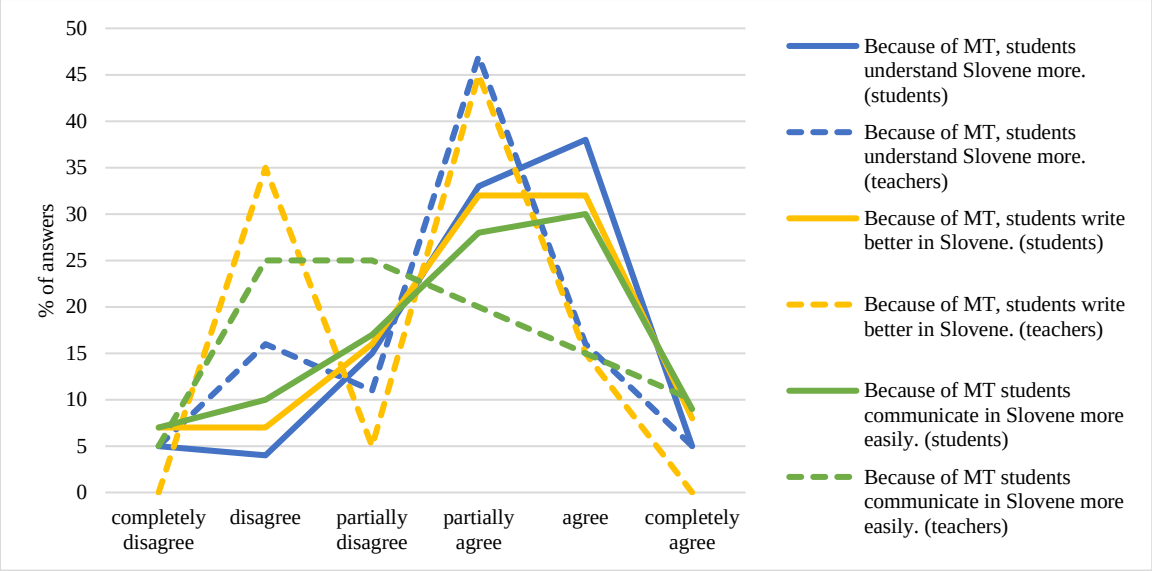

Figure 8: Level of agreement with statements about MT and performance in a Slovene environment.

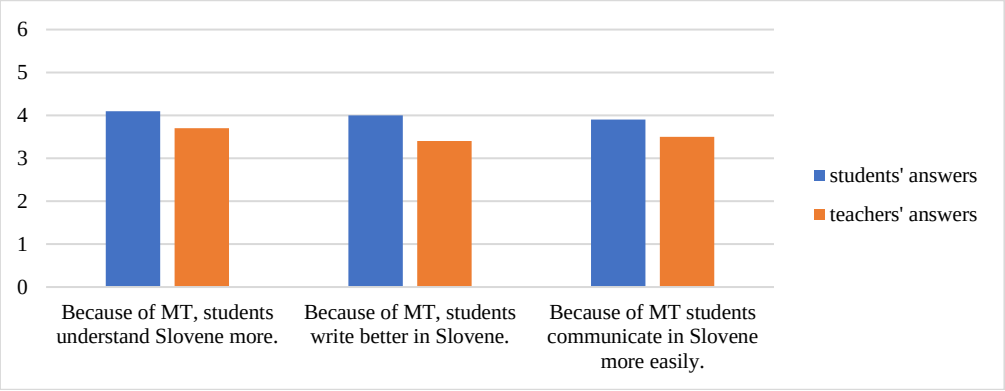

Figure 9: Level of agreement with statements about MT and performance in a Slovene environment, average ratings.

3.4. The impact of MT on language teaching

Regardless of the teachers' view of MT, its impact to learning is there. So finally, let us see how this affects them and their teaching.

In the teachers' survey, teachers were assessed whether MT had an impact on the way they teach. Only two rated the impact as considerable, 11 as partial and 8 as non-existent. Four of the teachers claim that they encourage students to use MT sensibly, e.g., while reading longer texts where it is not necessary to understand everything, and at the same time point out inappropriate translations. Some even use translation errors in language classes. Motivation is a crucial factor: one teacher states that he has no problem with his students using MT when writing homework because they are highly intrinsically motivated and do not want to cheat either themselves or the teacher. One teacher corrects homework differently than before because of MT, only underlining errors instead of correcting them. Finally, one teacher expressed direct opposition to MT: he treats machine-translated homework differently and is stricter with the student who wrote it.

4. Conclusion

MT is a daily reality in language classrooms: it is readily available, easily accessible, relatively efficient, and most importantly, widely used by language learners as well as teachers themselves. Students rate it as useful to their language competence in the second language regardless of its limitations – after all, they are members of the millennial generation and thus used to fast access to information. Teachers are somewhat more reserved about the usefulness of MT for language learning so it is not surprising that a relatively low number of teachers includes it in their teaching. In the words of one teacher: "It seems to me that MT will require us to change our teaching more in the future, and also include the teaching of its critical use."

Thus, MT is still not such a direct shortcut toward better language competence as it is usually described. Language learning is a slow process requiring a lot of hard work, so it is crucial for teachers to keep on showing to students – whether when teaching on-line or in person – why it is beneficial for them to improve their language skills without MT and also to use alternative, possibly more reliable language resources and technologies, such as spell-checkers, dictionaries, language corpora, etc.

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Learning Management Systems for Hybrid Teaching Models in Primary Schools in Serbia during the COVID-19 pandemic

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Abstract

Before the Covid-19 pandemic, the use of Learning Management Systems (LMS) had not been mandatory nor regulated at the primary level of education in the Republic of Serbia. After the Government decision on suspending face-to-face classes, the Ministry of Education obligated schools to implement a combined (hybrid) teaching model based on digital technologies. The aim of this paper is to analyse the quality of frequently used LMS for implementing an effective hybrid teaching model in primary schools in the Republic of Serbia, with regard to the current educational policies. The quality analysis was conducted based on the ELQ criteria. The research results indicate that the sampled LMS meet the set criteria, and although mandatory, the set criteria are not sufficient pre-condition for implementing the quality hybrid teaching in primary education.

Keywords

Learning Management Systems, Hybrid Teaching Model, Covid-19 pandemic, Distance Learning, Educational Policies

1. Introduction

Learning Management Systems (LMS) such as: Moodle, Canva, Talent or Google Classroom are applied in different scope and quality, depending on the type and level of the educational system that uses them, i.e. their goals and characteristics, as well as the technical and personnel capabilities of the institutions.

In the educational system of the Republic of Serbia, at the level of primary school education, the use of these systems had been neither mandatory nor regulated until the Covid-19 pandemic started. Due to the outbreak of the pandemic and the declaration of a state of emergency and the Decision of the Government of Republic of Serbia on the suspension of classes [1] in higher education institutions, secondary and primary schools, classes in the form of video lectures lasting 30 minutes were organised and publicly broadcasted via the Radio Television of Serbia (RTS). Alongside video classes, the accompanying activities for the schools, teachers and students were all organised by the Ministry of Education, Science and Technological Development (MoESTD). In this way, the continuity in the education of students and the work of educational institutions was preserved, at the achievable level and in accordance with the circumstances of the health crisis in which the entire society and the educational system were at that time. Via television channels and multimedia internet platforms, video lectures with certain interactive elements were broadcast for primary and secondary school students. At the same time, the schools organised follow-up educational work for their students in line with the provided instructions of MoESTD, in accordance with the available digital devices and tools, as well as the level of digital competences of the teachers at the given moment. In cooperation with the Office for IT and eGovernment of the Republic of Serbia, an internet location was established (*rasporednastave.gov.rs*), where the schedules of television video lectures were available; a link to the national platform for online learning built on the Moodle LMS, called *My school* (*mojaskola.gov.rs*) which, in addition to televised video lectures from RTS, also offered the possibility for interactive work through tests for self-assessment of students' knowledge, as well as recommendations for establishing

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online communication between teachers and students, i.e. software solutions and instructions. Furthermore, MoESTD issued a *Manual* [2] which instructed the necessary adjustments to the school work organisation should include, i.e. the application of a certain learning model in primary schools in order of health preservation and accordingly, promotion of the LMS application within the existing teaching organisation. New organisational approaches to the implementation of distance learning in the period of crises were designed in accordance with the knowledge about the current level of digital maturity of institutions, the level of digital competences of teachers, opportunities and while taking into the consideration the short deadlines. For periods when schools had to move to a total distance learning model, organisational guidance was also provided, which took into account the resources and level of digital maturity of the school and student capabilities [2].

The aim of this work is to detect which most frequently used LMS are in primary schools during Covid-19 pandemic, and then to analyse the quality of most frequently used LMS for implementing an effective hybrid teaching model in primary schools in the Republic of Serbia, in regard to the current educational policies. The analysis of the quality of the applied LMS as well as software solutions and tools in the national school system during the pandemic within the hybrid model of primary school teaching in the Republic of Serbia is planned based on first seven ELQ (e-learning quality) criteria.

The question of the quality of the implemented hybrid teaching in primary education rests on the quality criteria of the LMS, but also opened the questions of the digital competencies that are part of the complex professional competencies of teachers and the importance of digital maturity in schools.

It should be emphasised that there are different definitions of LMS. According to its basic characteristics, it is specialised software used for planning and implementing the teaching process in an online environment and involves enabling the interaction of all members, as well as ensuring the conditions for evaluating student achievements. Also, within the LMS, the planning of the teaching process includes, among other things, the creation of digital teaching content, the addition of educational resources, the design of various learning activities (assignments, workshops, forums) that foresee providing feedback, encouraging peer learning and providing transparent formative and summative assessments of student achievements [3].

Google Classroom was created in 2014 as part of the Google G Suite for Education package, which required registration of the institution. In 2017, Google made Google Classroom available to all users with a Google Account, which can be used to create online courses. The platform relies on Google tools, primarily on Google Drive where documents are stored, but also on other Google applications such as Google Documents, Sheets, Slides, questionnaires and various upgrades. This free platform allows teachers to build an online environment, where they can share materials, links, communicate with students, set assignments and evaluate their activity. A free Google G Suite for Education package was available for schools, which allowed the schools to manage and decide which Google services students could use, and it was supposed to provide a safer environment in terms of protecting the privacy and security which is important in a school environment. Google Classroom is a type of user-friendly platform for both teachers and students. All participants, both teachers and students, use it intuitively, which certainly affected the percentage of use of this platform.

During the pandemic period, the Microsoft Corporation provided schools with free use of a platform adapted for education - Office 365 for Education. The platform included Office Online (Word, PowerPoint, Excel and OneNote), one terabyte of OneDrive storage, Yammer, SharePoint, as well as other useful services such as Teams, which enables conducting a video conference which resembles a classroom. Although not many primary schools had been using the Microsoft platform before, it was widely spread at the University level - the services of this platform were used by over one hundred and ten teachers who are in the academic institution and students, and it had a set of different services that enabled teachers to collaborate effectively with students.

On the website for school support established by MoESTD, there were instructions for using the Microsoft Teams application, with which teachers could share the content of their screen with students through a group video call, as well as record the entire course of the lesson and make it available to all students from the corresponding study group. The platform could be accessed by millions of teachers in the world's leading universities, colleges and schools, it was available free of charge for computers and mobile devices; for those who had no other access to the Internet, free access to the platform was provided through the nationwide telecommunications operators. Also, video instructions have been prepared for teachers on how to use the video conference tool, namely: how to form a class and subjects;

how to schedule and hold a video conference class; how to distribute teaching materials to students; how to prepare an assignment and how to answer the assignment; how to review the returned assignments. Video instructions with guidelines were also made for the students.

Edmodo is a global educational network that was another available free software option, created in 2008, with the aim of connecting and cooperating teachers and students, sharing teaching content, sharing messages within groups, connecting teachers, sharing pictures and videos, recording activities in the calendar, forming a personal library with important web addresses, monitoring student work, publishing student work in one place, creating quizzes and surveys. Also, students' answers are processed statistically and automatically, which ensures immediate feedback. Teachers, students and parents have the option of opening a user account on this platform, through an administrator or email address. The research results on the use of the Edmodo platform during the Covid-19 pandemic show that it is effective and can be successfully used in a hybrid teaching model [9].

The Serbian Edmodo sub domain is accessed on the website *srb.edmodo.com*. This system has a user-friendly interface which is suitable for primary school students and is simple to use. On the national platform for online learning, there were no video instructions for its use, as was the case for the My Classroom TeslaEDU system based on the Moodle platform, The Institute for Improvement of Education of the Republic of Serbia prepared instructions for its use.

Moodle is a free online distance LMS with a professional and stable work environment for lectures and incorporates many pedagogical tools. The structure of Moodle supports many types of data, and is flexible for changing the appearance and functionality of an individual page or course. For this reason, it was used at many faculties in the Republic of Serbia. In this environment, students can interact both with their peers and the teacher, participate in polemics on the forum, use the interactive chat room, search and collect data, send their homework, take part in quizzes, use the wiki module and more. Also, it is available as the translated version in Serbian language. It is important to note that recently, trainings for school Moodle administrators from all primary and secondary schools in the Republic of Serbia have been conducted for the implementation of the Moodle LMS (90% of primary schools delegated participants); two iterations of trainings *Online and hybrid teaching in a digitally proficient institution* in which over 2,000 teachers, professional associates, headmasters and pedagogical advisors involved in the pre-university education participated; the online Instrument for Self-Assessment of Digital Competences of Teachers in Serbia Digikomp[2] was published, which was developed according to the Framework of Digital Competences - Teacher for the Digital Age 2019, the revision of which is planned in 2023; the *Digital School* program was started as a pilot project as well as *the Academy of Digital Schools*.

My TeslaEDU classroom - represents a unified package of functional modules based on the Moodle LMS, localised in the Serbian language and provided by the MoESTD in cooperation with the Office for IT and eGovernment and one tech company. For the purpose of helping out the users of this system, the website *rasporednastave.gov.rs* contained instructions for: accessing the web and mobile application, for teachers and students respectively; attending the course; reviewing and completing tasks; taking tests; for students communication (from the web browser, as well as from the mobile application). Video instructions were provided for teachers on how to: assign courses and add class groups to a course; create and grade assignments; create tests; communicate and monitor student attendance. The Institute for Education Quality and Evaluation prepared the guidelines for teachers that should help the users with the above-mentioned system [8].

2. Application of the hybrid model of organising the teaching process during the pandemic

Professional instructions for the organisation and implementation of educational work in primary school in the school year of 2020/2021, represented an obligation and starting point for organising, planning and programming the entire educational work in schools in difficult conditions, in accordance with the law and regulations governing the plan and program of teaching and learning, as well as work models that should be applied in school year 2020/2021, depending on the epidemiological

[2]https://digikomp.ceo.edu.rs

situation. The instructions and hybrid models for organising the teaching process were developed taking into consideration the potential of distance learning, as well as the video lectures that were available through the RTS, as well as the possibilities provided by the hybrid teaching model.

In January 2021, the Institute for Education Quality and Evaluation, as an expert institution of the Ministry of Education, issued the document *Online and hybrid learning - long-term aspirations and short-term guidelines* [3], with the aim of providing an expert framework and support for a new school class organisation in the Republic of Serbia that consisted of terminological definition, technology implementation models and school work guidelines the second semester of the school year 2020/2021, for the period of time before the planned establishment of the Moodle system for managed learning in all schools. The terms used in this document for different teaching models are somewhat different from the terms used in the Ministry's *Manual* [2], so the following are mentioned here: online and hybrid teaching. In addition, this document divides and presents models of the implementation of educational work using digital technologies in the teaching and learning process, namely:

1. Working face-to-face at school with occasional use of digital technology in class;
2. Online teaching, entirely conducted via the Internet;
3. Hybrid teaching, which combines face-to-face and online teaching.

The guidelines given for organising hybrid classes were precise, with clear and detailed instructions for planning and organising classes and intended for both the school and the teachers. Compared to the other two models, the hybrid model was most often applied during the pandemic, combining the advantages of the other two enlisted models. Except in the circumstances of the state of emergency, it is also applicable in various different situations.

The most significant feature of hybrid teaching is that face-to-face teaching is enhanced with online learning. There are several models of hybrid teaching, depending on the different approaches and practices of teachers. For example, *the flipped classroom* is one type of blended learning that can be applied in hybrid teaching, in which students are asked to study independently with selected online materials that will later be used in face-to-face teaching for a specific activity.

The hybrid teaching model enables the effective integration of technology and the school curriculum. However, similar to some other approaches in learning and teaching, it is necessary that the hybrid model also follows the pedagogical principles in order to be effectively implemented in teaching practice. This implies that the teachers are educated to implement methodologies which ensure achieving the teaching goals [4].

3. ELQ model for quality assessment

In our work ELQ model was used in the quality assessment of the LMS that were regularly used in the Republic of Serbia. The quality assessment model was qualitatively adapted in order to assess the quality of used LMS as well as software solutions and tools in the national school system during the pandemic within the hybrid model of primary school teaching. It consists of ten quality criteria: learning material and content; structure of the virtual environment; communication, cooperation and interactivity; student assessment; flexibility and adaptability of the system; teacher and student support; competences and experience of teachers; vision and leadership of the institution; content resource allocation and holistic and process aspect. The criteria are not listed in the order of importance; however, fundamental differences exist among them which imply the aspects are ordered from the smallest elements in the learning process to the more organisational, systemic perspective [5]. The following is a description of the first seven ELQ quality criteria of the quality of online learning, considering that the analysis of the quality of the applied LMS in the hybrid teaching model in the Republic of Serbia was planned based on them.

3.1. Material and content for learning in an online environment is "much more than a printed book, i.e. it represents a multimedia interactive environment in which the distinctions between content, virtual environment and teaching, as well as between learning and interaction, are lost" [5]. The material can be both printed and digital, but the selection, creation and adaptation

of content and learning materials are of utmost importance for the quality of learning in a digital environment. The material can be created by a teacher, a publisher or a group of experts, which is of highest importance when it comes to complex digital educational content. It should be noticed that teachers should be principally critical when it comes to the process of downloading existing materials from the Internet. The text can be transformed by software so that it can become an auditory media, or it can be transformed and enriched with additional illustrations and multimedia content by teachers, students or digital content creators. Considering the complexity and diversity of digital content, it is necessary to have quality standards of production, so that they can be used in different virtual environments and on different devices. Criteria that can be used to grade the application and quality control of content and materials for online learning are: guidelines for the selection and creation of digital content including clear pedagogical and technical criteria; guidelines for rights of use issues; application of the first two criteria and internal evaluation and improvement of elements in the first three criteria.

3.2. The structure of the virtual learning environment, in other words LMS, must be based on a pedagogical framework that implies an easy and structured way of finding information and quality communication with teachers and other students. The technical infrastructure should be of high quality, reliable, accessible and easy to use. In addition, modern learning platforms are being developed in the direction of multimodal communication and the integration of tablets and mobile phones. MoESTD set the multimodal communication as one of the most important conditions when it comes to the selection process of learning platforms in each school. The criteria that can be used for the implementation and quality control of the structure of the environment are: selection based on pedagogical needs; an environment that is of high-quality, consistent and harmonised with the technical infrastructure of the institution; internal evaluation, as well as modernization and improvement of the elements from the first criterion.

3.3. Communication, cooperation and interactivity are the main features of the learning process. Timely and efficient planning of these elements is of particular importance in online teaching. Communication in an online environment depends on the available infrastructure, the level of digital competences of teachers and students, as well as the teaching goals. Communication itself in an online environment can be synchronous or asynchronous. Online learning collaboration can be extended to open online communities, or secured and accessible only to students in a specific department within a LMS. Synchronous communication can be organised through communication channels and video conference tools between teachers and students. Synchronous communication is planned on a weekly basis within the guidelines for teachers, while certain interactive activities can be conducted among students only, without the synchronous presence of the teacher. When it comes to primary school, precise guidelines for teachers are given for weekly planning and also how to conduct synchronous and asynchronous communication with students. Criteria that can be used for implementation and quality control are: a clear strategy for communication, cooperation and interaction in accordance with pedagogical needs, available technology and human resources; implementation and evaluation; improvement of the first two criteria.

3.4. When it comes to assessing students and their achievement, there are significant differences between assessing students in face-to-face classes and in an online environment, later which has additional challenges related to student identification, proper formative and summative assessment, swift feedback etc. However, the way of assessing student achievement in the online environment can be diverse: by posting students' text works, through oral synchronous communication with the help of video-conferencing tools, through individual or group discussions, by posting digital materials by students, by giving tests... In the hybrid organisation of teaching, the assessment of student achievements is primarily conducted during face-to-face teaching, to avoid the shortcomings of online testing, but it is also possible to use testing in LMS, which provides various opportunities and advantages. Assessment of students in the online environment is a complex area, and more information about the

formative and summative assessment of students can be found in the available publication of the Institute for Education Quality and Evaluation [6]. The Criteria which could be used in the effective evaluation process of implementation and quality control are: strategy for objective, flexible and pedagogically based assessment; applied policy for plagiarism; protection in access and identification of students and evaluation; improvement of the first two criteria.

3.5. The flexibility and adaptability of online learning implies answers to various questions such as: where it is possible to learn; when it is possible to learn; what the pace is and how much time it takes students to learn; what is the language and style of the learning content and instruction; are there adequate adaptation methods used for students with special needs. It is essential to adapt the services of the LMS to the target group, when it comes to the mentioned characteristics. In this sense, precise instructions and recommendations were given for the use of the system in both hybrid and online teaching models in the Republic of Serbia. The criteria that could be used for measuring the implementation and quality control are: a strategy for enriching the characteristics of educational flexibility based on pedagogical foundations, student needs and requirements; implementation and evaluation; improvement of the first two criteria.

3.6. Support for students and teachers when using LMS affects the quality of the learning and teaching process. The support includes administrative and technical assistance for teachers, time allocated to support students in using the system and motivating students to use it, support and assistance for gaining Internet access, solving technical problems and more. The criteria that could be used to measure the level of implementation and quality control are: strategy for student support including technical, administrative and social support on request; strategy for supporting the institution, including technical and digital competence support on request, as well as the implementation of the first two criteria and the evaluation and improvement of all three previous criteria. The Institute for Improvement of Education has enhanced mentoring support for schools and teachers in planning and implementing the teaching process in a digital environment, which functions through an online system located on the National Education Portal (*www.portal.edu.rs/podrska*).

The qualifications and experience of teachers and associates for the use of LMS include a continuous system of support and professional development, increasing awareness of the use of new technologies, knowledge of how students learn with the help of different media and communication channels, a critical approach to new technologies and improving knowledge as well as the abilities for continuous improvement of the environment for online learning, and above all improving knowledge and abilities for the pedagogically driven use of new technologies. The criteria that could be used for measuring the implementation and quality control are: the strategy for the development of teacher and student competencies, as well as the implementation of the strategy and the evaluation and improvement of the strategy and its implementation.

When it comes to the remaining aspects of quality - the vision and leadership of the institution, the allocation of content sources and the holistic and process aspect - they are not discussed in this paper since they represent a more organisational, systemic perspective of the online learning quality, which can be a separate topic for analysis, within the analysis of educational policy and its application in the Republic of Serbia.

4. Quality analysis of the most frequently used LMS in the Republic of Serbia

For the purposes of this paper, the analysis of the quality of the applied LMS in the hybrid model of teaching in the Republic of Serbia was performed based on the above-mentioned seven ELQ aspects of the quality of online learning.

Data was obtained from official Informational Database of the MoESTD[7]- Dositej. Schools had the possibility to independently note down the title of the system in Dositej, in which the data is joint.

For the implementation of online teaching, which is fully conducted via the Internet, the MoESTD instructed in the *Manual* [2] that primary schools should use only one LMS per educational cycle, respecting the age of the students, as well as the guidelines for choosing the system: that access to content and activities should be possible at any time, depending on the program and pace of the user's work (24 hours a day, 7 days a week); that the system should be a closed virtual educational environment meaning it cannot be accessed by an unauthorized persons; that it should be accessible via Internet through various types of digital devices (computer, laptop, tablet, mobile phone...) regardless of the pre-installed operating system (Windows/Android/iOS/MacOS...); that it should be restricted to the Serbian language and/or the languages of ethnic minorities; it should enable the creation of digital content containing text, images, sound, video and links to verified web locations to which the teacher directs students; to enable uploading and downloading of basic files (text document, spreadsheet, multimedia presentation…); that it has built-in functionalities which enable communication between teacher-student and student-other students; to enable the integration of conference tools (sharing video, audio, screen) with the possibility of recording online lectures/content and videos that can be made available to all students on demand (VoD-Video on Demand); to enable teachers to create quizzes/texts or questionnaires to assess students' knowledge; to have the ability to store teaching materials and student works and to have the ability to integrate other digital online resources [2].

As a form of support, MoESTD has provided teachers and students with instructions for using the following systems and tools on the web location (*rasporednastave.gov.rs*): My TeslaEDU Classroom (based on Moodle LMS); Microsoft Teams, a video-conferencing tool within the Office 365 for Education LMS; Zoom application and Viber Community application. At that moment, these instructions were useful for teachers, many of whom were encountering the organisation of distance learning on a systemic level for the first time. The instructions were intended to help and support all participants in the teaching process – the teachers, as well as students, and their parents. However, other tools and platforms were also used, which were user-friendly and free, and thus are widespread and well-known, such as Google Classroom and Edmodo, which will be presented in the part of the paper on the solutions used at the level of the Republic of Serbia.

5. Results

Based on the data obtained from MoESTD [7], which are shown in Table 1, four different LMS are chosen for the ELQ model based evaluation. Taking into account that the schools had the possibility to independently note down the title of the system in MoESTD's official Informational Database Dositej in which the data is joint, the data obtained does not provide the most accurate picture of the level and manner of use of a certain system and/or tool, which is the main disadvantage for the effective application of the ELQ model.

Table 1.
Representation of LMS in primary schools during the pandemic[3]

LMS or alternative software solution or video conferencing tool	Percentage of use (%)
Google Classroom	78.9
Microsoft Teams	9.9
Other system	7.2
Edmodo	2.4
Moodle	0.7
School's digital platform	0.3

From the Table 1, we can see that the majority of primary schools used Google Classroom (78.9%), Microsoft Teams was used in a significantly smaller percentage (9.9%), while the Moodle platform was used to a considerably smaller extent (0.7%) which indicates the level of digital maturity in basic education in the Republic of Serbia.

Assessing the above-mentioned systems indicated that all of them meet the mentioned quality criteria, but that does not speak for the quality of the implemented hybrid teaching. During the analysis of the MoESTD data [7], it was detected that the questionnaire for data collection was not precise enough, i.e. the school representatives entered the names of the systems used, without complete information, i.e. it is not specified whether the schools that used the Google Classroom used the Google G Suite for Education system or only the G platform on which they created the Google Classroom. It was also not specified whether they used the complete Office 365 platform or only MS Teams.

Based on the data obtained from MoESTD [7], the other most frequently used tools by schools for building a hybrid teaching environment were: Viber, E-mail, Zoom, Google Meet, Facebook, WhatsApp, as well as the school website. The use of the Viber Community application and service was enabled and that made possible the effective group communication and the exchange of information and materials. Also, for those who do not have another access to the Internet, free access was provided through the mobile operators. MoESTD has prepared short video tutorials for both teachers and students for this application.

6. Discussion

The question of the quality of the implemented hybrid teaching in basic education certainly rests on the quality criteria of the LMS, but also on the digital competencies that are part of the complex professional competencies of teachers. When it comes to the initial education of teachers on the topic of obtaining digital competences in the function of creating a stimulative and safe hybrid teaching environment, the results of earlier research indicate that at Teacher Education Faculties that educate future teachers, more attention is paid in comparison to non-teaching faculties that have teacher profiles. Furthermore, faculties also need constant social support and cooperation, as well as a well-coordinated system of professional development of teachers from their initial education during studies to continuous professional development during work [10]. The Education Development Strategy 2030 speaks in favour of strengthening the entire system, which indicates the strengthening of the institution capacity of the pre-university education, which can result in raising the quality of hybrid teaching environments that also include the use of LMS [11].

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7. Conclusion

We can conclude that all four analysed samples of LMS meet the quality criteria according to the ELQ model, which include: building content and setting up learning materials; the structure of the virtual environment; multidirectional communication, collaboration and interactivity; student assessment; flexibility and adaptability of the system; teacher and student support; putting into practice the teachers' existing experiences; implementation of the institution's vision and leadership; allocation of content sources and a holistic approach.

Fulfilment of the quality criteria of the LMS according to the ELQ model are necessary, but there are no sufficient conditions for building a safe and stimulating hybrid constructivist teaching environment. The digital competences of teachers, students and associates play a key role, as do other factors (number of students in the class, age of students, nature of the subject, technical prerequisites, preparation of parents etc.) that we must not ignore and that need to be thoroughly and in-depth investigated. Pandemic living and working conditions have intensified the use of hybrid teaching models in basic education in the Republic of Serbia, which has also influenced the educational policy, which increasingly recognizes the importance of digital maturity in schools.

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A Lightweight Permissioned Distributed Ledger for Credentialing in Higher Education Institutions

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Abstract
Blockchain and similar distributed ledger technologies are often referred as the next disruptor in Information-Communication Technologies. The security properties blockchain technologies offer have surpassed the initial use-cases in cryptocurrencies, and a variety of blockchain-based solutions are appearing daily in healthcare, financial technology, supply chain management, and education. In this paper, we examine a permissioned blockchain, i.e., a distributed ledger solution for students' credentialing during their studies at a Higher Education Institution. Utilizing the Hyperledger platform, which allowed us to use a lightweight consensus mechanism, we aim to incorporate the model within an existing faculty- or university-level information system. With the innate properties of immutability and transparency, the presented model provides authorized users with a secure proof of student credentials which can be verified at any time.

Keywords
blockchain, distributed ledger, e-learning, student credentialing

1. Introduction

Even before the recent COVID-19 pandemic, online education portals such as edX, Coursera, and Udacity were getting a large influx of new learners, and Massive Online Open Courses (MOOCs) have gained a notable significance in the contemporary educational scenario [1]. Learning portals can be focused for professionals, such as LinkedIn Learning, or for a wider audience with various levels of prior knowledge, such as Skill Share and Udemy. These portals meant for learners often with no previous background required, cannot compete in quality compared to an accredited online curriculum offered by a Higher Education Institutions (HEIs). These policies are also mirrored in pricing options – some portals offer free courses or course snippets with paid certification after course completion, while others offer different subscription levels. However, most often these types of learning portals charge per course. Alongside MOOCs, a growing number of HEIs are offering their new and current students the option of online enrollment, or offer blended learning as a combination of face-to-face and online studies [2, 3]. In addition, HEIs may offer complete or truncated versions of their curriculum on other portals, delivering an equal or similar education content in terms of quality [4, 5].

The aim of this paper is to present a system for credentialing the certificates gained from HEIs and similar learning platforms by applying blockchain technology (BCT). Blockchains are append-only ledgers to which data can be added but changed or removed only in extraordinary circumstances. This feature guarantees the integrity of the data. BCT addresses interoperability issues by creating an overarching mechanism to link disparate personal records, such as badges and certificates from various learning platforms.

The rest of the paper is organized as follows. Section 2 presents our motivation behind applying blockchain to HEI credentialing. Section 3 gives a brief overview of blockchain fundamentals, followed

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by the proposed system model, where we use the lightweight Hyperledger distributed ledger. Finally, in Section 4, we draw conclusions, highlighting the areas for future research and platform development.

2. Motivation

Blockchain is often referred as one of the next disruptive technology [6]. The security properties that these classes of technologies offer, especially transparency, immutability and innate use of public key cryptography, made blockchain surpass the initial and most widely known use-case in cryptocurrencies and financial tech [7, 8]. Indeed, today exists a plethora of blockchain-based solutions in areas such as education, supply chain management, healthcare, and the public sector. [9 – 13] In addition, a very large number of start-ups in blockchain development and blockchain-as-a-service (BaaS) are emerging, while in the scientific community, journal special issues and conference tracks on blockchain may be found more and more.

However, regarding blockchain-based solutions for education, especially in credentialing, there exist only a relatively small number of papers published compared to other blockchain-based applications [14 – 16]. The authors of [14] state that their BCTs platform promises permanent authentication as well as storage for the so-called credentials market, that is made up of various kinds of micro-credentials. These micro-credentials include nanodegrees, MOOCs, and certificates and/or badges from various types of training programs. Their platform gives users direct control and, more importantly, management over their credentials. They highlight potential issues such as scalability, especially when the blockchain uses the computationally complex consensus mechanism proof-of-work (PoW), the same mechanism as Bitcoin. Paper [15] points out that blockchain-based solutions in education allow learners and as well as teaching staff to automatically verify the validity of certificates directly, without the contacting the organization that originally issued those credentials. This approach aims to remove the need for educational organizations to constantly validate credentials. The authors of [16] give an abstract model for secure credential in e-Learning to both HEI and MOOC platforms. In this paper, we mostly build upon the concepts found in [16], expanding to a more lightweight model, applying private blockchain technologies such as Hyperledger, and the use of lightweight cryptography often accompanied with Internet of Things (IoT) applications.

3. Lightweight blockchain-based system for credentialing

In this Section, we firstly give a brief overview of BCTs, highlighting the use of private BTCs for our model. Afterwards, we present the proposed model, expanding our previous model in [16]. Our new model is more focused on building a network of known peers, allowing the use of a more lightweight, but still secure credentialing network. Finally, we present two use-cases for the transactions in the network.

3.1. Blockchain fundamentals

Blockchain technologies impose a significant paradigm shift in the methods of data processing, especially when dealing with personal data. A blockchain network can be viewed as a data structure, which is shared among nodes comprising the network. The data structure is append-only, and all events, which are termed transactions, are stored in linked blocks [17]. Each transaction, besides the data itself, contains a unique cryptographic signature, ID and timestamp and a hash value of the previous block, which makes the blocks in the chain resistant to alterations. All blocks therefore form a chain, and can trace back to the first block, called the genesis block. As the blockchain is a distributed network, and all nodes in the network are updated with the current version of the blockchain in real time. A blockchain relies on distributed peer-to-peer networking, public-key cryptography algorithms, and distributed consensus, which is the mechanism allowing new blocks to be added to the blockchain.

The combination of these three core concepts is what secures the blockchain and its transactions. In a centralized system, there exists a single entity which is able to control the process of adding a block to the chain; however, in blockchain, each block is managed by all nodes, which share the same level

of permissions. Table 1 highlights the benefits of implementing a blockchain-based solution over a traditional centralized solution [18]. With decentralization, security issues can be resolved through the process known as distributed consensus. This process establishes a formal agreement between the participating nodes in the blockchain to validate a data block before it can be added to the chain. Depending on the consensus algorithm, nodes can e.g. compete among themselves for correct transaction validation, or be chosen to validate randomly. These algorithms can vary in complexity and power consumption.

Table 1
Comparison between using a traditional centralized platform and a blockchain platform [18]

Aspects	Centralized platform	Blockchain-based platform
Data Handling	Supports create, read, update, and delete operations.	Only read and write options are available
Authority	Controlled by the administrator	Decentralized even in private blockchains
Integrity	Data can be altered	Data are immutable and auditable
Privacy	High chances of malicious cyberattacks	Data are stored using cryptography technology
Transparency	Databases are not transparent	Data are stored in a distributed network
Quality Assurance	Administrators are needed to authenticate data	Data can be tracked and traced to the origin.
Fault tolerance	High risk of single point of failure	Distributed ledger is highly fault-tolerant.
Cost	Easy to implement and maintain.	Uncertainty in the operating and maintenance costs.
Performance	Fast, with great scalability	Slow; scalability is a challenge.

It is important to note that blockchains are a group of technology; the term refers to different forms of distributed databases with variations in their technical and governance arrangements and complexity. Custom-made, private blockchains developed for a specific purpose are often referred to as distributed ledger technologies (DLTs).

As far as the author's knowledge, implementing BCT in education is still a novel topic, and in existing literature, there exist different approaches as to which data should, and more importantly, which data should not be kept on the DLT [19 – 23].

3.2. System model

In this paper, we present an improved model for credentialing from [16], which is primarily aimed at a network of HEIs, such as different Faculties which belong to the same university, or for different Universities. We identify three main parts of our model, as shown in Figure 1. The first part is the authorized user, who can access the DTL using an online platform that connects to the DTL network. The user may or may not be a student from the HEI that he/she is requesting a certification validation; however, the user must be authorized. An individual node is the faculty or university which issues the Diploma/Certificate of their students. The third and most important part is the DLT network running Hyperledger, which can be accessed by the user, and by the node as well. Whereas in [16] the network can run independently of the platform, here we empathize that all nodes that the network is comprised of are known, i.e. we are using private blockchains or DLTs. By having known nodes, the model has significant improvements. Firstly, all nodes are therefore by default trusted parties. Secondly, by making the network private, a node cannot be added easily; usually, adding a node to a private network

requires an invitation. Finally, private DLTs such as Hyperledger allow the use of lightweight consensus mechanisms, making block addition less computationally complex and hence less power consuming.

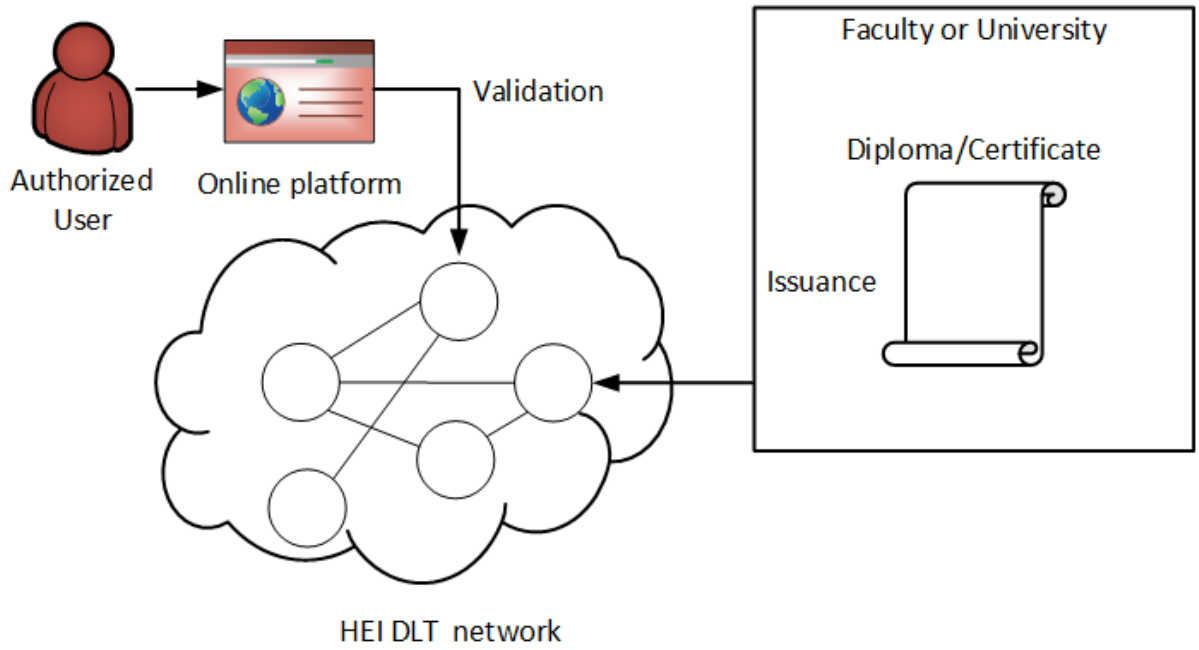

Figure 1: DLT-based credentialing model.

3.3. Network transactions

Two network transaction exist in our model – certificate issuance and validation. Every node in the network should firstly be able to issue a digital document representing a diploma and/or certificate. When a student of the HEI which as a part of the network is awarded the document, a DLT issuance transaction is triggered. It is assumed that the HEI will have its information system (IS) which keeps all documents as well, and it is the IS itself which is connected to the DLT network through an Application programming interface (API). This transaction will contain the same information as would the digital document itself, alongside the metadata required for the transaction header. Furthermore, each issuance transaction can be a single block, as there is no high frequency of issuing these types of documents and therefore no need for a so-called transaction pool. This information will be encrypted, and can be accessed only by the HEI, the student which the document belongs, and an authorized third party upon explicit request. Other nodes in the network will verify it and add it to the blockchain using a lightweight consensus mechanism. Platforms such as Hyperledger Fabric Lightweight or Hyperledger Minifabric can be used for the validation process, or an altogether new mechanism, such as Proof-of-Block-and-Trade (PoBT), primarily suggested for IoT applications [24].

The other type of transaction is certificate validation. This type of transaction can be triggered by a node of the network as well, or through a proxy, an authorized user. Upon requesting access for validation, the authorized user is given an access link, from which the user can verify the document by accessing the DTL through a web application. For example, let say a potential employed wants to verity a digital document that the student has provided for a job application. Rather than contacting the HEI that issued the document, the potential employer will be given with a verification link. Upon registering, this user can access the DTL network for document validation only through the issuing HEI. When the certificate file is uploaded, its metadata and hashed values are indexed and compared to previously validated entries in the blockchain. This represents the validation transaction, triggered from the HEI providing the verification link. If a match is found on the blockchain, the certificate file is validated and a corresponding message appears on the web interface. If not, a negative message appears instead. The sequential diagram for both transactions is shown in Figure 2.

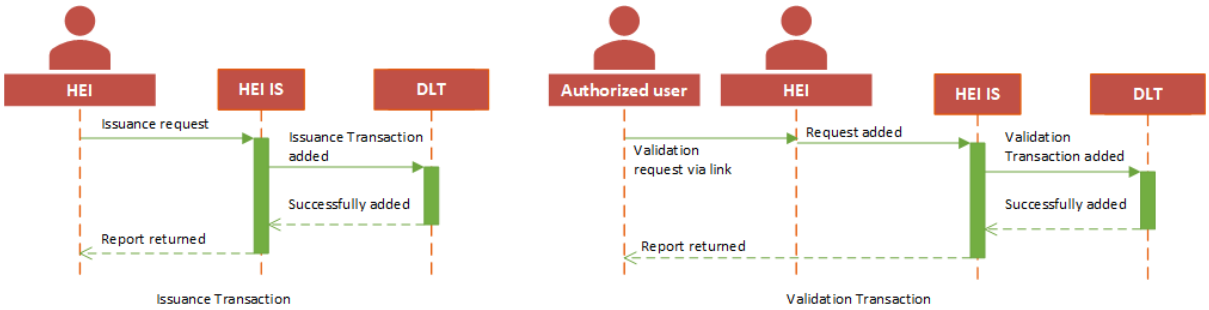

Figure 2: Sequential diagrams for both types of transactions.

The innate security properties of of DLTs, as a subset of BCTs, especially the immutability property, makes modified or fraudulent digital documents practically impossible to pass verification. Any tampering to the digital document file will result in a vastly different hashed value of the file, hence only valid documents can be correctly verified.

4. Conclusion

Using private blockchain, i.e. DLTs, sensitive data such as digital certificates from HEIs can be issued and verified reliably, without the need for complex computational power and electrical power consumption. Blockchain and distributed ledgers can aid HEIs such as Faculties and Universities by adding an additional layer to their credentialing process, with little maintenance cost but with added security. In this paper, we have presented a DLT-based system for issuance and validation that can be easily deployable and connected to a HEI's IS. With this layer, issuance and validation could become a seamless process as there are only two types of transactions that need to be implements in the network. Adding blockchain-based solutions to HEIs such as the one presented in this paper therefore presents a step towards more secure studying, from the perspective of the student, and from the education institution as well.

This model has its limitations. Namely, it is required that a HEI has an IS which can be expanded by adding the DLT layer. As of writing this paper, the model has not yet been developed; however, future work includes developing a standalone prototype paired with a mock HEI IS for testing, and later for implementation on a live system.

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Discovering the digital potential of HEI in Serbia: Assessment Practices

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Abstract

The objective of this pilot study is to examine and compare the degree of assessment practices that teachers from different fields of knowledge apply at higher education institutions (HEI) according to the policy documents in EU and Serbia. To this end, a specially designed questionnaire was administered to the (HEI) teachers. The main results of the study provide evidence of an intermediate level of assessment practices when compared to the reference documents. More specifically, teachers from Arts and Humanities showed higher level of awareness for the need of different assessment practices, esp. when it comes to the formative assessment than those teaching in Science and IT related fields. The results also indicate that more emphasis should be put on peer/collaborative assessment. More research is recommended to validate these preliminary results, as well as the development of teacher training courses aiming at developing teachers' competences to realize the full potential of digital assessment tools at their institutions.

Keywords

digital competences, assessment, evaluation, formative assessment, HEI, digital potential.

1. Introduction

Digital competences have become part and parcel of the required skill set for the 21st century. They are listed officially as one of eight key competences in the recently published EU policy document *Key Competences for Lifelong Learning.* Up to now, there have been several policy initiatives both in Europe and Serbia with the aim of fostering the development of a high-performing digital education and focusing on digital competences. They all generally focus on digital education and digital competences, primarily how to develop them with students. One of the areas that needs more research is the one dealing with assessment and using learning analytics better to improve students' learning. Having this in mind, the focus of this pilot study is to compare the present state of digital competences with teachers in the assessment part, particularly at HEI, with the policy documents in EU and Serbia. The results will provide authors with preliminary data to gain insight into the potential project on developing teachers' competences to gradually shift the balance from traditional assessment towards a more comprehensive repertoire of practices. This repertoire could include technology-enabled assessment practices that are student-centered, personalized and collaborative in line with the set policy documents both in the EU and in Serbia.

2. Theoretical background

Up to now, there have been several initiatives and documents defining frameworks and providing guidelines for successful implementation of digital tools in tertiary education (Digital Education Action Plan, 2021-2027; European Framework for Digitally Competent Educational Organizations; the renewed EU agenda for higher education 2017). This has been a result of a growing demand for modernizing higher education to meet the expectations, goals, and needs of students. One of the aspects to achieve this is developing digital competences not only with students but also with educators, focusing primarily on implementing formative assessment strategies and using learning analytics to

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improve teaching practices: “Rather than being an activity separate from instruction, assessment is now being viewed as an integral part of teaching and learning, and not just the culmination of instruction” [1] [2] .

In order to implement digital assessment practices, educators at higher education institutions should be digitally competent, know pedagogical concepts and models for assessment, and be aware of the policy documents and frameworks that recommend it. One study from Spain aimed to examine and compare the degree of digital competence of higher education teachers from different fields of knowledge and different gender and age ranges according to the DigCompEdu framework [3]. The results of this study showed significant differences with respect to the interaction between the competence dimension, field of knowledge and age range. The scores provided by the educators older than 40 were lower than the rest of their younger colleagues. Also, the findings of this study showed the lack of digital training for both genders of teachers, finding greater differences between areas of knowledge for female teachers and for teachers with the same or less than 40 years. The authors concluded that it is no longer enough to have a basic-intermediate level teacher, but a specialized teacher within their area of knowledge, in those technologies that can provide better training to their students. Therefore, they suggest that Spanish university institutions should organize training courses for their teachers. These findings about the impact of teachers’ gender and age regarding their digital competences are valuable for considering further steps in improving this area of knowledge among university educators. Similarly, research on university teachers’ digital competences was carried out in Serbia underlining the low level of digital competencies of university teachers; the main reason for this being the inadequate training of teachers during initial education. Despite having low level of digital competences, university teachers express positive attitude towards using ICT in teaching (using presentations), while the use of social networks is least represented. [4]

On one hand there are some indications that university teachers have low or intermediate level of digital competence; on the other, there are very ambitious frameworks and guidelines to be implemented into teaching practices. The EU policy document *Key Competences for Lifelong Learning*, adopted by the Council of the European Union in 2018, identifies eight key competences essential to its citizens for personal fulfilment, a healthy lifestyle, employability, social inclusion etc. [5]. The Recommendation sets up a common understanding of competences that are considered important nowadays and in the future. To achieve better results, the EU encourages their member states to provide quality early childhood education and care and improve school education teaching, further develop vocational education and training, and *modernize higher education*. Digital competence is among the eight key competences for lifelong learning. It involves the confident, critical and responsible use of digital technologies for learning, at work, and for participation in society. As described in the document, individuals should have essential knowledge, skills and attitudes related to this competence. They should understand how digital technologies function, how they support communities, and be aware of legal and ethical principles involved with using digital technologies. Skills include being able to use digital technologies for active citizenship, social inclusion, collaboration with others, and achieving personal goals, as well as the ability to use digital content, protect information, content, data, and digital identities, and engage with software, devices, artificial intelligence or robots.

Another important document for educators is *European Framework for the Digital Competence of Educators: DigCompEdu*[2]. It is more of a self-reflection tool, directed towards educators at all levels of education, from early childhood to higher and adult education, including general and vocational training, special needs education, and non-formal learning contexts, aiming to provide a general reference frame for developers of the Digital Competence model. The DigCompEdu framework distinguishes six different areas in which educators’ digital competence is expressed with a total of 22 competences: Professional Engagement (Using digital technologies for communication, collaboration and professional development), Digital Resources (Sourcing, creating and sharing digital resources), Teaching and Learning (Managing and orchestrating the use of digital technologies in teaching and learning), Assessment (Using digital technologies and strategies to enhance assessment), Empowering Learners (Using digital technologies to enhance inclusion, personalization and learners’ active engagement), Facilitating Learners’ Digital Competence (Enabling learners to creatively and

[2] https://ec.europa.eu/eusurvey/runner/CheckIn_HE_v2021_EN

responsibly use digital technologies for information, communication, content creation, wellbeing and problem-solving) [6].

The Strategy of Education in Serbia up to 2030 sets developing a digital competence framework for educators at HEI as one of the goals [7]. Teachers working in primary and secondary schools in Serbia had an intensive professional development training in the period 2014 – 2020 throughout several national EU-funded projects. The outcome of this was a published framework by Serbian Ministry of Education, Science and of Technological development in 2018 - *Digital Competence Framework – Teachers for the Digital Age* [8]. The framework represents one of the educational policy measures for the development of digital education in Serbia, by listing and defining the knowledge and skills that make up the corpus of digital competencies of the teaching profession, in accordance with the trends in the development of educational technology, as well as with reform initiatives in the field of digital education in the Republic of Serbia. It also distinguishes six different areas in which educators' digital competence is expressed with a total of 24 competences each divided into three levels: basic, intermediate, and advanced. This document can be used by teachers to assess the level of their own competences and to reflect on their own practice, as well as to identify the next steps of professional development. Such a framework exists for teachers in primary and secondary schools, but there is no such a policy document nor a self-reflection tool for HEI.

To contribute to under-represented research on the digital competence of educators at HEI in Serbia, and based on *The DigCompEdu, Digital Competence Framework – Teachers for the Digital Age and SELFIE tool*, we prepared a questionnaire for educators at HEI to determine the level of awareness of digital competences and the use of digital tool, particularly in assessment practices. The participants were given a series of reflective questions to assess their confidence and experience in using digital technologies, tools and resources for teaching, assessing and supporting learners. To this end, an empirical study was conducted. The study examined the following research questions:

- What is the level of digital competence of educators at HEI in terms of assessment and learning analytics?
- Are educators at HEI making the most of digital technologies for assessment?
- What is their present focus compared to what they should focus on in relation to the policy documents?

These questions were answered by using a sample of teachers from several higher education institutions across the country.

3. Method

The main method used for data collection in the study included a very comprehensive and detailed online survey, which was distributed to university teachers in Serbia. The questionnaire included sets of questions regarding teachers' awareness of digital competences, their institutions' support, professional development in this field, pedagogical aspects of using digital competences in the classroom, student digital competence and digital-based assessment practices. The focus of this paper is to discover the higher-education teacher's potential in relation to digital-based assessment.

The research results that will be presented in the paper are collected using the above-mentioned questionnaire. The findings of this pilot study are valuable because they provide an insight into the current situation in HEI Serbia regarding digital assessment practices from the teachers' point of view and are a good starting point for further development in this field. To this end, we applied descriptive statistics as a basic method of research in order to determine whether or not the university teachers use assessment practices as set in EU frameworks and guidelines.

3.1. Sample

This study used a convenience sample of 32 teachers from Serbia. The teachers were invited via e-mail to participate in the online survey administered. Out of 32 teachers, 31 teachers (96.9%) work only at higher education institutions, while one works both at faculty and in primary school. The teachers who participated in the survey come from three university cities: Belgrade, Novi Sad and Niš, both

from public and private universities. There were 42 teachers who started the survey; however, 10 of them discontinued. One of the possible reasons was that they reported the survey to be "too long". The survey was completed anonymously, thereby preserving the confidentiality of the data.

The participants' background data were the following: 21 teachers are females (65.6%), 11 are males (34.4%). Asked about the scientific field, most of them, 15 (46.9%), replied they taught courses that belong to arts and humanities (Table 1). 16 teachers (50%) stated that their current position was assistant professor, 4 - full professor, 4 - associate professor, 5 – lecturer, 2 - language teacher, 1 – teaching assistant. Almost 50% of them have been working as teachers between 11-20 years.

Table 1
Description of participants

Fields of knowledge	Women	Men	Total
Arts and Humanities	11	4	**16**
Social sciences, business and law	5	2	**7**
Science, engineering and IT	3	5	**8**
Teacher Training	2	0	**2**
	21	**11**	**32**

3.2. Instrument

Items (indicators) used to measure digital skills competences of teachers at HEI, derived from the *DigCompEdu* Check-In instrument. This questionnaire was adapted to the Serbian context by the first author of this study. Moreover, some items from the *Digital Competence Framework – Teachers for the Digital Age* were included in the questionnaire (Part 4 Assessment and monitoring students' progress). The instrument is composed of six dimensions (Leadership, Continuing Professional Development, Pedagogy: Supports and Resources, Pedagogy: Implementation in the classroom, Assessment Practices, Student Digital Competence) and a total of 55 items. This paper focuses only one the dimension of assessment practices, and the results presented refer only to it.

Dimension A, "Leadership", is focused on five items related to digital strategy, strategy development with teachers, new ways of teaching, time to explore digital teaching, copyright and licensing rules. The next Dimension B, "Continuing Professional Development" (CDP), comprises six items and is focused on CPD needs, participation in CPD, sharing experiences, CPD opportunities, usefulness of CPD activity, examples of effective CPD activity (open). "Pedagogy: Supports and Resources" is the third one, Dimension C, and is composed of nine items about confidence with pedagogical models, searching and creating online educational resources, using virtual learning environments and open educational resources, communicating with the school community, giving examples of useful technology for teaching. Dimension D, "Pedagogy: Implementation in the classroom" relates to the implementation in the classroom of digital technologies for learning, by updating and innovating teaching and learning practices.

The most important dimension in this study is Dimension E, "Assessment", and relates to measures that faculties may consider to gradually shift the balance from traditional assessment towards a more comprehensive range of practices. This range could include technology-enabled assessment practices that are student-centered, personalized and collaborative. It is composed of 15 items: assessing skills, providing feedback and suggestions for improvement, formative assessment, providing timely feedback, self-reflection on learning, feedback to other students, digital assessment, documenting learning, using data to improve learning, valuing skills developed outside school, learning analytics.

To measure the level of digital competence, the following question types were used: a 5-point Likert scale (Strongly disagree, Disagree, Slightly agree, Agree, Strongly agree), open ended questions and multiple-choice questions to select one or more options.

3.3. Procedure

To collect the values of the variables used in this study, an online survey was conducted. It made use of a questionnaire available on the internet. Items (indicators) used to measure assessment practices are listed in Table 2.

Table 2
Indicators of assessment practices

Skills	Indicator	Reference
Assessing skills	I use digital technologies to assess students' skills.	SELFIE
Providing feedback and suggestions for improvement	I use an electronic log/register/ information system to provide feedback on activity, achievement and student performance and make suggestions for improvement.	ODK, Part 4
Formative assessment	I use a variety of digital technologies and tools to track student achievement and provide descriptive feedback, guiding students to the necessary steps for further progress and development.	ODK, Part 4.2 Basic
Formative assessment	I use different approaches to formative assessment with the use of digital technologies and tools (e.g. anonymous peer assessment, e-portfolio) and based on observations results I provide detailed descriptive feedback on status and further progress of students.	ODK, Part 4.2 Advanced
Providing timely feedback	I use digital technologies to provide timely feedback to students.	SELFIE
Self-reflection on learning	I use digital technologies to enable students to reflect on their own learning.	SELFIE
Feedback to other students	I use digital technologies to enable students to provide feedback on other students' work (peer assessment).	SELFIE
Support for digital assessment	Our leaders support me in using digital technologies for Assessment.	SELFIE
Documenting learning	I enable students to use digital technologies to document what they have learned relevant to their qualification.	SELFIE
Using data to improve learning	I use digital data about individual students to improve their learning experience.	SELFIE
Valuing skills developed outside school	I value digital skills that students have developed outside the institution and work-based settings.	SELFIE
Using LMS	In my teaching, I use a learning management system (Moodle, Blackboard, LAMS, in-house LMS).	
Learning analytics	I use a learning management system to collect data about student activity and achievement.	ODK, Part 4 Basic
Learning analytics	I use digital technologies to compare and integrate data from various sources about the student activity and achievement.	ODK, Part 4.4 Intermediate
Learning analytics	I use digital technologies to analyze and combine various digital sources of data about the student's progress and take measures to improve their achievement and the general working atmosphere in the department.	ODK, Part 4.4 Advanced

The teachers from three different universities from Belgrade, Novi Sad and Niš were invited to participate in the survey by the authors of this study via e-mail. The survey was conducted within 6 weeks in August and September 2022.

4. Results

To answer the first research question regarding the level of digital competence of educators at HEI in terms of assessment and learning analytics, 17 teachers stated that they were familiar with digital competences to some extent, while 14 stated that they knew a lot about them. When asked about whether digital competences were covered in the education curricula in their context, 16 teachers answered they were to some extent, while 11 said they strongly agree. When it comes to educational policy documents that promote digital competencies, a considerable number of teachers, 17 of them (53,1%), stated that they were not familiar with them.

The second question about making the most of digital technologies for assessment showed that teachers use assessment tools for almost all aspects. However, it is noticeable that when it comes to using tools for formative assessment (25% of teachers), peer-assessment (41,7%) and providing self-reflection on learning (25%), teachers do not apply them. There is also a considerable number of teachers who do not use digital tools to document learning (25%) and using data to improve learning.

Table 3
Number of teachers answering questions in the Assessment Practices part

	Strongly disagree	Disagree	Slightly agree	Agree	Strongly agree
Assessing skills	0	2	12	3	15
Providing feedback and suggestions for improvement	0	1	13	11	7
Formative assessment (variety of tools)	0	3	17	8	4
Formative assessment (different approaches)	3	5	11	8	5
Providing timely feedback	0	2	13	5	12
Self-reflection on learning	3	5	12	5	7
Feedback to other students	6	7	10	5	5
Support for digital assessment	1	4	11	6	10
Documenting learning	2	6	13	7	4
Using data to improve learning	2	4	13	5	8
Valuing skills developed outside school	1	0	15	3	13

When it comes to learning analytics, the results show that the majority of teachers use digital technologies (learning management systems) to collect data about students' activity and achievement (88,6% of teachers). Teachers also use digital technologies to compare and integrate data from various sources about students' activity and achievement and to take measures to improve their achievement and the general working atmosphere in the department (78,1% of teachers).

5. Discussion

The purpose of this pilot study was threefold: firstly, to determine the level of digital competence of educators at HEI in terms of assessment and learning analytics; secondly, to learn whether educators at HEI are making the most of digital technologies for assessment; and thirdly, to know descriptively the level of assessment practices of teachers in different scientific fields.

Regarding the first purpose, the results highlight the intermediate level of application digital competences in terms of assessment and learning analytics. Although 84,4 % of teachers stated that digital competences were covered in their education curricula, they do not use them for assessment to such extent. Special emphasis should be placed on using collaborative tools for assessment and using digital technologies to enable students to provide feedback on other students' work (peer assessment). To improve learning, students need regular opportunities to make judgements about quality in relation to standards. In higher education this will require take advantage of peer evaluation processes, where students review and make comment on each other's work and on self-assessment processes where students review and make judgements about the quality of their own work (reflective learning).

One of the comments provided at the end of the questionnaire showed that this study posed important goals for university education. The participants had to go through self-reflection statements with the final aim of making them aware of all the possibilities they have: "Amazing, comprehensive, and inspiring questionnaire. I feel like most of our educational institutions (I'm referring to higher education) are many years behind when it comes to modern advancements in blended learning and are still taking baby steps to make any progress in this area (and it appears financing will be the main hurdle to moving forward any faster)."

The findings from this study contribute to the under-represented research on the digital competence of educators at HEI in Serbia and reveal potential for developing teacher training especially for assessment practices. Our results are similar to the ones of Cabero-Almenara et. al highlighting the importance of digital training for educators if universities wish to improve digital competences of their teaching staff [3]. The comparable results can be found in the study on digital competences of university teachers in Serbia; however, the implications are different. Trivunović explains this in terms of the inadequate training of teachers during initial education [4]; the point we do completely agree with. Nevertheless, it is not plausible to introduce pedagogical courses (with special emphasis on learning and assessing) at all universities in Serbia. A better solution would be to introduce further development training for all university teachers focusing on pedagogy AND policy documents regulating this aspect.

One of the limitations of the study is the use of a non-probability sampling of educators based on convenience, which makes it difficult to generalize the data. As a future work, probability sampling techniques (cluster sampling) should be used. The future research should include the differences between those teachers working in public and private universities because the access to ICT resources and infrastructures of centers could affect the results.

Moreover, this study is based on self-reported data where the teachers provided the answers themselves and they may have answered what they think they are doing, which might not be their actual practice. To increase the credibility and validity of research findings, triangulation techniques should be applied.

6. Conclusions

Modernizing higher education requires hard work on developing key competences of both teachers and students. Digital competence has been a major policy emphasis in many educational systems. There is also a stated need for creating tools to assist in implementing digital assessment practices based on policy documents. In this pilot study we provided a review of policy documents, such as EU assessment frameworks and guidelines, and implementation and assessment-related documents. The findings of this study highlight the fact that university teachers are not very much familiar with these documents and that there is usually not a systematic approach to implementing them in university courses. More emphasis should be placed on further teacher training to implement formative and peer/collaborative assessment practices into their instruction. This repertoire of practices should include technology-

enabled assessment practices that are student-centered, personalized and collaborative in line with the set policy documents both in the EU and in Serbia.

Data availability. The dataset that supports the findings of this study is available upon request from the corresponding author.

Authors' contributions. Author 1: Conceptualization, Theoretical background, Method, Statistical analysis, Writing original draft. Author 2: Theoretical background, Writing – review & editing. Both authors read and approved the final manuscript.

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Psychometric Properties of a 21st Century Digital Skills Scale

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Abstract

To prepare students to cope successfully with increasingly complex life and work environments based upon the extensive application of information-communication technology (ICT), today's education should focus on cultivating 21st century digital skills. To assess the extent to which these ICT-based skills have been attained, an appropriate scale with good psychometric properties needs to be applied. By using a sample of 667 teachers from about 200 secondary schools across Serbia, this study examined the psychometric properties of a 21st century digital skills scale. These properties dealt with representativity, reliability, homogeneity, and validity. The examination showed that this scale was of a good quality for each of these properties. Suggestions for further research are included.

Keywords

Digital skills, online teaching, psychometric properties, scale, secondary school teachers

1. Introduction

Today, education needs to prepare students to cope successfully with increasingly complex life and work environments (e.g., [1]). To this end, different aspects of learning need to be fostered, such as communication and collaboration, whose learning benefits have been advocated by many social and constructivist approaches to learning (e.g., [2]). Those aspects of learning may concern 21st century skills that promote successful citizenship in a global society (e.g., [3, 4]).

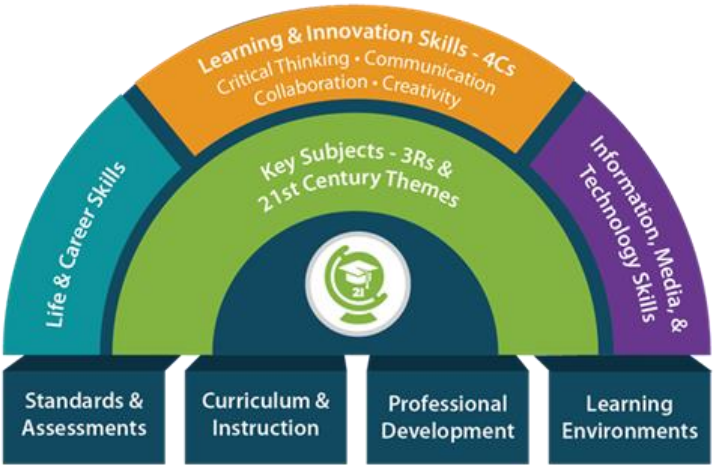

Figure 1: Framework for 21st century learning (https://www.battelleforkids.org/networks/p21)

A recently proposed 4C's model underlines four 21st century skills: creativity, critical thinking, communication, and collaboration (see Fig. 1). It is stressed that these skills should be considered as the foundation for a full model of learning and innovation skills comprising: (1) creativity and innovation, (2) critical thinking and problem solving, (3) communication, and (4) collaboration [5].

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Concerning the extensive application of information-communication technology (ICT) in almost all areas of life and work, it is appropriate to focus on 21st century digital skills. A recent detailed review of the literature identified *seven* such core ICT-based skills. These skills were: (1) technical skills, (2) information management skills, (3) communication, (4) collaboration, (5) creativity, (6) critical thinking, and (7) problem solving [6]. Many of these skills can be cultivated in innovative digital learning environments (e.g., [7, 8]). Note that a model related to learning with technology, proposed more than twenty years ago, suggests there should be three Cs related to thinking: critical thinking, creative thinking, and complex thinking, the last of which can be used to denote thinking that occurs in the activities of designing, problem solving, and decision making [9].

It is important to underline that all digital skills require digital competence, which has been recognized as one of the eight key competences for lifelong learning, focusing not only on digital technologies but also on communication, critical thinking, and collaboration, among other things [10]. To measure the development of digital education in Serbia, the Serbian Ministry of Education, Science and of Technological development recently published "Digital Competence Framework" [11], whose application would contribute to the development of students' digital competences for living and working in a digital society.

Apart from learning a specific subject, e-learning may be used to cultivate 21st century digital skills. To be able to evaluate the extent to which these skills have been promoted, an instrument measuring this promotion needs to be applied. According to the authors' readings, such an instrument is lacking in the literature at present. To improve this state, we developed a short instrument (a 7-item scale), being concerned with using it to determine potential benefits of online teaching using platform technologies (which was especially relevant during the Covid-19 pandemic).

The reliability (Cronbach's alpha) of this instrument was over 0.90 and the single-factor model of the applied seven items could explain more than 70% of the total variance among their values [12]. To apply this scale in further research confidently, it needs to have good psychometric properties. Hence, the present study focused on the examination of these properties, which dealt with representativity, reliability, homogeneity, and validity. These properties, respectively, stand for the following issues: the adequacy of the sampling of the applied items from the universe of all items concerning the same construct to be measured; the precision of the measurement of this construct using these applied items; the size of the main component measured by the applied items; and the individual alignments (correlations) of these items with this main component [13].

The applied research question was: Do the developed 7-item scale have good representativity, reliability, homogeneity, and validity? A positive answer to this question could contribute to the improvement mentioned above concerning the missing instrument that assesses the promotion of 21st century digital skills.

The second section describes the methodology used in this empirical research, while the third section summarizes and discusses the main findings. The final, closing section critically examines this empirical research and gives suggestions for further research.

2. Methodology

A convenient sample was used. It comprised of 667 teachers: while 279 were from primary schools, 388 were from secondary. Of those 388 teachers, 181 came from gymnasiums (grammar schools), whereas 207 worked in vocational secondary schools. Teachers came from about 200 schools across Serbia. Among them were 100 primary schools, 40 gymnasiums, and 60 vocational schools.

The attainment of 21st century skills was examined using a 7-item instrument, whose indicators were derived from the above-mentioned study of van Laar and colleagues [6]. These indicators are listed in Table 1. To collect their values (measured on a 0–10 scale ranging from never to almost always), part of an online questionnaire was used. The questionnaire also comprised several questions concerning participants' background data, including their gender, experience with online teaching, and type of school they teach in.

The collected data were examined by an SPSS macro [13], which determines representativity, reliability, homogeneity, and validity of the instrument in question. Although developed in the end of

1990s, this macro has been used in many empirical studies that assessed these psychometric properties of different instruments (e.g., [14, 15]).

For each psychometric feature, this macro calculates the values of different measures. These values are expressed on a 0–1 scale, considering values close to 1 as a sign of good quality.

An acceptable cut-off for those values may be set around 0.70 or 0.80. For example, the usual reliability cut-off is 0.70 [16], meaning that the reliability above 0.70 is acceptable. Regarding representativity, in particular the so-called Kaiser-Mayer-Olkin measure of sampling adequacy, values between 0.70 and 0.80 are usually considered good [17].

Table 1
Indicators of seven 21st century digital skills

Skills	Indicator
Technical skills	I encouraged students to understand the basic functionalities and modes of work with digital platform and computer programs used
Information management skills	I encouraged students to search, select, and organize information in order to successfully attend lectures
Communication	I encouraged students to effectively share different types of information (text, images, videos, etc.) among class participants
Collaboration	I encouraged students to work in teams in order to effectively share different types of information, have discussions, and make decisions regarding the work goals set
Creativity	I encouraged students to consider known facts in new ways or to use new ideas to produce the solution required
Critical thinking	I encouraged students to evaluate validity and expediency of the information and approaches used in the class work
Problem solving	I encouraged students to understand the tasks given, knowledge and skills needed to solve them, as well as to apply such knowledge and skills to find solutions required

3. Results and Discussion

The representativity, reliability, homogeneity, and validity of the translated instrument are presented in Tables 2–5. The content of these tables clearly evidence that the applied scale had good psychometric features, which answers the applied research question in a positive way. It can be thus said that this scale successfully measures one underlying construct and thus it can confidently be used in further research. Hence, the outcome of this study contributes to developing an instrument that assesses the promotion of 21st century digital skills, which has been a neglected research area so far, to the authors' readings.

The data summarized in Table 5 evidence good individual psychometric features of the applied items. Hence, statistical analyses may deal with using individual items as well. Their somewhat low reliabilities (especially of items 1, 3, 4, and 7) can be improved when the initial, raw scores are transformed into Guttman's [18] image scores; this approach have been successfully applied in a number of studies elsewhere (e.g., [19, 20]).

To clarify potential significance of using this 7-item instrument in educational research, it was checked whether there were differences among teachers from different kinds of school regarding the extent to which they promoted 21st century digital skills in their online teaching during the Covid-19 pandemic. By representing the value of the promotion in question by the average value of responses to the applied seven items, it was found that secondary school teachers fostered digital skills more than primary school teachers (the medians were 8.00 vs. 7.43, respectively; recall that a 0–10 scale for teachers' answers was applied), whereas gymnasium (grammar school) teachers fostered those skills more than vocational school teachers: the medians were 8.43 vs. 7.71, respectively [12]. Because students' abilities are, in general, more diverse in vocational schools than in gymnasiums (as well as more in primary than secondary schools), this outcome, which should be taken as a sign of external

validity of the applied 7-item instrument, does support its application in further research on promoting 21st century digital skills.

Table 2

Scale representativity

Kaiser, Mayer, Olkin measure of sampling adequacy	psi 1	0.99
Kaiser, Rice	psi 2	0.92
Kaiser	psi 3	0.96

Table 3

Scale reliability

Reliability Under the Classical Measurement Model		
Guttman	lambda 1	0.80
Guttman, Cronbach alpha	lambda 3	0.94
Guttman	lambda 6	0.93
Reliability Measures of the First Principal Component		
Lord-Kaiser-Caffrey	beta 3	0.94
Measures of Reliability Under Guttman's Measurement Model		
Guttman-Nicewander	Rho	0.94

Table 4

Scale homogeneity

Mean correlation	h 1	0.68
Participation of the first Guttman's factor in the total predictable (image) variance	h 2	0.96
Knezevic-Momirovic	h 5	1.00

Table 5

Representativity, reliability, homogeneity and internal validity of seven items

ITEM	REP	REL	HOM	H
I encouraged students to understand the basic functionalities and modes of work with digital platform and computer programs used	0.99	0.61	0.76	0.82
I encouraged students to search, select, and organize information in order to successfully attend lectures	0.99	0.75	0.85	0.90
I encouraged students to effectively share different types of information (text, images, videos, etc.) among class participants	0.99	0.59	0.76	0.82
I encouraged students to work in teams in order to effectively share different types of information, have discussions, and make decisions regarding the work goals set	0.99	0.58	0.75	0.81
I encouraged students to consider known facts in new ways or to use new ideas to produce the solution required	0.99	0.75	0.85	0.89
I encouraged students to evaluate validity and expediency of the information and approaches used in the class work	0.99	0.71	0.83	0.87
I encouraged students to understand the tasks given, knowledge and skills needed to solve them, as well as to apply such knowledge and skills to find solutions required	0.99	0.62	0.78	0.83

REP – Representativity; REL – Reliability; HOM – homogeneity; H – Validity in Hotelling's space; B – Validity in Burt's space

4. Closing Remarks

By using a large sample of secondary school teachers, this study examined the psychometric properties of a 7-item scale that was used to assess the extent to which participants promoted 21st century digital skills in their online teaching. These properties dealt with representativity, reliability, homogeneity, and validity. The examination showed that this scale was of a good quality for each of these properties.

Despite this outcome, nothing can be said about the use of this scale to survey students' opinions about the extent to which they acquired 21st century digital skills in their online (or other technology supported) learning. Further research may thus examine the psychometric properties of this scale when used by students whose learning has been supported with technology in some way.

Further research may also focus on developing and testing a larger scale, where each 21st digital skill is represented by several items (indicators). Bearing in mind 4C's model of 21st century skills mentioned above (whose founding skills are creativity, critical thinking, communication, and collaboration), this larger scale may have a complex factor structure that would include some of those founding skills.

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Online vs. conventional students at Belgrade Metropolitan University: Achievement analysis - case study

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Abstract

This research paper examines the difference between online and conventional students for a case study of learning achievements of students at the Faculty of Information Technology at Belgrade Metropolitan University in Serbia. This was conducted by examining demographics, students' grades, background and affiliation of students, in order to determine the correlation of these parameters to the learning outcome they achieved in an elective course on C# programming language. A cross-reference method was used for the analysis of sample date from the table. The results indicate that online students achieve a significantly better result in the overall grades distribution. The findings also imply that there is a significant change in the perception of the quality of online studies, since the majority of the most successful students were third-year students, and especially, online students. Further research needs to be done with a larger sample, to determine if this type of studies and their achievements and models should be the focus of the University's IT department in the future.

The conclusion of the paper determines that certain incentives need to be offered to students who pass subjects with "very good" in order to achieve and maintain the quality of the forms of IT education presented. Special focus in future research must include department-specific analysis of this and other compatible sample data.

Keywords

Online studies, conventional studies, quality, Metropolitan University, C#, object-oriented programming, case study, IT studies

1. Introduction

It is known that quality changes with time. Education models developed over generations have been greatly changed and adapted to accommodate today's average student needs. On the other hand, the question of quality of acquired knowledge needed for transition to work, arises. If the qualitative goal is to complete as many thematic units as possible in a certain time period, then the concept of quality loses its meaning, because the engagement of students is decreasing and the amount of material completed corresponds rather to the "pass" and not to a greater amount of knowledge and reward for it. This results in students possessing minimal knowledge, and assistants and professors facing frustration, if a student does not want a higher grade than "mere pass". Higher grades are an important parameter for determining the success of both students and teachers, and will be indicated in this case study as determinants for students' successful course completion. The main focus of this paper are the learning achievements of the students taking the C# programming language course through online and conventional studies.

2. Aims and goals

This paper is focused on the latest transitions to e-learning, aimed to improve the process of IT-based learning at the University level. The case study analysis has been conducted within the period of one academic year (2021/2022), with the purpose of improvement of today's learning process. How to guarantee that the materials will be adequately transferred to an individual learner, is always a remaining

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question, as analyzed by Peng et al. [1]. Finally, whether online or conventional[2] learning models show to be better for acquiring knowledge among students in object-oriented-programming courses, and, in general surpass conventional concepts of education, is the question this paper rises. The goal of this paper is to analyze online vs. conventional learning method, compare different models for quality and make a statistical discussion on if and why some groups of students achieve better results than others and to indicate how this can be related to their choice of studies and previous or ongoing experience. The expected outcome is to convey which other factors other than a model of study, play a significant role in the educational process of today's IT academic departments. According to Mukhtar et al.[3], a similar case study was done among faculty staff aged 36-42 and was aimed at both teachers and students and their acquisition of knowledge. Nishitha and Pandey [4] conducted a study on online learning and student perception of this process, by analyzing different platforms for online learning, among other parameters. Dimitrijevic and Jovanovic [5] suggest a "learn-by-coding" approach for e-learning systems for computer programming fundamentals, such as Java. Suggesting advanced levels of knowledge acquisition for social sciences, a study [6] determined benefits of online tools for non-IT studies. However, none of these made an in-depth study or comparison of online and conventional studies and student's success in both.

3. Methodology of the paper

A case study of an elective course in Programming with C# at the University's center in Nis and online course, both Nis and Belgrade has been done, by analyzing demographics, background and affiliation of students, as well as models of studying they have pursued in relation to their learning achievements, such as students' grades. The sample includes 30 students who attended online studies and an online elective course on C#, supported by LAMS[3] materials, along with 15 students who studied in a hybrid mode and 2 conventional studies' students. De facto, there were 30 online and 17 conventional studies' students, since two conventional studies' students studied in a hybrid mode. This means they did their homework weekly, had interactive courses, both lectures and exercises, and had to fulfill all the requirements of a hybrid study model, along with other 15 hybrid model studies' students. For the purpose of pertaining to the methodology described, and due to COVID-19 Pandemics –induced specific conditions[4] the latter shall be considered as conventional students too. The cross-reference method was introduced and material from ISUM analyzed in detail [2].

Figure 1, View of Belgrade Metropolitan University, Center in Nis, from a local archeological site

[2] Conventional or traditional studies, according to the University's curricula, mean that the students take courses in the classroom or, actively follow course through zoom application and deliver homework weekly, with projects delivered prior to entering exam. Online studies, according to the University's curricula, mean that the students have the liberty of delivering pre-exam homework and projects prior to entering the exam.

[3] Internal online education platform developed by Belgrade Metropolitan University for e-learning purposes.

[4] The conditions imply that the conventional classroom-based studies were replaced by zoom-app-based lectures and exercises, whenever there was an issued warning by the University to conduct classes online. The difference between this "hybrid" model and an online study, is that students were active in fulfilling their subject duties through the school semester, unlike online studies' students

4. Results of the analysis

The following table displays the results of the sample analysis.

Table 1
Distribution of number of students with demographical and other parameters, according to the type of studies (conventional/ online)

Type of studies		Conventional	Online	Total
a. Number of students		17 (36%)	**30** (64%)	**47** (100%)
a1. Female students		1 (6%)	5 (16%)	6 (13%)
a2. Male students		16 (94%)	25 (83%)	41 (87%)
b. Academic year of study				
2nd year		4 (24%)	10 (33%)	14 (29%)
3rd year		[1] 10 (58%)	[2] 15 (50%)	[3] 25 (54%)
[4] 4th year[5]		[5] 3 (18%)	5 (17%)	8 (17%)
c. Number of students who have passed exams		**9**/17 (53%)	**14**/30 (47%)	**23**/47 (49%)
c1. Number of students who passed exams with "pass" (grades 6,7 and 8), per study year	2nd year	3/17 (18%)	2/30 (7%)	5 (11%)
	3rd year	2/17 (12%)	5/30 (16%)	7 (15%)
	4th year	1/17 (6%)	0/ 30 (0%)	1 (3%)
c2. Number of students who passed exams with "very good" (grades 9 and 10), per study year	2nd year	1/17 (6%)	1/30 (3%)	2 (4%)
	3rd year	1/17 (6%)	5/30 (17%)	6 (13%)
	4th year	1/17 (6%)	1/30 (3%)	2 (4%)
d. Number of students who failed subject exams (including non-taken at all)		8/17 (47%)	16/30 (53%)	24/47 (51%)

[5] The C# subject is offered as an elective course in the second, third, fourth year of departments Information Technologies (IT), Software Engineering (SE) and Computer Games (CG)

5. Discussion of the results

In the table point “a”, there are results for two major groups of students. The first ones are conventional studies students (see figure 4 for a picture of conventional studies exercise class). They comprise 36 % of the sample, whereas online students comprise 63%. Here there is a greater percentage of female students among the overall number online students (16%), than the conventional studies sample (6%). Male students still make an overall majority of students researched, with 41 students (87%), 16 conventional (94%) and 25 online (83%). Most of the students are in their third year of studies, 58% among conventional and 50% of online studies students. Around 18 percent of all researched students were in the fourth year (17% of online and 18 % of traditional studies) and 29% of students were in their second year of study (24% of conventional and 33 % of online students).

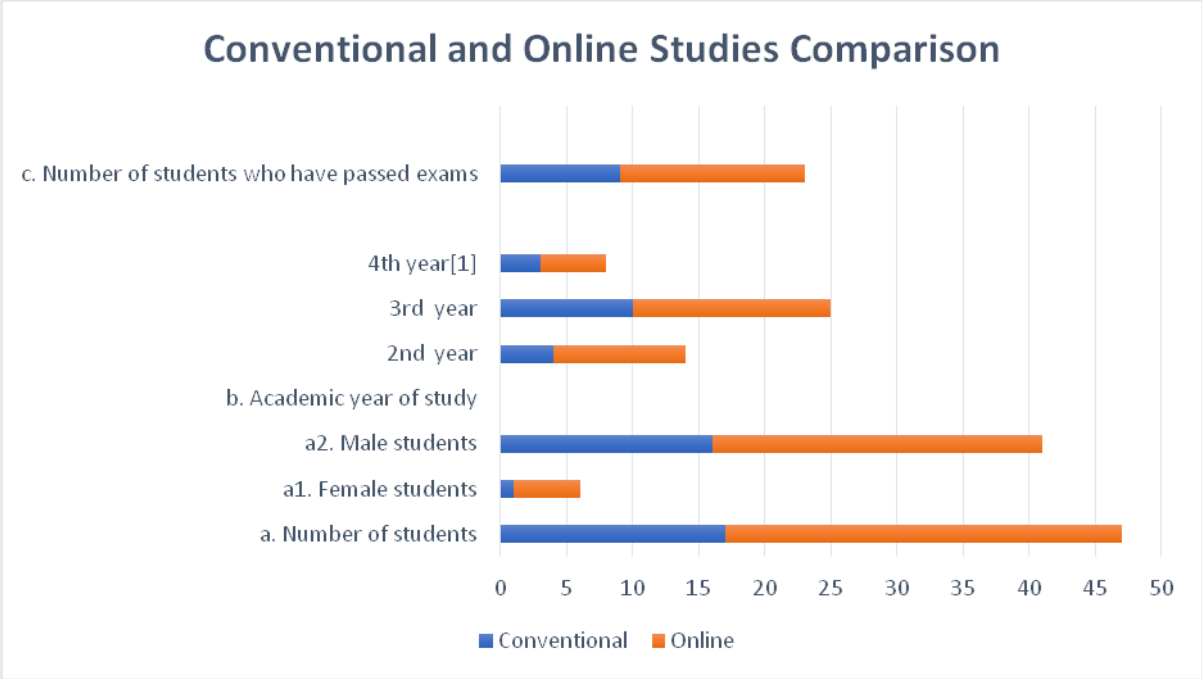

Figure 2, Comparison of numbers of online vs. conventional students within the sample examined

In overall, 21% of all students (10 students) achieved a "very good" grade, with 13% studying in the third year. Number of students who have passed exams with “very good” in the second and fourth year was 2(4%), both. This indicates that with more experience with computer programming, students achieve better results in the C# course exam in the middle of studies. At the second year, students are confronted with lack of programming experience and have less interest in studying for better grades. In the final fourth year of their studies, students lack time and are confronted with many obligations and time management problems, which leaves little time to devote themselves to each subject in their curricula. The greatest number of "very good" grades was among online students, with 7 students (23% of all online students), in comparison to 3 students doing conventional studies (18%). This is a minor difference and shows that both online and conventional studies show similar success.

There is a significant number of students who have failed the exam, according to point “d.” in the table. According to this parameter, there is again similar data between online and conventional studies (47% of conventional and 46% of online students). This data includes the number of the students that have not yet taken the exam and, to some extent, includes the ones who have not completed their pre-exam obligations. Therefore, their number and distribution within the overall sample should be analyzed with caution since they represent the majority of students who were not participating actively in the lectures or exercises, and, which would have qualified them for entering exam in Programming with C#.

There is a significant advantage of students of the third academic year on the side of online studies, according to point “c2.”, indicating “very good grades” the third-grade students have achieved (17% vs. 6%, respectively). This was considered as a significant finding and important for further analysis.

Therefore, a chi-square test (Figure 3) was performed to show the relation between academic year and successfully passed exams in the overall sample distribution. It indicated that the relation between these parameters is significant. The chi-square statistic is 18.465, with p-value of .005169. The result is significant at $p < .05$.

However, this must be analyzed further by acquiring a larger sample of students, by year of study.

Results						
	conventional pass	conventional grade "very good"	online pass	online grade "very good"		*Row Totals*
2nd year	18 (12.12) [2.85]	6 (6.06) [0.00]	7 (8.08) [0.14]	3 (7.74) [2.90]		34
3rd year	12 (18.18) [2.10]	6 (9.09) [1.05]	16 (12.12) [1.24]	17 (11.61) [2.50]		51
4th year	6 (5.70) [0.02]	6 (2.85) [3.48]	1 (3.80) [2.07]	3 (3.64) [0.11]		16
Column Totals	36	18	24	23		**101 (Grand Total)**

Figure 3, Chi-square test, relation between academic year of students and successfully passed exams, showing significance of results

Figure 4, Classroom number RU 1-III one of the classrooms used for conventional studies exercises, Center in Nis

6. Comparison to similar research and restrains of the results

An example of restrains connected to this research is, for once, that some students who were included for this table in terms of their exams pass, were in the process of delivering their final projects and entering exam. However, because of the dates of this conference and, despite the wish of the author to include the final grades into the sample, they did not qualify for the pass grade, and were therefore considered to have failed the exam. Statistically, this mistake includes 5%-10% of overall sample, and would have to be considered for the future research in terms of accuracy. This implies that the overall conclusion on successful students multiplied by 1.1 and grades achieved should be calibrated accordingly. Year of study of the examined sample of students (second, third or fourth) is an important parameter and has been examined in this paper. Another important parameter is whether students come

from the departments Information Technologies (IT), Software Engineering (SE) or Computer Games (CG). This parameter was undermined, due to lack of data and time at the moment of writing this paper.

Introduced by Mukhtar et al.[3], a similar case study aimed at both teachers and students and their acquiring of knowledge, showed that online learning is more beneficial during the lockdown and Covid-19 pandemics. In the paper by Nishitha and Pandey [4], benefits of online studying are presented, and technical problems suggested as main drawbacks of using digital learning. However, these papers focus on the tools rather than the whole concept of online studying as forthcoming.

In the comparison of online and conventional studies presented in our paper, online studies have proven to be at least of the same quality as conventional studies, but were considered rather as a concept of studying and not as a tool. As suggested by Ilic et al. [7], the research verified that digital models and technologies discussed in the paper were indicative for optimizing future learning models and this corresponds to the results presented in this paper. In this aspect, online students performed better because of the opportunity to organize their workloads individually, which led to their performance depending solely on their organizational and time-management skills, apart from the quality of the materials in the course. Finally, pedagogical aspects and models pertaining to both online and conventional studies need to be developed and calibrated to fit each of the programs separately and to pertain to the achievement of the same workload for students.

7. Recommendation and conclusion

The authors have analyzed a sample of both online and conventional studies in a computer programming course in programming with C#. The results have shown that online studies' students achieve a significantly better result in the overall grades distribution. This implies that there is considerable advantage of online studies in terms of quality. The majority of the most successful students were third-year students, with online students at the upfront.

The next goal in future research that needs to be done is to pay attention at the distribution of students' number and percentage, according to department they came from, while doing this elective course on Programming in C#. It will indicate the difference between acquiring knowledge of students according to their determination and profile, and, synthesize results on experience-related issues as parameters for successfully passing the exam with "pass" or "very good" grades, along with the year of studies as a parameter, already discussed in this paper.

Furthermore, some sort of ECTS stimulation or employment offered from the private sector is necessary as an incentive for students who pass subjects with "very good" in the future. This could be a model for solving an issue mentioned in the introductory part of this paper. A survey on students' attitudes towards online learning should be done, both at IT faculty and other non-IT related University departments, in order to determine the more specific issues related to student success at studying at the University level in the future.

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9. List of figures' sources

The use of eLearning technology for the training of new employees in an IT company

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Abstract

Training new employees is one of the most important tasks for any business. Training effectively equips workers to achieve the demands and objectives of their jobs. Employee training using only classroom methodology has become outdated due to the rise of eLearning, especially during the COVID-19 pandemic. Using online employee training software can make training faster, and more engaging and allow trainees to absorb more information. Trained employees minimize the wastage of resources in the organization. In this paper, an e-learning ecosystem architecture is proposed for the needs of a specific IT company with an agile environment dealing with the development of enterprise ERP systems. Also, we propose an eLearning system that can support working User Story and Tasks from Agile software development alike Learning object.

Keywords

Industry, Education, eLearning, Agile methodology, Scrum, User Story

1. Introduction

One of the frequent problems faced by companies is organizing the training of new employees. Companies and new employees have the same goal - how to adapt and be as successful as possible. The main aspects that workers take into account when looking for jobs are training and career development. In fact, according to LinkedIn's 2019 Workforce Learning Report [1], 94% of employees say they would stay at a company longer if it invested in helping them learn.

The goals which the company needs to have are:

- Teaching employees to be problem solvers as they learn how to be creative and innovative, enabling them to confidently take on tasks
- Improving employee engagement, leading to higher retention of staff
- Increasing efficiency in processes, resulting in financial gain
- Reducing the frustration of not knowing how to complete tasks or use tools
- Increasing engagement by providing opportunities to build skills employees are interested in
- While exact onboarding tasks may differ, there are a few best practices that can be followed to help you achieve all of these goals.

ELearning, a type of e-Service [2] is one of the most important recent developments in both schools and businesses. On the other hand, staff members who require training do not need to congregate in one location at the same time, so they are not required to travel a great distance to attend training sessions [3]. In the implementation of e-learning, distance education is a crucial link. Distance education is a very powerful teaching tool, whether it is used in university-level courses or corporate training programs.

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The use of eLearning is on the rise as many corporations have adopted eLearning for new employee training and learning to create a collaborative learning environment. In the paper [4], eLearning is defined as combining technology with learning, delivered using telecommunication and information technologies, and as a type of training delivered on a computer supporting learning and organizational goals. The goal of using e-learning in an organization is to assist the individual in increasing job performance and satisfaction, comprehending on-the-job skills, and assisting the business in developing a competitive workforce. The idea of e-learning is expanding quickly, which is not surprising. According to information systems researchers, in paper [5], it is presented that satisfaction is the most crucial element in the success of system implementation and it is influenced by factors attributed to the teacher, student, course design, technology, system design, and environment.

1.1. Reason for using eLearning in companies

According to paper [3], key reasons for most companies to use e-learning are:

- Information age, using sophisticated developed tools for communication
- Demand for post-secondary and life-long learning
- Creating competitive advantage, by aligning the workforce with company strategy
- Globalization, the capacity to work from anywhere in World
- Budgetary restrictions for internal and external kind of education

Although many companies use e-learning for the same reasons, some have their agenda for wanting to use eLearning. Clarke and Hermens.[6] also, explain in the paper that the ability to align e-learning with high-level business strategies along with the capacity to train entire workforces to support these tactics is one of the main reason that put companies into the e-learning.

Companies and organizations must provide cost-effective, effective, and comprehensive employee training and education. E-learning can offer the means for businesses to successfully achieve these objectives. Before beginning the actual development of both technology and eLearning media for distribution to employees, businesses need to take into account both the advantages and limitations of e-learning and develop a strategy to use it to achieve their strategic goals. Moreover, employees can control their learning speed and the learning process.

To improve bottom-line performance, eLearning helps keep employees' skills up to date. As a result, many organizations are looking to use eLearning as a way to guarantee regular training. In paper [7] for both large, and medium size organizations, the cost of eLearning is viewed as the primary concern. Otherwise, in article [8], the willingness of companies to engage in eLearning is shown, with a special emphasis on small and medium-sized enterprises that had more difficulties when introducing eLearning systems than large corporations.

In this paper, we will present our eLearning architecture proposal for training new employers for an IT company whose narrow specialties are solutions for governance, risk & compliance. That solution contains two parts - the first part is the implementation of a Learning management system (LMS) and the second part is the conceiving and designing of learning objects.

A software program called an LMS is used to organize, produce, manage, and deliver online material. In the eLearning sector, an LMS—whether cloud-based or on-premises—is frequently used as a distribution and management tool for online courses, training courses, and learning and development courses. An open, digital educational resource known as a learning object (LO) is produced to support a learning event. Learning and reusability reside at their core. Each learning object will have a learning design.[9]
Due to the specificity of the company that is engaged in the development of ERP systems, each of the teams is engaged in a certain activity and each newly hired person needs to have certain training. Also, if there is a change in the team, the employee should have some form of training. Due to data protection, the exact name of the company is not mentioned in the paper, but a description of the activity is given

as well as a proposal for a training solution for newly hired employees, see also section 3.1. The main goal of the work is to design learning objects (LO) that are narrowly specific to the corporation, which include every type and type of learning for a new employee.
There is no a lot of research data about supporting agile scrum methodology and eLearning system. One of the most important paper gives proposing a process-driven e-learning system which support QA in agile software development [10]. A lot of research can be found which present using agile methodology in the process of developing eLearning system. [11-13]

2. Types of eLearning in IT Company

There are several types of e-learning and combinations thereof currently being deployed [2]:

- **all online** - self-directed and self-paced methods of learning (no interaction between learners and instructors)
- **asynchronous** - self-directed and self-paced methods of learning (learning will have some interaction between learners and instructors)
- **blended or hybrid** - a mixture of face-to-face and online learning (most valuable when a company wants to leverage all of the eLearning advantages while still maintaining the nuances that oftentimes face-to-face training gives to the student)
- **synchronous -** both the learner and the instructor are present in the technology-based learning environment and can interrelate with each other instantaneously (there are interactions in real-time, for example, in a chat room or within more forms of collaborative software)

In our case, because of the specifics of the company's work, the best solution would be to use the blended or hybrid type of eLearning. More specifically, the training of employees due to the narrowly specialized software solutions used in the work requires, in addition to the eLearning system, also a tutor who would help during the training and eliminate all the problems in learning. A Tutor can also describe rationales behind chosen patterns or implementations, to give trainees a deeper understanding of the themes to learn. A Tutor can answer questions that cannot be foreseen in learning materials.

3. SCRUM in IT company and connection with eLearning

The Present IT company is working in agile methodology - scrum. Scrum is an agile development methodology used to develop software using incremental and iterative approaches. Scrum is an adaptable, fast, flexible, and effective agile framework designed to deliver value to the customer throughout the project's development. Figure 1 shows the main artifacts of that [14].

According to Scrum co-creators Ken Schwaber and Jeff Sutherland Scrum is a framework to build solutions for complex problems. Briefly compromised: Scrum consists of the following roles and artifacts: Scrum Team, Scrum Master, Product Owner, Developers, and Product Backlog Item. Product Backlog, Sprint, Sprint planning, Daily, Sprint Review, Sprint Retrospective [14].

A Scrum Team consists of a Scrum Master, Product Owner, and Developers. Product Owners are responsible for creating product Backlog items and priorities them in the Product Backlog. A Sprint consists of a subset of the highest prioritized items of the Product Backlog. A Sprint is time-boxed. The length of the Sprint can vary and is often a decision of the Team or Organization to which the Team belongs. Developers of the Team are committed to complete all Work selected for the current Sprint in that timebox. Daily Scrum meetings are held to identify problems that interfere with the current progress of the team. The Scrum master is responsible for solving those problems. Sometimes some unforeseen Problems can occur, e.g.: when issues are detected in the current release of the software product, the team may decide whether to fix this issue immediately in the current sprint or not. If a decision is made to fix it in the current sprint other backlog items must be removed from the current sprint in order to retain the sprint timebox for the remaining sprint backlog. At the end of the sprint, two meetings are provided. In the Sprint review meeting, the Team presents the produced results. Team members and stakeholders inspect the results. Based on that the Team and Stakeholder decide what to do in the next

Sprint. In the Sprint retrospective, team members can identify problems in their effectiveness for the current sprint and can select actions to increase quality and effectiveness [14].

A Scrum Master needs to establish a setting where all Team Members can fulfill their roles effectively. The crucial part of this Role is to care for all Team Members so they can conduct their work as effectively as possible. During Sprint planning the Team selects Items (User Stories, Issues) of the Product Backlog for the next Sprint [14].

Effective working with Scrum is highly dependent on the skills and knowledge of all Team Members [9]. New Team members must integrate into this setting as soon as possible. So, they can effectively contribute to the Team. eLearning can help shorten this time effectively [15].

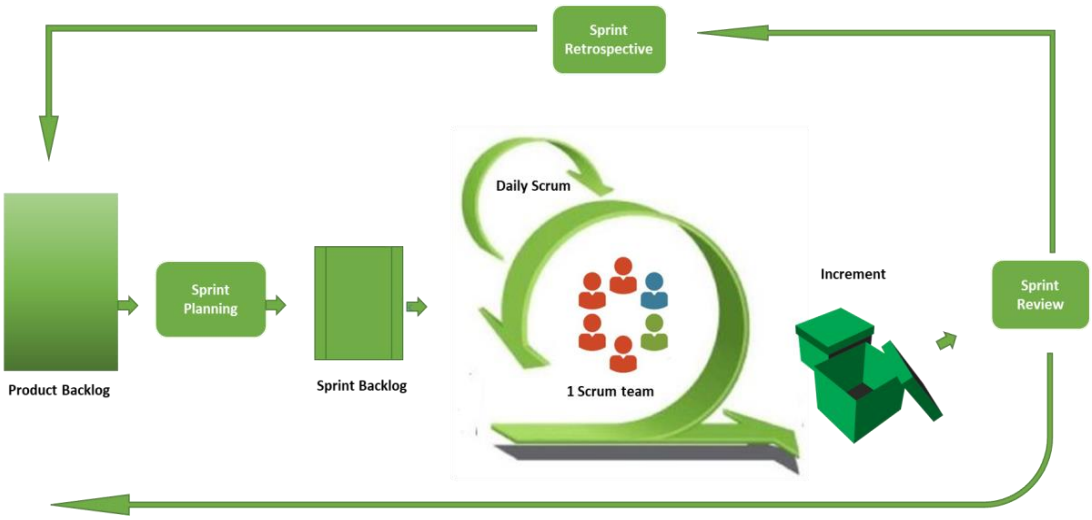

Figure 1: Scrum framework

3.1. The Presented Company

Due to data protection, the exact name of the company is not mentioned in this paper. The company has been active in software development for several decades. The core target market is the energy and water industry. The company employs about 500 people up to 7% are parttime. Distributed over several locations. Different departments in the company are responsible for the different products. Departments consist of several teams, each implementing a group of modules. Team sizes vary between 5-15 employees. Home office is also allowed.
Currently, about 40 modules are developed and maintained. These modules are offered as part of an integrated solution. Integration with third-party manufacturers is also available. Additionally, data centers are operated for customers.

As in any company, there is a certain amount of employee turnover. Approximately 15-20 people are hired each year. The Team which prepares learning for new or experienced Developers consist up to 10 people.

4. Observed Learning Practice in presented IT Company

In this section, we will describe how instructing new developers without an eLearning System is conducted in that presented IT Company. This Company delivers a highly scalable and flexible software platform to its customers. It is based on a Service-oriented Architecture. Business processes are implemented as workflows or dialog flows. Workflows can call other workflows directly or by firing events. Messaging is used to decouple workflows from each other. All these parts are supported by different types of proprietary tools developed by the company itself. Within this platform, the company

delivers a large array of application modules. So, customers can do organizational work according to legislative demands. Multiple teams develop subsets of this array of modules. Each team consists of a scrum master, developers and business analysts.

In this scenario, every new developer has to climb a high learning curve before getting effectively productive for his Team he joined.

In this specific IT Company, the training of new developers consists of two phases. In the first phase, the new developer gets a list of artifacts presented. This can be

- Intranet xWiki Articles
- Videos
- PDF Files
- Sample Code
- Productive code from the source control system
- Bug Fixes
- User stories

All the Artifacts provide detailed Information about the important aspects of the development process like:

- UI development
- Service development
- Workflow development,
- or Database development

Videos are recorded Workshops on these topics. Showing the use of the proprietary Tools specifically created to develop artifacts for the proprietary platform.
A mentor is a person already familiar with the development process and tools. And has high expertise in the team. He supports the new developer in learning the needed knowledge. He answers questions and helps understand the knowledge.

Besides the technical part, there is also the professional domain to be learned to understand the business logic and to be able to develop needed changes or extensions of the modules. The mentor is responsible for teaching this knowledge.

In the second phase, the new developer is gradually integrated into the team. First, a few simple Issues from the sprint backlog are worked through. Later also user stories. Here the mentor supports the preparation of the development environment. Kickoffs are held for issues or User Stories. The mentor explains whether one or more modules can be affected by the Bugfix or the User Story. What impact fixing the issues or editing the user stories can have on it? Which parts of the modules may be affected? Which part of the domain model is used? And additionally, the required business domain expertise. If the changes to be made are similar to older issues or user stories. This can be used as a model or a template. Based on these steps, the necessary changes are discussed and the development tasks are planned. The content and information learned in phase 1 are also referenced in those tasks.

With this information, the new developer can start to fix the issue or implement the user story. Initially, the issues and user stories are processed together with the mentor in pair programming [16]. Here, a high knowledge transfer happens between mentor and trainee. The topics from the first phase are often referenced and worked through again on a live object.

5. Categorization of observed learning Object types in IT Company

New developers have to familiarize themselves with many areas. The faster they acquire this knowledge, the faster they can contribute productively.

The familiarization of new developers consists of several types of learning objects (LO) that support:

- familiarization with the development platform, e.g. for proprietary tools for building services, workflows, dialog flows, database patching
- familiarization with company specific patterns
- familiarization with the business domain of the software
- optionally, if the new developer does not know the development environment used in the company, a learning object must also be provided for this

The following describes the required categories of LOs in more detail.

The presented IT company has proprietary development platforms and libraries that are used to build software for their target group. Certain patterns are used. Partly well-known, partly also specific company-owned patterns. These patterns are related to UI design, UI implementation, service design, service implementation, or database design and tools and artifacts to be used. If the developer is a beginner, separate LOs must be provided to give him the basic knowledge needed for development.

This software house offers fully integrated software. There are multiple business levels to learn. So learning is not only required on the technological level but also at the business level domain.

The produced software is divided into different modules/applications which are implemented for the respective business level domains. This should be taken into account when designing the learning objects.

6. eLearning system proposal

The eLearning eco-system proposal for the needs of the IT company has two parts. The first part is the learning management system (LMS) second is designing and creating company-specific learning objects (LO). For the needs of an IT company, we decided to use Moodle 4.0 LMS. The second important part of the work is the design of learning objects as well as the specification and standardization of learning materials. Also, that part includes putting together different LOs to create a course.

6.1. MOODLE LMS in IT company

Moodle is free software, a learning management system providing a platform for eLearning and it helps various educators in conceptualizing the various courses, course structures, and curriculum thus facilitating interaction with online learners. Moodle stands for Modular Object-Oriented Dynamic Learning Environment and statistics reveal that about 14 million consumers are engaged in about 1.4 million courses propagated by this learning management system. [17]

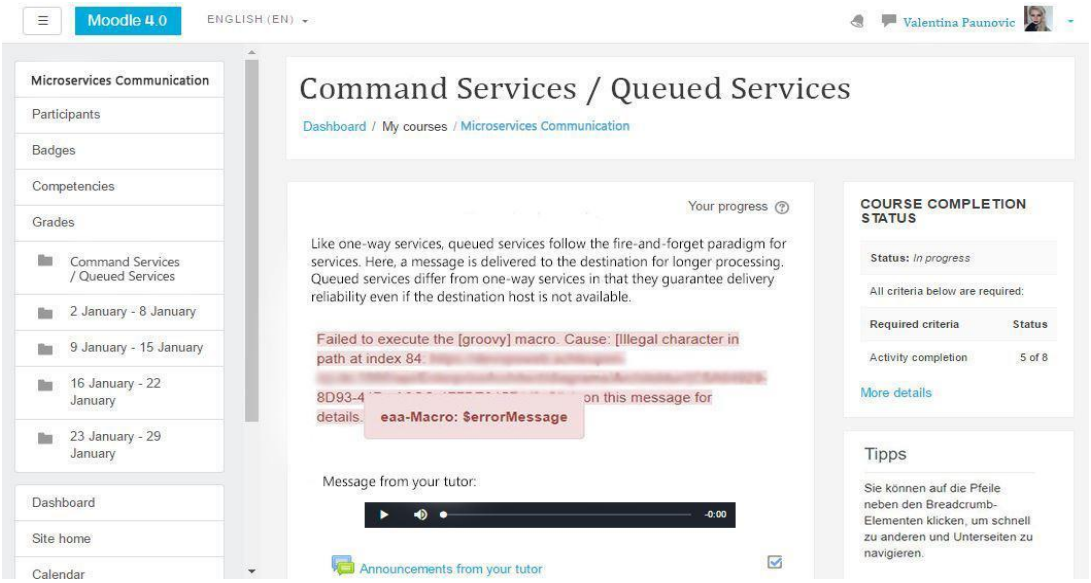

Figure 2: Preview of Moodle course for IT company

6.2. Functional overview of proposed eLearning system

The main unit of learnable knowledge is defined as a learning object. In this eLearning solution, the learning object consists of one or more artifacts (as defined in chapter 5) relevant to the topic of that LO. Learning object also has a title and description, and a set of keywords.

Learning objects can be organized into courses. Courses are learning paths that cover one specific area and help employees get introduced to a new domain logic or parts of a system they didn't have experience with.

One course is the combination of many learning objects. The new employee will start with some tasks that he needs to solve - learning by doing. The task, in this case, will be the implementation of the specific type of Command Service as shown in Figure 2. Depending on the complexity of the topic, the course itself can contain many different types of learning objects (have different artifacts). Every course can be started with an introduction to the topic - mostly can be started with an xWiki article about the topic. For example, in Figure 2 we can see the Command Service article which can be started with an introduction in theme - and that LO is directly connected with xWiki - site which organizes Intranet information architecture from the presented IT company. After that can be presented the most similar user story - tfs code with our task.

Apart from courses used to systematically teach employees about a broader topic, one other way of reducing the need for mentor time was also identified. It was identified that the company has a certain number of typical tasks, which regularly need to be taught to both new employees, and sometimes to even more experienced ones. A form of community learning was envisioned, where every time an employee comes across a task that can be deemed typical (like creating an activity service), they are encouraged to create a learning object that teaches how to do that task. After that, every time that a user story containing that typical task is created, a learning object can be attached to it, with an idea that the person implementing the ticket can have that LO to learn how to perform the task, if they are not familiar with it, or as a refresher or a reference if they are, which can be founded in Figure 3. Ticket creators will be able to choose which LOs to attach to a ticket, based on suggestions, that will be fed into the project management solution from LMS via integration, or can directly search for LOs which is presented in Figure 3.

What is deemed crucial by the authors for this approach to work is to have a means of quickly weeding out LOs that are outdated or just not helpful enough, so that people working on user stories get presented

with useful LOs, and only then will mentor time be reduced, increasing efficiency. To facilitate that, a rating system would be deployed, whereby a person working on a ticket with a particular LO will be presented with a rating screen after they finish the ticket, where they can rate LOs that were attached to that ticket, see Figure 3 Use Case Rate learning object. This rating will then directly affect suggestions when writing a ticket, where better-rated LOs will be placed closer to the top of the suggestion list, and LOs with bad ratings will be marked as “unfit” and will require creating a new LO on that topic.

Another crucial factor in making this work is planning for and allowing the time needed to create LOs for typical tasks. These should be treated as part of the definition of the done, where a ticket is not deemed done until a LO has been created, provided it is identified as a typical task and an LO does not exist, or an existing LO is unfit. The person to identify a ticket as typical and therefore require LO creation would be the person reviewing the pull request.

The remaining use cases in Figure 3 are now described with more detail:

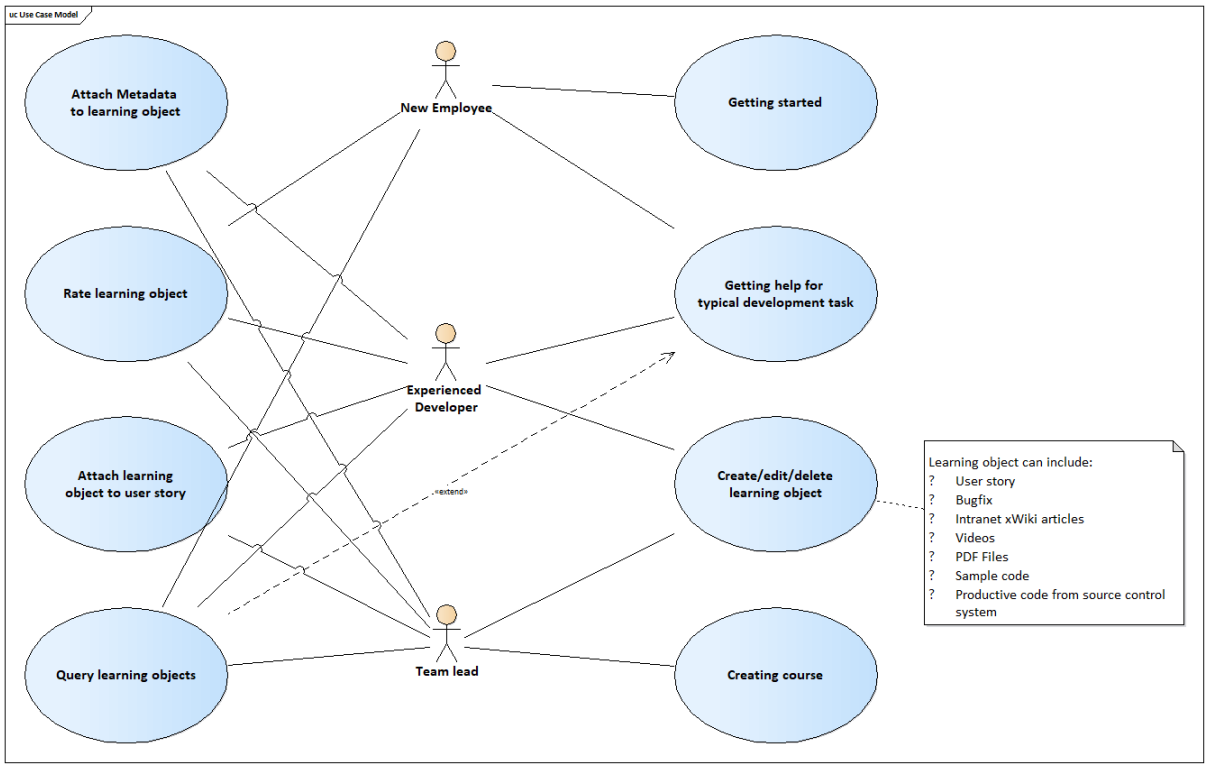

Figure 3: Use-case diagram for eLearning system

Use case ‘Getting Started’: Every new developer always needs some initial hands-on information. To get started in the new Development team. With this use case every team can create a special course with learning objects directly connected to information and knowledge of the team's domain. This use case describes the observed first phase of learning practice as shown in chapter 4.

Use case ‘Attach Metadata to LO’: User should be able to attach Metadata such as: keywords, text, or documents learning object. Users can then lookup LOs within the metadata. see Use Case ‘Querying LOs’.

Use case ‘Query Learning objects’: In this use case users can search for LOs. The searching should be conducted as follows. With the given search parameter, firstly the keywords attached to the LOs will be searched. Then name of stories, and after that the text of the LOs. All matches should be presented as a result.

Use case 'Getting help for typical development task': While working on a new task there is sometimes a need to refresh the knowledge about that. With this use case users can search LO's tagged as typical development tasks. Also, relevant LOs can be linked directly to user stories

Use case 'Create/edit/delete Learning Object': User should be able to create, edit or delete LOs.

Use case 'Create course': By creating a course. Users can build a learning unit from multiple LOs to teach attendees about a specific topic. A topic can be knowledge that is specific for technology, a new Pattern, new business domain specific knowledge, new proprietary tools etc.

6.3. Connecting Moodle with Azure DevOps

The presented IT company uses Azure DevOps [18] to organize work through its agile methodology supporting features. And to store produced artifacts in version control of Azure DevOps to connect an LMS like Moodle [19], there are mediating components required. To support the above-shown use cases in Figure 3. Both Moodle and Azure DevOps provide Rest APIs to query and manipulate artifacts of the respective systems. Figure 4 shows the components. Also, the end of the course can connect with a similar user story for practicing or solving the next task which can be found in Azure DevOps.

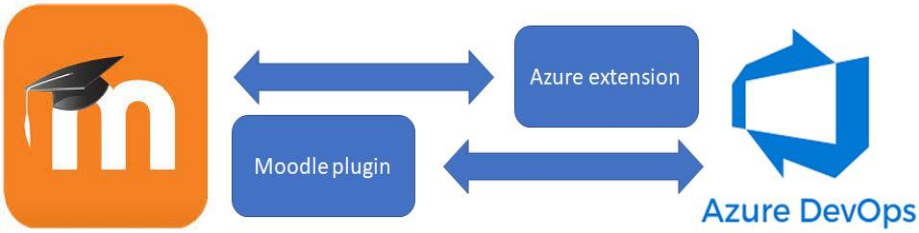

Figure 4: Components required to integrate between Moodle and Azure DevOps

7. Conclusion

The authors of this paper created the overall eLearning ecosystem using the Moodle LMS with our construction of learning objects and the whole course. While development is an overly complex and long-term process. We observed the learning practice in the presented company and extracted needed learning objects to support the learning process of new Developers. Based on the identified use cases, we proposed an eLearning system that supports effective learning. The direct connection of User Stories and Issues with LOs will give a base of optimal preparation of knowledge and we expect that new developers will faster integrate into the team.

We also have three pilot testers included in this project. Here, one of the presentations of the ecosystem is shown, but the work is ongoing and in the subsequent iteration. Considering the interaction of the pilot testers, the first impression is that this type of system can contribute to better training for new employers. Future study will focus on the system in a real collaborative software development environment, mainly aiming to enhance learning for team members.

Our expectation is this kind of course can be helpful for new employees to learn needed knowledge to solve user stories or error in their software product. Also, mentors which prepare user stories will greatly benefit from shorter creation time and reducing direct collaboration between mentor and new employee.

Acknowledgements

This work was supported by the Ministry of Education, Science, and Technology of Serbia (Project III44006).

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High-Stakes Exam Transitioning from Traditional to the Online Test Center, A Canadian Institute Use Case

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Abstract

Online test centers, as a direct result of technology integration and education, have emerged as a powerful medium of knowledge testing mainly using Internet technologies. Test centers have been the most reliable and practical way of certification and testing for years for institutions that do not have their own infrastructure and capabilities to organize these events themselves. Following the COVID-19 outbreak, this practice was jeopardized, and standard processes of necessary certification needed to be continued in an equally credible and legitimate way, but under the new lockdown circumstances. This paper aims to showcase the benefits of conducting high-stakes exams in an online test center remotely with a practical use case of a reputable Canadian institute that transitioned to the online test center and modernized its examination processes.

Keywords

distance learning, e-learning, online test center, educational technology, information technology, online proctoring, online examination

1. Introduction

It does not come as a surprise that the 2020 pandemic accelerated many digital trends as a series of unfortunate events led to the extensive use of innovative solutions and ideas. What was once considered science fiction became a reality overnight, and an array of useful software became available at our disposal. Among the solutions that were supposed to make everyone's lives easier during hard times were online exam solutions. As everyone switched from on-premise to distance learning and examination, the use of E-learning solutions skyrocketed. E-learning is an umbrella term that covers web-based education, digital learning, interactive learning, computer-assisted teaching, and internet-based learning.[1] Since 2020, much research has been performed to conclude that E-learning has become a pillar of education and examination. This significant amount of research in E-learning has advanced our understanding of the pivotal success factors of E-learning, such as system quality, information quality, service quality, satisfaction, and usefulness.[2] Public institutions, governments, and testing organizations worldwide have had to determine whether to move from paper-based exams to proctored online exams due to social distancing measures to prevent the spread of COVID-19. Transferring from paper-based exams to online exams has many benefits for the environment, as there is no printing, paper disposal, test shipping, printer cartridge disposal, etc. While transitioning from traditional to online test centers may seem complicated at first glance, many solutions on the market simplify this process and help education institutions, business owners, and governments organize their examination processes more efficiently than ever. YouTestMe, a Canadian online examination solutions provider, offers such solutions to schools, enterprises, and governments. This paper aims to showcase what the future of high-stake examination looks like with a practical use case of transformation of a reputable Canadian institute's examination processes.

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2. Issue

Traditional test centers have become obsolete. Some of the most significant downsides of this concept include high travel expenses, unflexible hours, high service rates, no AI cheating prevention, and the examination must be organized physically in a rented space that is often expensive. A study has shown that 51.2% of the study sample claimed that E-learning implementation helped them manage their time effectively.[3] In today's economy, enterprises and governments should look for alternative solutions that save time, budget, and the environment. Online test centers meet all the beforementioned criteria. They can be deployed anywhere in the world, there are no travel expenses, dedicated support and proctors are available at all times, and cheating at exams is completely eliminated thanks to advanced AI proctoring technology. The transition from pen & paper to computer-based testing can be seamless and secure if it is done professionally by people trained and certified to conduct online examinations. The fear of change is a logical factor behind being insecure about transitioning from paper-based to digital solutions, so educating and preparing decision-makers for this step is essential. Webinars and presentations are an excellent way to introduce these technologies to decision-makers in the education, enterprise, and government sectors. This paper focuses on a practical example, a case study, of a reputable Canadian institute that modernized and simplified its operations through deploying an online examination and learning solution.

3. Revolutionary E-Testing Center

By recognizing the need for online assessments and their' problems, YouTestMe has developed a superior IT solution, the Online Testing Center, which contains all the features needed for the successful examination process. Finding software that fully supports paper-based examination scenarios is not easy for educational institutions, and it is a struggle that exam papers can not be copied into some software.

- Test makers face challenges that include:
- Test integrity and security
- An environment that is no longer standardized
- A need for more time to develop appropriate proctoring and security protocols

Taking care of all these needs, YouTestMe e-Testing Center has been developed to be flexible and easily adaptable to any exam structure (i.e., one or all questions per page, having sections within the test, containing a text editor, supporting various multimedia files, etc.). It imitates a real-life test organization that functions via exam booking, cancellation, and rescheduling. YouTestMe e-Testing Centre is a comprehensive, end-to-end solution that provides a fully outsourced service for developing and delivering high-stakes certification exams. The important thing is that it has a user-friendly interface since the main aim of technology is to simplify the process, simultaneously simplifying our lives. There is no point in investing in technology that is difficult to understand or handle.

It is designed to be easily accessible because a test-taker should be free to use it anywhere and anytime with just a computer and an internet connection. The system should be entirely web-based for candidates without a compulsion to install or download the software.

In case that transition is gradual, and some of the students still prefer traditional examinations, YouTestMe is a hybrid solution that supports the import of paper-based exams. Some people will be more inclined to the traditional approach of face-to-face examinations. In this scenario, it is possible to arrange an in-person session. Perhaps the student in question needs a stronger Wi-Fi connection or requires an equipment repair. There are many technical reasons for which their choice can be accounted for. Even in these situations, the students will be covered to take the exam safely. For other reasons, they could prefer the traditional approach. The familiarity of taking an in-person exam could be what helps certain people excel in their results. Every alternative is validated if it follows academic and ethical standards.

We meet educational institutions that want to wait to move to online test-taking. In that case, they may begin keeping records in the online examination system and leave their students to take the paper exam.

4. Online Proctoring

Online proctoring allows candidates to take exams in a virtual environment, providing a completely secure and transparent exam delivery and test-taking process. This method has many advantages over traditional methods, including lower costs and greater flexibility for both candidates and instructors.

5. AI Proctoring Technology Used In YouTestMe Exams

By utilizing artificial intelligence (AI) technology, the system records and monitors test attempts using behavioral trackers. Once the exam is finished, the system generates a credibility report and stores the exam footage for the optional subsequent human validation and review. There are no special technical requirements for the student's PC or laptop as the software is a browser-based application.

5.1. Workflow

1. Authentication of Candidates

Before the exam starts, automated software conducts the equipment check, i.e., ensures the candidate is sharing a screen with video and audio recordings.

Optionally, additional ID verification can be enabled, where students must present their photo IDs for the system to scan and compare with the face in front of the camera and profile pictures.

2. Real-Time Monitoring

Candidates are monitored via web camera during the whole test-taking process. All their screen activities are recorded, and any suspicious behavior is flagged using behavioral trackers. Artificial intelligence technology marks moments when there are multiple or unauthorized faces in front of the camera, background noise, changing focus to another window, and many more. After the exam, the system generates the credibility report, i.e., proctoring report containing the score and assessment of candidates' behavior.

3. Video Archiving and Review

Audio and video recording data of test attempts are stored on the cloud and available for additional human review. Test managers can go through only suspicious moments and verify credibility reports generated by the system.[4]

5.2. Proctoring Session Lifecycle

Participants of events (students) undergo proctoring sessions in accordance with the life cycle, the diagram of which is shown in Figure 1. It includes two logically separated blocks - preliminary steps and supervision

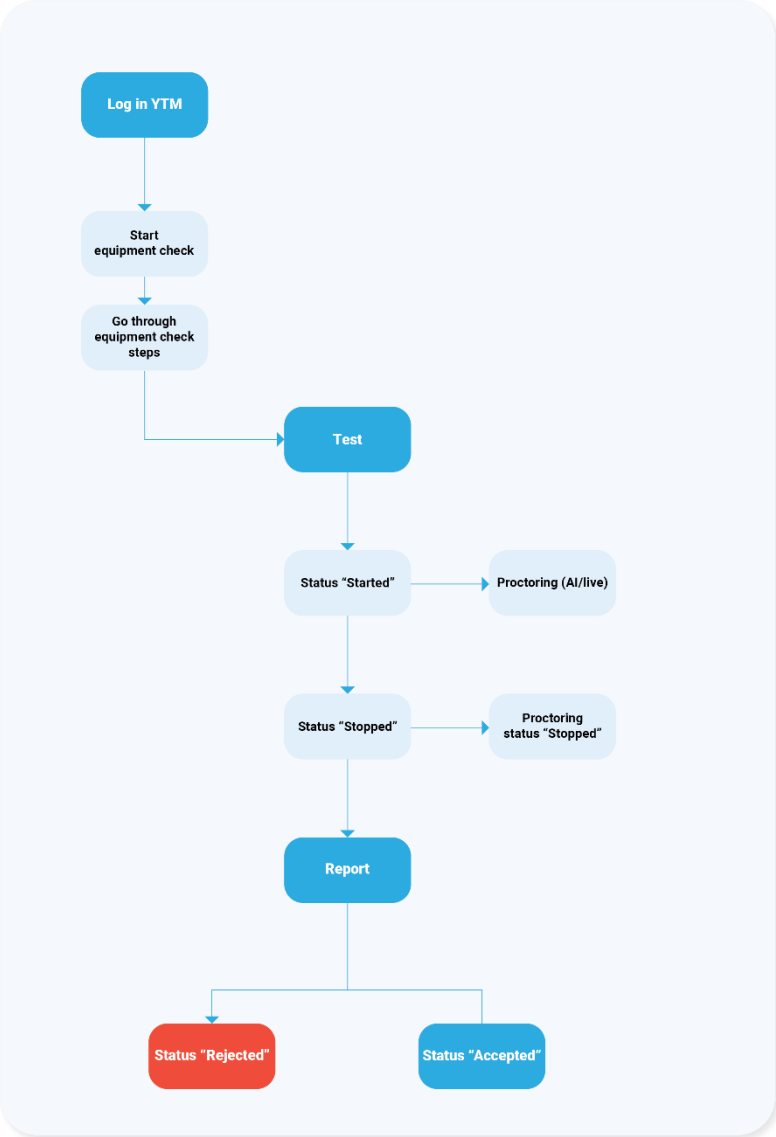

Figure 1. – Session life cycle

Proctoring sessions are created automatically with the creation of the exam.

5.3. Behavior Trackers

Using behavior trackers, proctoring evaluates student behavior throughout whole online assessments and flags the moments of suspicious behavior. When a student tries to cheat, the system flags such behavior and includes it in proctoring credibility report. The report with behavior data and behavior grades can be generated automatically and reviewed further by test administrators. Now, which behavior is considered a suspicious behavior is configured in the proctoring module. Keeping in mind that different test owners have different requirements regarding honorable conduct. In the "Metrics" tab of the session card (Figure 2), test administrators or the support team, on their behalf, can enable trackers and set their weight that adheres to their appropriate-behavior criteria. Each metric has its own weight, which is equal to 1 by default. This weight is used to form a confidence rating. The fixed indicators in the session are multiplied by it.

The following metrics are available for selection:

- Browser is not supported (b1)
- Focus changed to a different window (b2)
- Full-screen mode is disabled (b3)
- Webcam is disabled (c1)
- Face invisible or not looking into the camera (c2)
- Several faces in front of the camera (c3)
- Face does not match the profile (c4)
- Found a similar profile (c5)
- Atypical keyboard key writing (k1)
- Microphone muted or its volume is low (m1)
- Conversation or noise in the background (m2)
- No network connection (n1)
- No connection to a mobile camera (n2)
- Screen activities are not shared (s1)
- The second display is used (s2)

5.4. Add-Ons: Proctoring Settings

Depending on the required level of exam security, test owner's preferences, and policies, several add-ons that can be enabled for each session individually. Most of them, such as video recording and behavior trackers, are enabled by default and advised to be standard add-ons for any exam.

- Equipment check includes the stage of checking equipment, the list of checks is formed based on the selected indicators, this includes checking the browser, network, camera, microphone, and screen.
- Manual face photography - includes the stage of photographing the face by the student.
- Manual photographing ID — includes the step of photographing an identity document by the student.
- Uploading the scan of the document — includes the step of uploading the scan of the identifying document by the student.
- Additional mobile camera — includes the step of connecting an additional smartphone camera using a QR code to record the test environment before the exam starts.
- Checking readiness to start the event — turns on a dialog before starting a session, where the possibility of starting a session and confirmation of readiness by the participant is checked.
- Require the presence of a human proctor — enables checking the availability of a proctor. Only proctors with the "Active" flag enabled will be assigned to the session.
- Track metrics — starts tracking behavior indicators in the session.
- Record video — saves the video recording of the session.
- The allowance to run on mobile allows one to pass the test with proctoring on mobile devices.
- Turn on the screen capturing — allows using the video from the screen.
- Turn on the WebRTC check — activates the functionality check of the WebRTC on the step of the equipment check.
- Allow start only from a safe exam browser— allow session start only if the user opened the page through a safe exam browser (the screen is locked so students cannot navigate away from the test-taking screen).
- Content copy protection — enables protection against copying content (test) in a session, prohibits the selection and copying of text and images, prohibits saving the page through the print dialog, and prohibits using the "PrintSrc" key.
- Webcam preview — displays the preview in the form of a circle with a camera's picture of the student, allows the students to receive feedback from the proctoring system, and adjust their behavior.
- Chat with proctor — allows the student to open a chat with a proctor during the test-taking.
- Uploading files into chat — allows a student to upload files to the chat.

- Block the screen in cases of violation— activates the freeze of the screen when the system detects violations, which have a duration of more than 20 seconds, the block deactivates 10 seconds after violations are addressed.
- Available by a link — makes the session available by a link without authorization, meaning that a proctored exam can also be started by so-called guest users, students that do not have an account in YouTestMe.
- Automatic conclusion — allows the proctoring system to set the conclusion for the session based on confidence assessment.
- Verification of names on documents — performs verification of the name inputted by a student and the name in the scanned/photographed document.

5.5. Credibility Report

The credibility report (Figure 3) represents proctoring report, i.e., a report on the candidate's behavior during the exam. It is calculated using the following formula:

$$E = 100 - \sum_{k \in M} \left(w_k x_k \right)$$

Figure 2. – Credibility report formula

E ∈ [0, 100] is the credibility score (if E < 0, then E = 0), xk is the session-averaged value of the metric k, wk is the weighting coefficient of the metric k, M ∈ {b1,b2,c1,c2,...} are the metrics.

Thus, the credibility score shows the total average percentage of violations for the entire session. The session duration is taken as the actual one, i.e., the difference between when the student started the session and when they finished it.

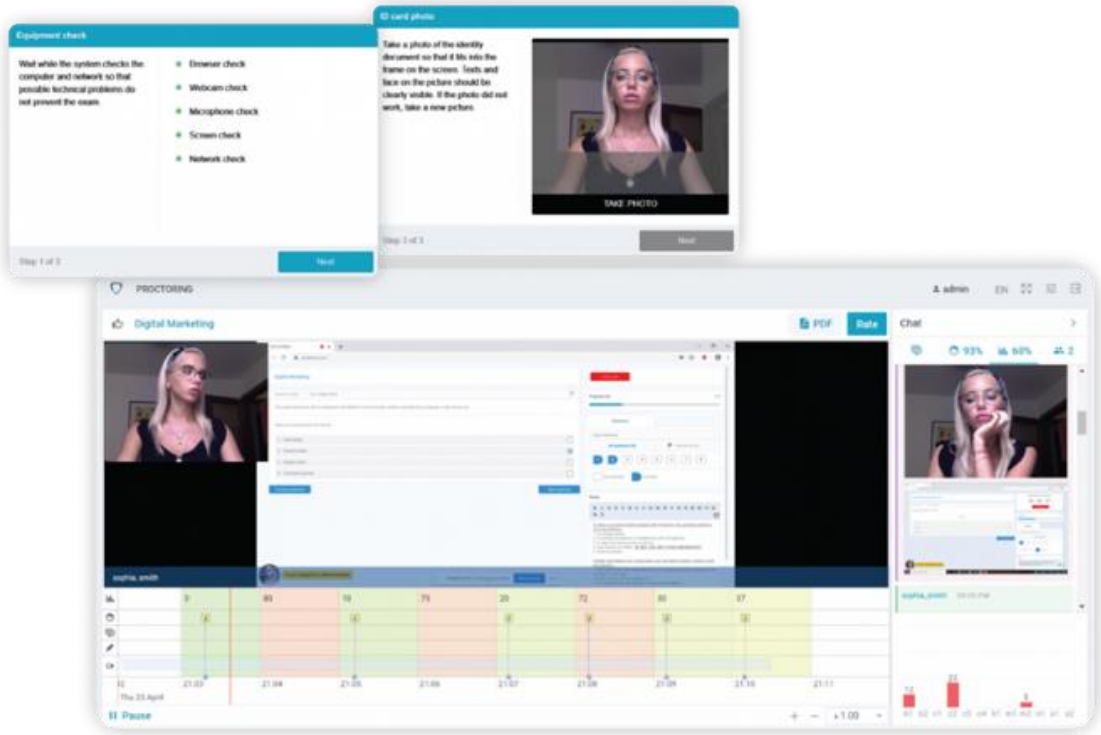

Figure 3. – Automated proctoring: equipment check and credibility report

6. Technology and Human Touch

Learning is one of the most vital and integral parts of our lives. Education is a virtue that shows human freedom and, in many respects, a necessity for society. So, what will happen when this indispensable part of our lives moves to an online platform? What are the ventures of migrating from a classroom to a monitor screen?

Study shows that online learning, or as people call it, "e-learning", has shown to be more flexible in time and space than on-premises exams. The Web stretches to unimaginable lengths now, so much so that in 2005 data showed that 68% of Canadians were regular internet users, which means in 2022 those numbers are even higher. Simply put, moving online can provide a larger quantity and quality of materials for a successful exam for citizens with or without a physical disability. The body of content we see today is unequivocal to what was available a decade ago.[4]

A significant risk for many educational facilities and institutions is how to preserve integrity and keep a secure learning environment while at the same time not overstepping boundaries with the students. Among the many approaches to this issue, one of the best could be in the realm of the Artificial Intelligence world.

Its remarkably advanced technology prevents unwanted behavior and leaves test organizers at ease. Although it is professional, with YouTestMe, this process can be humanized. In addition to AI proctoring, a human proctor can monitor the entire process in real time. Live proctoring is a hybrid model that includes a formal human audit and automated proctoring. Students feel comfortable during the test-taking process and don't feel they are being monitored unjustly. Proctors greet the students politely; YouTestMe certified proctors are very professional, precise, and attentive. The student can always request a small break or ask for a review at the end of the session. Sometimes a successful exam requires a pause, and all of this is considered by the assigned proctor. During test-taking, it is familiar to feel a sort of exhaustion and confusion. The student could look away for a moment in thought or to recollect an answer in their mind for the test. These situations are, in actuality, not cheating but could be mistaken for such. In these scenarios, the proctors show understanding and empathize with the student. This solution is the most secure and minimizes the chances of cheating to an absolute minimum, ideal for high-stake exams. YouTestMe certified proctors are trained to handle all the test monitoring in a lawful manner, which helps test owners feel more comfortable that the integrity of their test is protected.

Proctors supervise the whole session in real time, with the assistance of automated software. Therefore, proctors can intervene to rule out cheating behavior whenever a red flag is raised.

The rapid transition from a traditional to an online platform has shown us not only the importance of a secure environment but also to consider comfort. Proctors should be the gatekeepers of the success and integrity in exam taking. While students should show that they can uphold their honor code, adhere to academic policies, and preserve rectitude, even from the comfort of their own homes.

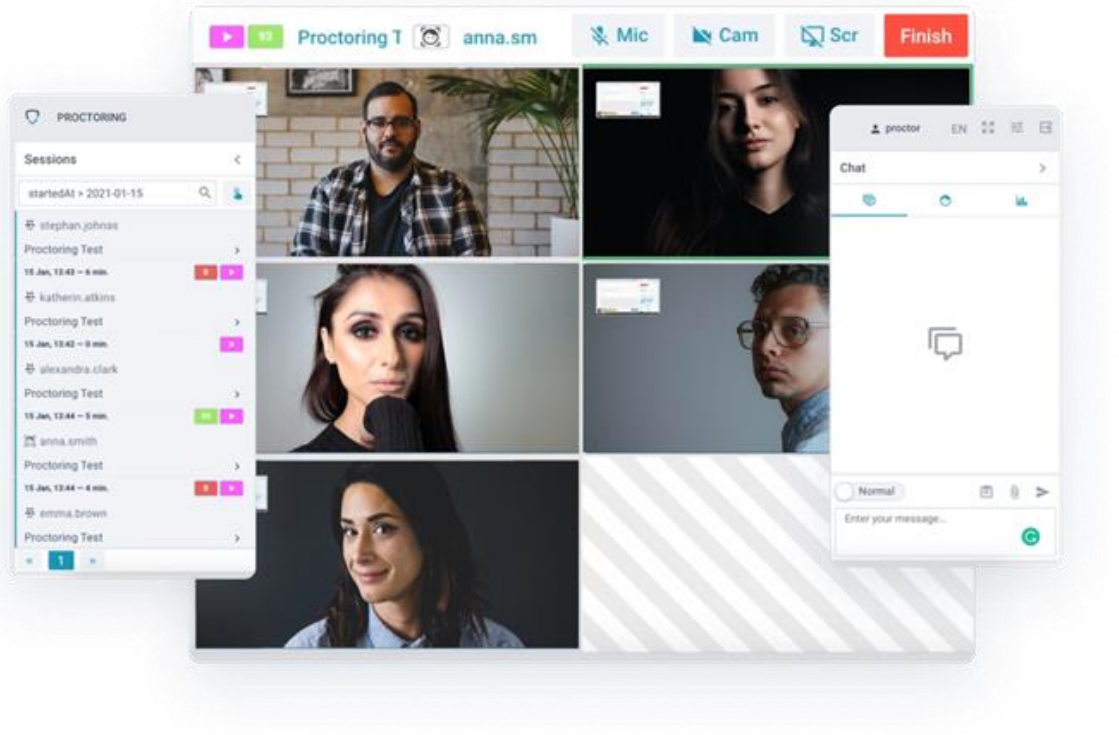

Figure 4. – Real-time monitoring

7. Use Case: A Canadian Institute's Transition to the 21st Century

To better understand how the beforementioned technology can change an enterprise of the 21st century, the following part of the paper will focus on the practical use case of a prominent Canadian institute and how YouTestMe technology helped it become more productive and efficient.

Due to the pandemic, the need for the E-learning sector accelerated. The demand came from almost all industrial sectors. As businesses were rapidly switching to a remote regime, one of them, an economic institute from Canada, which counts hundreds of thousands of tests annually in various locations and time zones, seek for professional help. The institute needed software and a service that would enable the transition of their scattered and administratively complex system to something uniform.

At that time, they were organizing test-taking daily in English and French. The test format differed from test to test, and they were not uniform:

- Some tests were taken on paper
- Some tests were taken in legacy application
- Some tests were taken in a physical test center

Synchronizing all the data daily from different test formats and user profiles was a struggle and the institute found it challenging to provide premium service to the candidates. This was when they realized they needed an end-to-end solution for examination that would make the whole process seamless and uniform.

Historical data was migrated, and a system that follows their entire process was developed – the candidate buys the test and gets the opportunity to schedule it on one of the offered dates. When the test is scheduled, the system sends an e-mail confirmation and starts notifying the candidate on a regular basis. This way, the candidate would not forget about the test and have all the necessary information to prepare for it accordingly.

The candidate has the opportunity to check the technical equipment before they begin the test. This is useful as it eliminates potential technical issues during the test, and the candidate can relax and avoid any inconvenient scenarios. The least stressful place is the comfort of a home, and their test-takers can

do tests from there. YouTestMe proctors greet each candidate individually on the day of the test, present the test rules, and are there to help in any way necessary at all times.

Thanks to modern online examination technology, 80% of manual labor was offloaded from the institute. Tests were uninformed, the software was branded accordingly, and they have access to the user database and dozens of other useful features that could ease the completion of daily tasks, such as administrative tasks. The institute can now manage even more test-takers, directly impacting its profits.

8. Other YouTestMe Benefits

A flexible, one-stop solution for all types of online knowledge assessments, YouTestMe features automated test and answer generators, simple organization of questions into question pools, certificate designer, automated and adjustable grading, robust reporting system, straightforward process of exam schedule, and much more.

More can be found on the Key Features webpage: https://www.youtestme.com/online-examination-software.

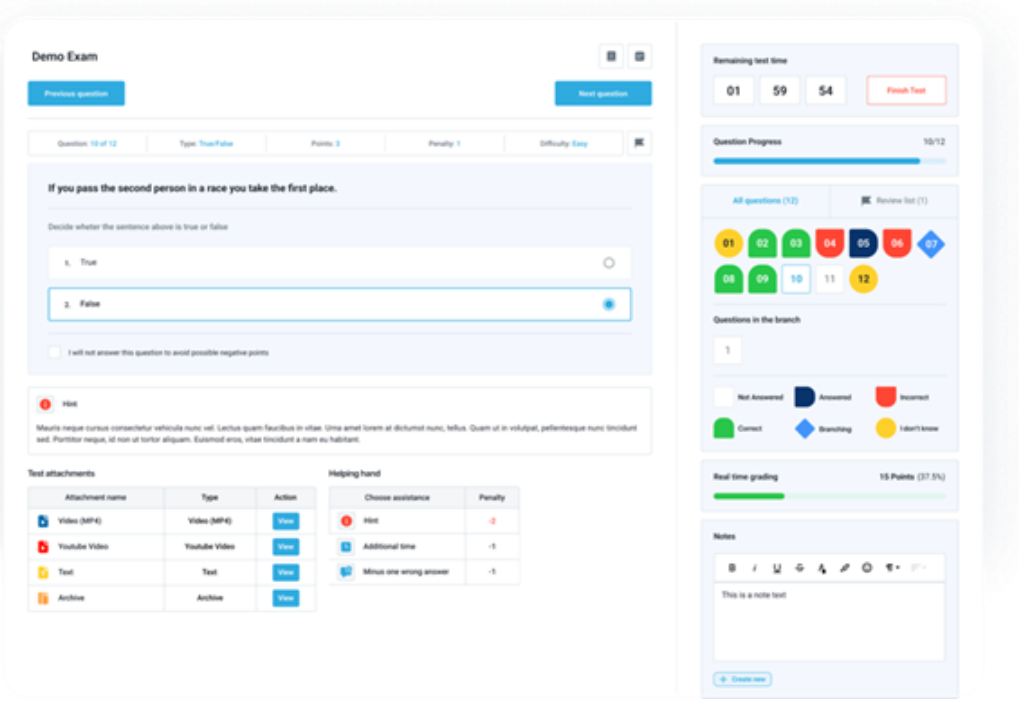

Figure 5. – Test-taking interface

Conclusion

It is safe to say that online test centers are the future of test-taking. With all their benefits, it is impossible to ignore them or think of them simply as an alternative to physical test centers. Like the Canadian institute, the educational sector could benefit from using a software for test-taking, on-site and distant testing. Less administrative burden means more time to do what matters – educating young people to become professionals in their fields.

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Application of Artificial Intelligence in e-Learning: The Role of Chatbots

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Abstract

This paper discusses the application of Artificial Intelligence to educational systems and e-learning with an emphasis on chatbots that are representatives of this technology. Until very recently, the use of cell phones was banned in many classrooms around the world, forcing teachers and professors to take their favorite devices away from their students during class. But after innovative applications showed that cell phones could also improve the education system, those same educators began to encourage the use of this technology. This paper discusses why there are chatbots in the classroom today that help students in education and learning in many ways. Also, this work adresses how chatbots promote learning and what part of the work they perform in relation to teachers.

Keywords

Artificial Intelligence, AI, Machine Learning, MI, e-Learning, Chatbots

1. Introduction

According to many educators, modern technology is one of the biggest enemies of the education system. The trend of increasing use of new technologies in all segments of people's lives has not bypassed the sphere of education either. The changes caused the need to adapt the materials used in teaching through which current and future generations will be educated, bearing in mind that the future is based precisely on the application of information and communication technology (ICT).

E-learning can be defined as the use of ICT (CD, DVD and Internet) in the performance of the educational process. Thus, the interaction between teachers and students is done with the help of technology that transmits the teaching content. Essential elements of e-learning are challenging the learning process with technology and monitoring student results and success. When education relies entirely on the use of the Internet, then e-learning is one of the forms of distance education, i.e. online learning.

E-learning is a broader concept than the concept of online learning, because it can be realized even when the computer does not have access to the Internet. The technology that is most prevalent in e-learning and whose application leads to great progress is artificial intelligence.

2. Artificial Intelligence in e-Learning

Artificial intelligence is an epochal novelty in the history of human civilization. Its beginnings appear with cybernetics and automation and its development was initially focused on machines and robots, especially on space and similar technology. However, the emergence and mass application of digitization led to a strong expansion of AI and extended its field of action to practically all areas of human life. The adjective "smart" began to adorn an increasing number of nouns: smart machine, smartphone, car, city, smart toy, building, lighting, classroom, blackboard - best illustrating the rapid expansion of AI [1].

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The most popular positioning strategies used by companies regarding the application of artificial intelligence and machine learning in higher education institutions and EdTech companies are personalization and customization, analytics and performance reporting, virtual tutor (Virtual tutor), learning support (based on chatbots) and gamification (gamification).

Adaptive (customized) learning is made possible thanks to solutions like the Century Tech platform, which starts from the assumption that every student in the learning process sooner or later will encounter an obstacle that will slow him down and affect the quality of the acquired knowledge, and it is the teacher who should identify those obstacles and to remove them.

However, tracking each individual student, analyzing individual results and creating materials according to each student's needs is too time-consuming and almost impossible. That's why the Century platform was created, with the help of a team of educators from the Century Tech company, which allows educators to take "smart interventions" with each student based on the data about the knowledge and needs of each student that the platform collects.

The platform combines artificial intelligence, learning science and neuroscience. In addition, to help students develop their own skills and retain knowledge throughout life, the Century platform uses a learning principle such as interweaving. Students study several subjects at the same time instead of just one. It stimulates the brain to associate different topics and make connections between them, which improves long-term memory.

An excellent example of an AI-based system is the Knewton ALTA platform. This company has constructed the ALTA platform so that students can attend lectures. Like other platforms based on the principle of adaptive learning, this platform also learns from students and recognizes gaps in their knowledge.

The ALTA platform allows educators to organize courses, exercises and quizzes that students solve, providing insight into their performance "in real time". For example, suppose a student is having difficulty with a course material or a particular exercise. The platform recognizes this and offers "timely intervention" - feedback, help or going back to the material already covered, which will help the student to solve the task.

The main advantage of this platform is "timely intervention" for students and "real-time visibility" for teachers. It is a platform that tries to keep the student in the learning process through immediate help in cases where the student has difficulty mastering a certain task. Therefore, the number of students who drop out of the course is much lower than the number of those who successfully complete it. The teacher has a clear insight into the performance of his students, as well as support in creating new courses or exercises [2].

Automation of education is possible with Microsoft's package. However, the inability of educators to devote themselves sufficiently to each individual student in a group (class) causes mediocre performance and the existence of a large number of students who drop out of education/courses.

The basic element of automation is QBot. When a student asks a question, QBots use the tags of the lesson to which the question relates and the teacher from whom the answer is expected. After a certain period in which only teachers answered questions, the chatbot recognizes segments of answers to the questions asked and suggests possible answers. If the chatbot fails to find a suitable answer in its database, it forwards the question to the teacher. At the same time, in addition to answering questions, the chatbot also takes into account discussions in which similar topics have been discussed.

When talking about gamification, the Memrise app is a good example. This app uses gamification technology to make language learning more interesting for learners/users. In this case, the user is an astronaut embarking on a long journey of language learning.

He has different cards with words and ways to remember them, but he can also point his phone's camera at an actual object, and the phone will write that word on the screen and say it in the language the astronaut is learning. The student collects points, and the higher the number of points, the more his "pet alien" will grow. In addition to all this, the app gives him constant insight into his own progress and is full of colorful and fun ways to remember words. Its purpose is to solve the problem of learning words and expressions that students encounter in standard courses and in textbooks. The application provides different ways to learn and memorize words.

Another great AI-based app is Sololearn, which uses gamification technology to create programming courses. Like any educational platform, Sololearn contains lessons and teaching material for learning almost all programming languages. This platform offers a Code Playground, where players can compete

against each other in coding challenges, and the winner earns XP (experience) points. It is also possible to follow the courses on mobile phones, computers and tablets.

The Sololearn platform uses progression, EXP (experience points) and leaderboards to encourage players to continue learning to code.

The platform simultaneously solves the problem of great interest in coding and the lack of courses that are challenging enough for participants. By learning programming languages, students gradually master the basics, and the application provides them with sufficiently challenging material and tasks.

The platform offers a large number of challenges and the opportunity to compete with other participants. Sololearn constantly returns to the teaching material and questions that the student has not fully mastered [3].

The application of artificial intelligence always depends on the existence of a suitable data set. If the critical data does not exist or is not sufficiently "clean", the application of AI will not be successful. In the application of artificial intelligence, a computer program composed of algorithms makes inferences based on data sets. Without data, the algorithmic set is unable to recognize trends, and therefore does not have a good basis for making decisions. It is possible to set up the equations perfectly, but AI will not interpret or predict the information well without an equally good set of data [3].

3. History of Chatbots

In 1950, Alan Turing proposed the so-called Turing's test ("Can machines think?"), and from then on the general idea of a chatbot started. The introduction of chatbot technology began in 1966 with a computer program known as ELIZA [12], developed by a group of professors from MIT University.

ELIZA could mimic a human conversation by trying to answer a user's question by matching scripted responses, ie. by simple pattern matching. It was developed by Joseph Weizenbaum. He was designed to mimic a psychotherapist and had a knowledge base in this domain. She was able to pass the Turing Intelligence Test during that time [12].

PARRY presented an inexplicably simulated person with paranoid schizophrenia developed in 1972. PARRY was much more serious and advanced than ELIZA, and was also described as ELIZA with attitude.

JABBERWACKY was developed in 1988 and was one of the first attempts to create artificial intelligence through human interaction. Mainly based on the form of entertainment, it aimed to move from a text-based system to one that is mainly speech-based.

DR SBAITSO was an AI-based speech program created for MS DOS. It was designed in 1992 to represent the digitized voice. However, DR. SBAITSO was far from an actual living being, despite having the role of a psychologist interacting with users [13].

A.L.I.C.E. (Artificial Linguistic Internet Computer Entity) was developed in 1995. It was a natural language processing bot. This bot could apply heuristic rules that matched the rules of human input, i.e. it could have a conversation. ALICE relies on a simple algorithm for pattern matching with basic intelligence based on Artificial Intelligence Markup Language (AIML), which allows developers to define the building blocks of knowledge for a chatbot [14].

SMARTERCHILD is an intelligent bot that was widely distributed through SMS networks in 2001. With features such as fast data access and engaging 26 personalized conversations, it was considered a precursor to Apple's SIRI and Samsung's S Voice.

BOTS FOR MESSENGER is a platform that was developed in 2016 by the Facebook company, which allows developers to create bots that can communicate with Facebook users. There are currently over 300,000 active bots on this platform [7].

TAY was also designed in 2016 to imitate the speech and habits of American teenage girls. This chatbot that was developed by Microsoft quickly developed an awful paranoia. TAY was shut down after 16 hours of existence and was never heard from again [7].

Over the years, other chatbots have incorporated modern and more sophisticated techniques to better understand user questions and provide more relevant and useful answers.

Today, a chatbot can perform many of the functions of a mobile app or website, all within a messaging app conversation, without requiring the user to install or download new apps.

A larger number of chatbots appeared at the beginning of the twentieth century, while the last six years have seen a sharp increase in the number of chatbots due to the increased market for mobile phones and other smart devices and of course the advancement of machine learning. Chatbots are now embedded in popular digital assistants such as: Siri, Cortana, Alexa, Google Assistant, IBM Watson, etc [6].

4. The Role of Chatbots

Chatbots are the ones that take precedence in solving the problem of providing an immediate response to a query. Virtual agents, dialogue systems, or chatbots are programmatic conversational systems that interact with users using natural, everyday speech. The purpose of the chatbot system is to stimulate, that is, to imitate human conversation. Namely, the chatbot architecture integrates a language model and algorithms to imitate an informal conversation between a human and a computer, using natural language [9].

In order to better understand chatbots, it is necessary to start from the conversational interface, which is defined as an interface with which the user interacts through conversation, either in written or oral form. A natural user interface (NUI) is an interface that interacts with natural flows such as speech, hand gestures and touch, while a chatbot is an example of a combination of conversational and NUI interfaces.

It is an artificial entity designed to stimulate conversation with human interlocutors in their natural language, and is considered one of the classic human-machine natural language communication interfaces. From a conversational perspective, there are three ways chatbots can talk to users: system-driven chatbot (the system is the leader of the conversation), user-driven chatbot (the user is the leader of the conversation), and combined chatbot.

Limitations of user-driven chatbot dialogue are errors in conversation recognition and comprehension, given that users can say anything and there is a chance that the system will not recognize it. Limitations of system-driven chatbot dialogue is that user input is limited, but understanding is at a higher level.

The advantage of the combined dialog is that the system can quote the user, but the user has the ability to say whatever he wants, as well as ask questions. The limitation is that the system must be technically advanced in order to take care of its structure and agenda, and understand and correctly respond to the user's statements, as well as remember important information [4].

There are three main implementations of modern chatbots:

1. Digital assistant
2. Information provider
3. General chatbot

Chatbots are most often used in today's technology for purposes of education, information retrieval, business and e-sales and as customer support, which is estimated to be the main reason for using chatbots in the future.

The application of mobile messenger chatbots for commercial purposes is at the beginning of the development phase called conversational commerce. Namely, the chatbot is able to recognize the user's intention and adjust the offer according to choices and interests.

Social bots have seen an expansion following Facebook's decision to integrate chatbot capabilities into its Messenger functionality in 2017. A social bot is a computer algorithm that automatically creates content and interacts with people on social networks, in an attempt to imitate and possibly influence their behavior [5].

An example of a popular instant response chatbot is the Viber chatbot, however there are many other platforms that use their own chatbots. This type of chatbot is intended to provide service measured through user satisfaction, accuracy, availability, accuracy and completeness of task execution. Although chatbots have introduced a global revolution in customer service, they are still

considered a novelty in Serbia, both by service providers and users, which can explain the lack of research on this topic [6].

5. Classification of Chatbots

Over the past few years, the field of chatbots has become so dynamic with the advent of new technologies that the precise classification of chatbots has become subjective in relation to the extent of their use.

Chatbots can be classified into different categories based on several criteria, for example. mode of interaction, domain of knowledge, their use and design techniques (response generation method) commonly used in building chatbots. These criteria may include the underlying design philosophy of the chatbot or the degree to which context should be preserved and considered in understanding the conversation or the type and purpose of the conversation for which the chatbot should be designed.

A broad classification can be made based on the following criteria:

1. Oriented or non-task oriented;
2. Method of iteration (text, voice);
3. Generating answers;
4. Open and closed domains, ie general (generic) and domain-dependent knowledge bases;
5. The type of chatbot relationship with the user;
6. Need human assistance or not;
7. Good and bad chatbots;
8. Chatbots developed on open or closed platforms

Task-oriented chatbots are defined as short-conversational chatbots designed to perform a specific task from a known subset of preconfigured tasks triggered by a conversational process. For example, an online shopping chatbot is designed to assist users in their shopping process by searching for products and resolving account-related issues. Non-task oriented aim to simulate the human conversational process without a specific task or action as the main goal of their interaction. Leisure or entertainment chatbots fall into this category.

Regarding non-task-oriented chatbots, some distinguish between conversational and informational chatbots [10]. While conversational chatbots fit the definition of non-task-oriented, informational chatbots are defined as a type of chatbots that are not task-oriented, that do not follow a specific activity or task to perform, but interact and the process of conversation has the purpose of gathering information. Chatbots for providing frequently asked questions and answers for service support fall into this category. Task-oriented chatbots usually mean that the chatbot is integrated as a tool or submodule of another software system that provides a set of functions to the user, or the chatbot requires integration with third-party software services to perform these tasks. Often these task-oriented chatbots are also called transactional chatbots.

The interaction dimension defines the communication mechanism used by the chatbot to process user information and generate responses to the user. For this purpose, chatbots use text interfaces (messages), voice recognition, images or a combination of all of the above.

Typically, chatbots that integrate voice interaction with their users introduce some kind of speech-to-text and text-to-speech or automatic speech recognition as the top layer of the conversational process they support. speech and text, and integrate natural language data processing techniques. This is the case of well-known commercial voice assistants such as Alexa or Cortana.

Some chatbots introduce image recognition as a feature to support and extend the limitations of natural language communication, supported by other commercial, popular chatbots such as Siri or XiaoIce [10].

Classification based on input processing (phrases, messages, sentences, questions) and response generation refers to the mechanism used by the chatbot to process inputs in natural language and to generate the appropriate message (response) and/or action (if any) also in natural language user.

Primarily, two main categories of solutions are distinguished: deterministic models - based on rules and models based on artificial intelligence. Deterministic algorithms process user input messages to

extract some kind of structure, interpreted knowledge, and apply some kind of deterministic strategy to associate this structured data with a specific output message or action. They select a system response based on a fixed predefined set of rules, based on recognizing the lexical form of the input text without creating new textual responses.

The knowledge used in a chatbot is often manually coded and organized and represented by conversational patterns. Most existing research on rule-based chatbots studies conversational response selection in a single conversation, which considers only the last input message. In better humanoid chatbots, multi-step response selection takes into account previous parts of the conversation to select a response relevant to the entire context of the conversation.

On the other hand, newer strategies exploit the potential of AI-based strategies, which integrate the use of machine learning and deep learning models to process user inputs and build output messages based on knowledge sources and training data. Broadly, there are two types of AI-based strategies: discovery-based models and generated models. Slightly different from the rule-based model is the discovery-based model, which offers more flexibility while querying and analyzing available resources using an API.

Discovery-based models use machine learning and deep learning models and techniques to understand inputs and predict the most correct answer from a closed set of answers using an output ranked list of possible answers. These models can provide more reliable and grammatically correct answers. They are easier to learn because they require less data, but they are not able to answer questions outside their knowledge base and they cannot create new text and learn on their own based on previous conversations, but choose an answer from a fixed set.

This type of chatbot requires manual assistance from the operator for non-typical questions. On the other hand, generated-based systems focus on using deep learning models to synthesize and build responses to specific user input, rather than selecting from a closed response data set. They generate new answers from the start because they can answer ambiguous questions [11].

6. Advantages of Chatbots in Education

Supported by artificial intelligence, chatbot technology personalizes the educational environment and fundamentally changes the educational system. In addition to electronic commerce, customer services, catering and other industries facing consumers of products and services, the wide field of its application today also includes student cooperation [6].

The chatbot guides students through the learning process, providing much-needed assistance along the way in the form of:

1. Better support for students
2. Learning assistance
3. Motivating students
4. An insensitive educational experience
5. Updating lesson plans and schedules

6.1. Better Support for Students

Programmed to answer various types of student questions and thereby improve the overall educational experience, chatbots give educational institutions the opportunity to provide a better support system to their students.

Chatbot technology offers information about classes, libraries, tuition, internships, private education costs, teaching staff, dormitories, and more. Chatbots can serve as guides to college life for students — instead of asking older students for help or waiting days for a professor to answer, freshmen can ask chatbots for a solution in the middle of the night, since chatbot technology is available 24 hours a day and 7 days a week. All possible questions that a pupil or student might have can be loaded into the chatbot technology using a programming language. If a student wants to know how to register for an exam, how to get more ESPB points, or what to expect from a certain course, chatbot technology will provide him with a quick but accurate answer.

This level of student support is invaluable and essential [7].

6.2. Learning Assistance

Chatbot technology can also serve as an effective (albeit digital) learning assistance. Thanks to artificial intelligence, chatbots handle repetitive tasks of professors like grading assignments and tests with ease and precision. In this way, chatbot technology saves them time and allows them to fully devote themselves to providing the most developed and rich educational experience.

AI chatbots can recommend course material, help students achieve goals, track student performance and progress, and provide personalized feedback. Being able to analyze learning styles and individual needs, bots can offer students personalized and proactive assistance in the form of customized learning resources and functional knowledge tasks.

Through chat with the bot, students themselves can provide feedback on the courses they are taking, or offer specific ideas to improve the quality of a particular curriculum. Chatbot technology analyzes this data and thus helps professors to make the educational experience easier for students, offer better courses and curricula, and turn the entire educational process towards more meaningful goals [7].

6.3. Motivating Students

Social networks and instant messaging services have made it even more difficult to motivate students to work. If educators are to be believed, today's students struggle not only with a lack of interest, but also with a lack of concentration. These learning disabilities are particularly noticeable in elementary and high school students.

Chatbot technology can also help solve this problem, since it can be applied precisely to teenagers' favorite social networks and instant messaging services. Professors can use the so-called "omnichannel" approach to help students through their favorite online channels.

Chatbots thus further improve communication with pupils and students. Instead of relying on slow email correspondence and various online portals to search for urgent information, students can simply contact a chatbot through the same platform they normally use to communicate with their friends, and get the answer they want immediately — regardless of the time of day or place. on which they are located [8].

6.4. An Insensitive Educational Experience

With the help of chatbot technology, complicated aspects of the educational process — such as school administration or communication between professors and students — are simplified to the point that the focus can be placed entirely on learning itself. We can thank artificial intelligence for this, which is developing the ability to process natural language in chatbots. As a distinct field of computer science, natural language processing gives bots the ability to understand contextual meaning, so they grasp the full meaning potential of student questions and provide meaningful and relevant answers.

Supported by artificial intelligence, natural language processing and machine learning, chatbot technology understands human language and talks to us in a completely natural way. Artificial intelligence also contributes to the speed of data processing, so chatbot technology can process them in just a few seconds.

Another advantage of this technology is the ability to simultaneously communicate with a large number of users, so that no student has to wait for the necessary help and answers. This combination of AI and chatbot technology can improve the educational system to a great extent. All recommendation to educational institutions is to rely on the SnatchBot omnichannel chatbot design platform. Not only does it offer the most powerful AI system on the market, but it also allows users to design AI chatbots for free, and easily deploy them to the communication channels of their choice [8].

6.5. Updating Lesson Plans and Schedules

With the help of chatbot technology, pupils and students will always be up to date with lesson plans and schedules of lectures and exams. Information regarding exam dates, study and research resources, paper and essay topics, and all other teaching activities will also be provided to them in a timely manner.

Chatbots can also be programmed to send reminders and notifications related to exam deadlines, whether it's exam preparation literature or exam registration and exam costs, so students can fully focus on academic growth and development. and professors to students.

The number of educational institutions implementing AI chatbot technology is growing at an ever-increasing rate, primarily due to its enticing ability to facilitate and enhance the educational experience.

The educational system is thus becoming more and more modern and aligned with the modern needs of students and professors, and in the future we can expect even more innovative and useful ways of applying chatbot technology in the traditional classroom [16].

7. Development of Chatbots

The development of chatbots involves different techniques. Understanding what a chatbot will offer and what category it falls into helps developers choose algorithms or platforms and tools to build it. At the same time, it also helps end users understand what to expect.

Requirements for designing a chatbot include an accurate knowledge representation, a response generation strategy, and a set of pre-defined neutral responses to respond when the user's expression is not understood. The first step in designing any system is to divide it into component parts according to a standard so that a modular approach to development can be followed. The process starts with a user request, to a chatbot using a messaging app like Facebook, Slack, WhatsApp, WeChat, or Skype, or an app that uses text or speech input like Amazon Echo.

After the chatbot receives a user request, the language understanding component analyzes it to infer the user's intent and related information. Once the chatbot has reached the best interpretation it can, it must determine how to proceed. He can react directly to new information, remember everything he understood and wait to see what happens next, request more information about the context or ask for clarification [8].

Once the request is understood, action is taken and information is retrieved. The chatbot performs requested actions or retrieves data of interest from its data sources, which can be a database, known as the chatbot's Knowledge Base, or external resources accessed through API calls. Upon retrieval, the response generation component uses natural language generation (NLG) to prepare a human-like natural language response to the user based on the intent and context information returned from the user message analysis component.

The dialog management component stores and updates the conversation context that is the current intent, identified entities, or missing entities needed to fulfill user requests. Furthermore, it looks for missing information, processes user clarifications, and asks follow-up questions. There are many commercial and open source chatbot development options available. The number of technologies related to chatbots is already huge and growing every day.

Chatbots are developed in two ways: using any programming language such as Java, Clojure, Python, C++, PHP, Ruby and Lisp or using the most modern platforms.

All of these platforms are powered by machine learning. They share some standard functionality (they are cloud-based, support different programming and natural languages), but differ significantly in other aspects [16].

8. Conclusion

Education must be as accessible as possible in the 21st century. Access to education and lifelong learning is included in the most important global strategies, including those of the UN. No sector of the economy has been able to escape data management, which is why education-related systems need to use data analytics to design new personalized education programs that can quickly and accurately bridge "knowledge gaps." In addition, it has long been believed that teaching the same material to a large number of students is dysfunctional.

The problems at higher education institutions have only been exacerbated by the lack of educators in many educational systems. Educators can learn about students' strengths and weaknesses using smart systems based on artificial intelligence and machine learning. As the demand for highly educated workers continues to grow, educational institutions and companies plan to continue using AI and MU in the future.

Chatbots can reach a wide audience in messaging apps and be more efficient than humans. At the same time, they can be developed into a capable information gathering tool. They provide significant savings in the work of the customer service department.

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A Review of Gamification in Learning: Impact and Outcomes in the Computer Science Domain

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Abstract

Gamification is the process of adopting game elements to increase memory capacity. When used in conjunction with excellent teaching methods, gamification in education can improve students' learning. This paper focuses on how the gamified method of learning may be used in the field of education to increase learning, motivation, and engagement. The paper shows what research needs to be done to determine how gamification is affected by factors such as age, gender, resource person knowledge, and users' fundamental analytical and mathematical skills, before the actual implementation of gamification. Higher education in computer science can be addressed as a challenging field of study, thus it is necessary to make use of the different gamification advantages that have previously been researched. To more accurately analyze the games, the evaluation techniques should additionally take into account gameplay statistics, group sizes, and observations. There is room for more research into how gamification affects classrooms, distance learning, and crash courses. Future studies should target graduate students and concentrate on teaching the least-taught programming principles using games.

Keywords

Gamification, Learning, Computer science education

1. Introduction

Research on the usage of digital games in education is necessary given the rise in their popularity. The digital games industry is a lucrative global business. Digital games have become a very popular and lucrative form of entertainment in modern world culture [1]. Digital game thinking has been applied in many industries. Gamification is the process of adopting game elements and applying them in a non-gaming context to increase memory capacity in different ways [2]. At least since the beginning of 2010, the research community has developed a strong interest in the idea of gamification. When used in conjunction with excellent teaching methods, gamification in education can create an engaging environment that can improve students' learning experiences.

First, it must be made clear that gamification does not involve the use of games for serious or non-entertainment reasons; rather, it provides components of a gaming experience to increase retention. The gamification of learning uses eight-game aspects, including rules, goals and outcomes, feedback and rewards, problem-solving, stories, players, safe environments, and a sense of mastery [4]. However, there is ongoing discussion regarding which game characteristics and in what proportions should be used to gamify learning. Gamification is regarded as a new strategy that can bridge the generational divide between teachers and pupils and is one of the developing technologies that will have a significant impact on schools and education in general [6].

However, nothing is known about how adapting gaming features to a student's profile may affect that learner. The majority of gamified systems integrate game components using a "one size fits all" approach, without taking into consideration users' specific preferences, even though learners interact with games for a variety of reasons. However, we may credibly claim that tailoring gamification to the

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individual can generate significant gains in engagement and hence increase learning gains, similar to the largely favorable impact of individualized coaching on learning [4].

The separation of gamification and collaborative work while attributing the results to either of these can provide a significant barrier. To evaluate the long-term learning element of gamification, we also want to investigate how well it works over time in terms of student performance and happiness. The ancient and antiquated methods of learning are less effective in the modern era. According to numerous studies, game-based learning improves student interest and learning experience compared to traditional learning. Nevertheless, despite gamification's popularity and demand, the majority of games to date have fallen short of meeting expectations [2].

Software plays a bigger role in our lives than it ever has. Today's software has a significant impact on how we go about our daily lives. Due to the excitement that technology has generated in the industry, people are beginning to gravitate toward computer science degrees. However, software engineers are in high demand worldwide, despite a very high dropout rate for computer science students in educational institutions [2]. Therefore, this study the objective is to investigate the impact of gamification and various group settings on students' learning outcomes in higher education, especially in computer science courses. To help academicians gain an understanding and to modify future classroom size and teaching techniques, it is necessary to investigate the impact of gamification in higher education, along with the effects of groups of various sizes and over time [11].

2. Theoretical background

The study of gamification in education has so far mostly been related to institutions of higher education and mainly included students in IT courses. If professors experience a certain application as interesting, and stimulating, if they enjoy using it, if they feel safe in their ability to work with the application without prior training, and if they do not feel anxious when working with their computer, they strive to advocate for the adoption of that application as a regular means of teaching [3]. One research looked at differences between professors and their personal experiences with technology, as well as their perceptions of how meaningful digital games are to their students [5]. In-game reward systems such as badges, points, and leaderboards can significantly influence student engagement [11]. Also, having levels and unlocking higher levels in games increases motivation and is a measure of students' learning progress. The emotional state of a person plays an important role in technology acceptance.

It is known that games can encourage soft skills as well as technical skills because they can provide several types of different contexts and scenarios for students. Game-based learning has a much greater advantage over classical learning because practice precedes theory, and under this assumption, the learning process is developed to solve problems whose appearance is controlled by the training environment. There are three views of learning game-based: First and foremost, it is based on the fact that learning is based on games driven by game technologies. Another view assumes that the learning process is based on games guided not only by game technologies but also by pedagogy. The game is included in the learning process, but several defined activities are created around the game and complement the game itself. A third view assumes that game-based learning is principle-driven game design (success, competition, reward system, roles). Games allow people who play them to experience failure that will have minimal personal and social consequences [7].

The 21st century brought with it a new generation, better known as "Millennials", that is, a generation that has been exposed to the influence of information technology since birth. One of the concerns of the modern education system is a trend of declining motivation and engagement among students. Also, there are even bigger problems, increasing cheating on tests and the use of plagiarism. In response, professors strive to develop innovative learning methods to gain and maintain the attention of students, especially millennials. One approach to solving this problem is gamification. Games cause strong emotions like frustration, pleasure, and curiosity. It mentioned the influence of games as a motivational tool for professors to consider how this concept can be used for educational purposes. The previous literature talks about how gamification has a positive impact, but its effects are highly dependent on the context in which it is used and the profile of the users themselves [8]. One concern is that gamification can cause addiction or compulsive behaviour in people with certain personality types. A large group of students, consisting of undergraduate students, were satisfied with the outcome of

learning based on games. They expressed satisfaction because they competed and won prizes, motivating them to work harder. On the other hand, a small group of students who were in higher years of study found this way of learning frustrating. Because it is bulky and heavy literature, they believe that learning through games is not suitable for higher levels of study [8].

Games enable students to actively participate in learning activities, to strengthen their interest, motivation, and willingness to participate in activities. They often focus on communicative and functional aspects of language. Kinect is a device that detects movement and consists of four core components: an RGB camera, 3D sensors, a multi-dimensional microphone, and built-in processors. Gestures or voice commands can be employed to operate without remote management of any system developed using the software [9]. This research talks about different reasons for using motion-sensing input devices like Kinect technology in education. Some suggest this: students don't need any equipment to control their actions. Every movement that the student makes is projected on the screen, and it seems to the student that he is playing a game regardless of whether it is in an open or closed environment. Kinect makes it possible for these moments to be naturally included in the student's subconscious. Although its production was discontinued back in 2017, during the last years of its production, Kinect technology has been implemented in learning foreign languages. For example, some of the researchers investigated the impact of games based on Kinect technology in the virtual language classroom [9]. The results showed that there is a significant difference in test results in favor of an experimental group of students learning with Kinect technology. Students' motivation has been increased by using Kinect technology. There were several analyses of the effects of using Kinect technology for motion detection in English language learning. The results showed that the motion detection interface is not a key factor influencing short-term or long-term attention for learning, but suggest using this interface specifically for interactive operations to gain students' attention for learning the English vocabulary language [9].

In general, games give pupils a stimulating atmosphere in which to study. Similar to this, educational games are made to give students a chance to study while attempting to complete the game's obstacles. The key to the game is to keep the player in a flow state by raising the level of difficulty, which has a good impact on the players' skills. Players take on a role in these games, managing the activities of the game's character while learning the course material. Several review studies have been undertaken by various writers, taking into account various viewpoints on online game-based learning.

3. A proposed framework for gamification-based learning

This research is based on 15 scientific papers, which were taken from Kobson and Google Scholar. How the texts were found involved the selection of the topic as well as the keywords based on which the selected topic was searched. The following keywords are entered in the fields of the advanced search section:

Innovation in education
AND gamification in education or game-based learning
AND teaching strategies or teaching methods or teaching approaches or classroom techniques
AND flipped classroom or flipped learning or blended learning or active learning AND video lecture or recording or video or online lecture.

After entering the specified keywords, the Full-text field is marked on Kobson, and then the range of years of publication of the texts is entered. Newer texts, from 2017 to 2022, were selected for this research. The categories from which the texts were selected are Computer Science, Education, Information Technology, and Science and Technology. Based on previously selected search parameters, 413 texts were obtained. To find the most relevant texts for the selected topic, it was necessary to select Academic Journals from the Source Types section. After applying this filter, 351 texts were obtained. The last filter used is related to the Subject, where the word gamification is selected. As the final result of the search, 32 scientific papers were obtained, from which 14 relevant texts were selected. For finding the fifteenth text, the Subject was changed to game-based learning. Based on the new parameter, 15 new texts were obtained, of which one was selected. The research includes the following aspects of the aforementioned topic: innovation in education, gamification in education, blended learning, active learning, video lecture or recording, and online lectures [1].

This paper deals with the research on the use and influence of gamification in learning through different stages of schooling. The topic was chosen due to the increasing popularity of the use of information and communication technologies in the educational system around the world. Millennials from an early age encounter video games and animated content, so a modern way of learning through information technology attracts much more attention than the traditional one.

Studies have shown that symbols that show the status of points, i.e., the progress line, can have a huge impact on the behaviour of the person playing the game. The previous research showed that badges have a strong impact on increasing motivation as well as increasing commitment to games. Badges can function as rewards, inducing people to perform certain activities to earn badges. On the other hand, students may be motivated to collect badges because they would compare their results with those of other players. One study looked at the influence badges had on the motivation, activities, and overall performance of participants in an online course during one semester. Figure 1 shows the example of core gamification pillars materialized through the aforementioned design elements, resulting in the overall gamification assessment and students' satisfaction. Students were divided into groups: "students who can see their badges and the badges of other students on the course," "students who can only see their badges" and "students who don't see badges". Interestingly, it was expected that students from the groups "students who can see their badges and the badges of other students on the course" and "students who can only see their badges" partake in the course more vigorously. However, that did not happen. Another assumption was that students from the two previously mentioned groups achieve better results in the course than students who do not see badges. And this one assumption turned out to be wrong. Another mistaken assumption was that students who see their badges and the badges of other students, participate more actively in the course than students who only see their badges. Another assumption was that sighted students would get their badges and the badges of other students to achieve better results in the course than students who can only see their badges [11].

This study aims to investigate how gamification affects students' learning outcomes in terms of how well they perform on exams, quizzes, and assignments as well as how satisfied they are with their education. To assess the combined impact of group size and gamification, these measurements will be made after including various group sizes in various classes. This study can shed light on several overlooked topics in the literature, such as the ideal class and group sizes, the effects of gamification on computer science instruction in higher education institutions, and the evolution of gamification [14].

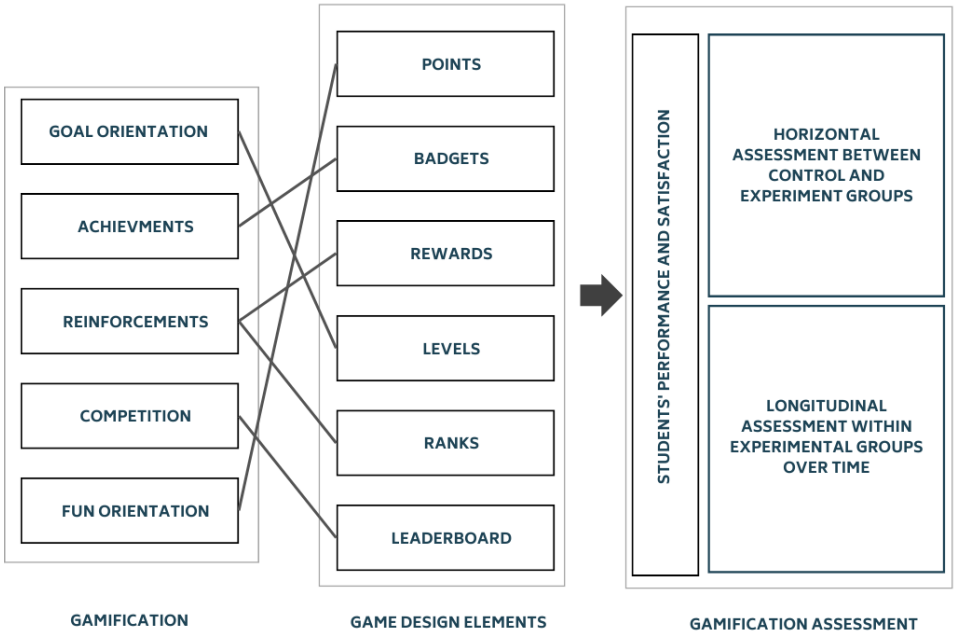

Figure 1: Proposed gamification framework [2]

Particular attention was paid to distinguishing gamification activities from group work to prove causation between the gamification setup and its results, as well as to rule out the possibility of an alternative explanation. Only activities that can improve participants' feelings of group belonging were used for this goal. This involved group discussions in class and the weekly display of group status based on grades at the start of the first class. The teacher used to give each group a separate topic for the class discussion exercise, and the group members were expected to submit a brief report on it after 10 minutes of unsupervised group discussion on one side of the classroom. Before the following group discussion, the reports were graded, and the group performance results were made public. Additionally, each week, a graph comparing all the groups in the class indicated the group standing based on the combined scores of all the group members on various graded assignments, such as quizzes, assignments, and examinations. No comparison or leaderboard for the individual students was kept in any of the group settings; just the whole group was kept.

4. Results

Learning through gamification does not always produce good results and is not always effective. Some authors note that the use of gamification in learning can be a double-edged sword [1]. For students who are interested and motivated to learn, gamification has a positive impact on their motivation [1]. In recent times, due to the use of media, learning foreign languages is becoming easier. There are different learning methods, such as learning with images, sound, video, text, animation, and video games. Game design has a significant impact on the overall user experience in the learning process. Learning through mobile devices and wireless technology facilitates learning in different locations. Learning foreign words through playing games makes them easier to remember. Digital technologies are especially important to younger students, who, through playing games on mobile devices, unknowingly learn and improve their skills. Learning through apps produces better results than traditional methods, especially among children of younger ages [4].

Challenges should be included in game-based learning, but some participants' research critiques ways of designing and implementing challenges in games. Challenges create a fun environment, but also when repeating the same structures and levels of ease can be boring for the participants. Participants prefer to click on one of the offered options rather than to write a response, they also prefer to have the rules explained to them via an audio recording rather than in writing.

Studies showed that students whose learning was based on games had better results on practical tests compared to theoretical tests and they were less engaged in class activities [9]. One of the proven hypotheses showed that the performance of students is much better in game-based learning than in traditional learning. The results of this research show that game-based courses can have additional benefits for students if they fit into their lifestyle (students who have jobs) and students' motivation [9].

Despite the listed expectation in the proposed framework section, it turned out that students who could see only their badges were more motivated than students who could also see others' badges. The results of this research showed that badges neither increase nor reduce the motivation, activities, and results of students taking a certain course [7] [11].

This research did not take into account the connection between the player profiles of the learners and the examined game mechanics. Results of an experimental investigation demonstrate that adaptive gamification can, in comparison to counter-adaptive gamification, greatly increase the involvement of learners who use the environment the most frequently. In addition, experimental findings imply that user motivation and user involvement are two aspects that can be independently modified by various game elements [10]. Furthermore, some participants criticized the scoreboards because they believe they create a competitive environment while, on the other hand, many participants like the presence of results tables for this very reason [12].

Finally, studies found that levels of motivation and participation fluctuate significantly depending on the assigned attributes. This suggests that the effects of the features that have been included vary depending on the game mechanics: some have an immediate effect on motivation to use the learning environment, while others have an indirect impact on time spent. For instance, if a student wants to beat their best time, the timer motivates them to restart the current level and practice for longer. Another illustration of how the recommendations make the exercise more relevant is by giving students a way to assist other students [10].

In conclusion, results show that individual student performance in gamified environments is statistically significantly higher than student performance in traditional environments, according to the results. According to the test results, small-group students perform statistically significantly better in the gamified setting than they do in the traditional context. According to the test results, large groups of pupils perform statistically significantly better in a gamified setting than they do in a non-gamified environment. The sum of these metrics reveals that in all three group situations, students in gamified sections fared statistically considerably better than those in non-gamified sections. Gamification can be utilized to improve learning results in conventional classroom settings, but for this new technology to be most useful, a comprehensive analysis of the gamification components and their impacts is required [14].

5. Conclusion

Based on the analyzed texts, it was concluded that effectiveness was not proven in all cases of applications of gamification in learning. Most research has shown that the effectiveness of the applied learning method depends on the student himself, therefore that it is individual and varies depending on the courses and students [10]. In light of this, there is general agreement that gamified learning must be customized, that it must take into account how different students are influenced by it, and that it must consider the effects of gamification on the many profiles that make up the class.

So far, it has been established that there are positive implications for the future of alternative types of learning, but whether there will be a complete replacement of the classical type of learning with another, remains to be seen. Some of the advantages of this type of learning compared to the classical one are: it is not monotonous, it is more interactive, students become interested more easily, students have greater motivation, and learning is enabled at a distance. Based on the analyzed articles and presented work, it was concluded that the use of virtual reality is not a researched topic. Virtual reality has great potential to bring improvements to the educational system (especially in areas such as medicine, architecture, and construction), and therefore, it is necessary to focus a lot of attention on its study and use for educational purposes. The consensus among academics is that integrating game aspects into the classroom requires a closer examination of their advantages and disadvantages, rather than viewing gamification as the magic bullet for education [6].

In addition to verifying the research findings by integrating control and experimental groups, this study also evaluates the impacts of gamification and group size over time. Future research should take steps to customize and digitize gamification environments. To improve users' behaviours, gamification settings should also include additional game aspects, such as gameplay. It can be fascinating to investigate how different gamification components affect various group sizes. There is certainly room for more research into how gamification affects seminars, distance learning, and crash courses [13].

Additionally, as the results of the direct study in the computer science field showed, through empirical analysis, it has been found that in all three group situations, gamification has increased students' learning outcomes in the form of grades. Furthermore, it has been found that larger groups exhibit greater grade improvement than individuals or small groups. However, the performance of students in large groups did not improve over time, which casts doubt on the usefulness of gamification as a long-term learning technique in such settings. Moreover, this performance degradation may also be related to the challenging exam questions in one of the instruments. The students' satisfaction levels increased in individual and small group settings, but not in large group settings. Also, there was a significant association between students' happiness levels and their grades [14].

Finally, the use of games in learning is usually based on the possibility of learning difficult topics to investigate with traditional methods. This difficulty is often caused by the limitations that arise due to the nature of the topic itself, time constraints of traditional methods, or practical problems related to real-life experiences that are difficult to explain in classrooms through traditional lectures. There is still room for research into the use of learning methods based on games in some areas, such as software quality, software modeling, and analysis [15].

Future studies should target graduate students and concentrate on teaching the least-taught programming principles using games. Additionally, when creating the game's stages, designers should take the user's past knowledge and skills into account. It is necessary to research to determine how gamification is affected by factors such as age, gender, resource person knowledge, and users'

fundamental analytical and mathematical skills. To more accurately analyze the games, the evaluation techniques should additionally take into account gameplay statistics and observations. To verify this study, we suggest that further research involving more student participants be conducted across different education contexts [16]

6. References

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Virtual Reality Environments used for e-Learning

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Abstract
This paper discusses Virtual Reality and its features limited to applications in education and e-learning. This work talking about the types of Virtual Reality environments and their development in learning. There are areas in education where this technology is more prevalent, such as physics and medicine. Paper also talking about virtual museums and the motivation of students to learn in this way. Of course, there are also all the advantages and disadvantages of this technology, as well as assumptions for progress in the future.
Keywords
Virtual Reality, VR, VR Environment, e-Learning, VRML

1. Introduction

The popularity of the Internet as a source of information is constantly growing. More and more online services are now available such as online banking, e-government, e-learning and e-commerce. Today's age of modern technologies and globalization brings rapid changes in all aspects of human life. New information is created every day, and general development continuously requires new knowledge and skills. There is a need for faster, more timely education, which will be open, broad and accessible at the same time.

E-learning is an interactive or two-way process between teachers and students with the help of electronic media, where the emphasis is on the learning process, while the media is only an auxiliary tool that completes that process. Today's technology trends play a major role in both influencing e-learning and offering entirely new ways to share knowledge and deliver content. Some of the technologies that raise e-learning to a higher level are: Artificial intelligence, big data, machine learning and virtual reality [1].

2. Virtual Reality

Virtual reality is a computer technology that uses a virtual reality headset or multi-project environment, sometimes in combination with props or a physical environment, to create realistic sounds, images and other sensations that promote the user's physical presence in an imagined or virtual environment. As it has proven to be very functional, the applicability of virtual reality has become huge and it has certainly become one of the more popular technologies in e-learning. For now, the most noted applications are in the fields of medical training and physics, where it stands out the most.

The main advantage of this technology is that it can transport students to the farthest corners of the universe in the blink of an eye and surround them with an engaging and deeply educational environment. Improved motivation for learning is also a very important factor and we can consider it even the biggest advantage, considering that it raises the level of motivation of students. This way they will no longer be stuck with pages of boring text, bullet points and illustrations, but will have the opportunity to really go through the experience and get the most out of it instead.

Virtual reality has great potential in the future. Although it peaked in video games, VR is expected to go beyond that, including areas such as training and education, as well as VR movies, sports and

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music. In order for the use of virtual reality in e-learning to be possible, first of all, a large number of experts who use programs and platforms adapted to this technology are needed [2].

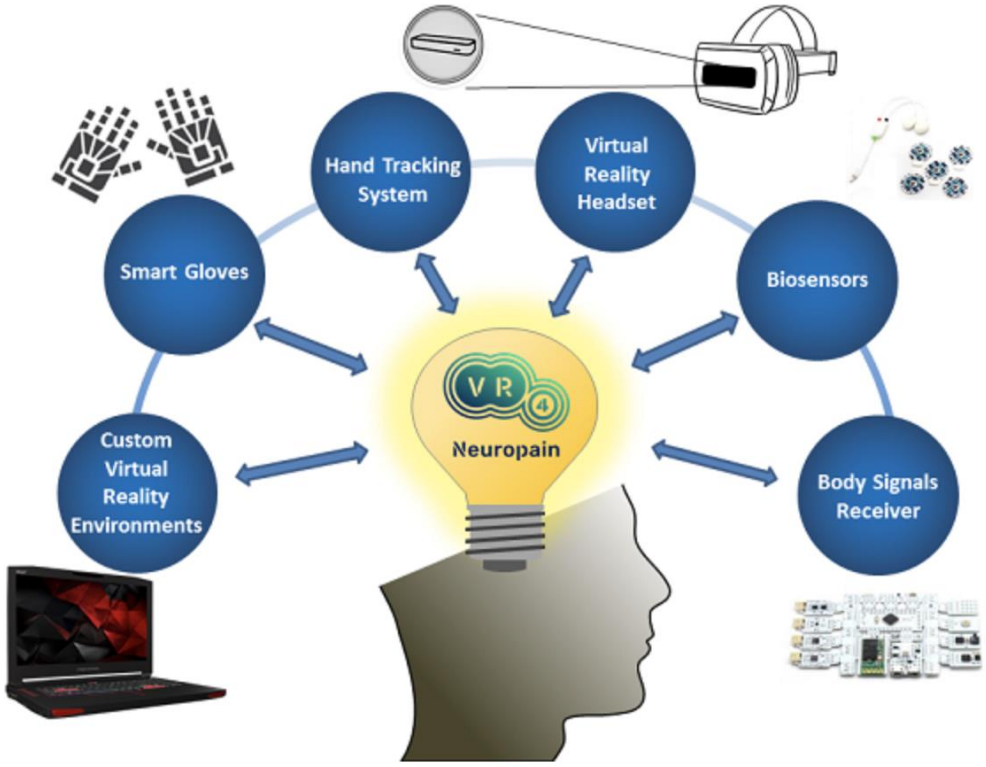

Figure 1: Virtual Reality system

Modern education often requires students to understand complex concepts or to read some frames and situations that no longer exist. It provides interactivity by responding to the movements and natural behavior of people in the real world. In this regard, VR can prove to be a powerful resource that can assist in teaching by providing an environment that allows the student to experience scenarios and situations rather than imagine them.

Children learn through activity all their lives. With little control over his limbs, the process of learning about the world begins with exploration by reaching, touching, looking, smelling and tasting everything around him. By combining all the senses, the child begins to associate different features with different objects and through memory can form different categories and concepts from the seemingly different and chaotic signals it receives from the world. Even in adulthood, perception and activity are crucial to learning.

The five senses of sight, hearing, touch, taste and smell provide different information for different purposes. We focus on vision, touch and audition as these are the senses that are primarily used in virtual reality. Of all the senses, sight is the most versatile and provides us with a wide range of information about ourselves and our environment.

Audition can also be used for spatial perception as well as recognition and communication. For spatial perception, sound cues involve interaural changes in loudness and pitch. For example, one is able to localize sound in the horizontal plane by differences in sound intensity between sounds reaching two ears. Properties of objects can be derived from two sources: skin sensation and kinesthesia. It is customary to use the term haptics instead of touch to refer to the use and study of both of these sources of information [3].

In everyday situations, action is associated with changes in sensory input in the form of a perception/action loop. Our brains are adapted to take advantage of this coupling by making predictions

about what will happen given certain input and what responses are appropriate. One evolutionary advantage of this coupling is that it responds more quickly to rapidly changing events because it reduces the involvement of cognitive effort, which is relatively slow. Another advantage is that it allows for more concrete construction of the concept and thus facilitates learning.

Virtual environments offer a lot of potential, use impressive technology, engage human perceptual and kinesthetic abilities in ways impossible with other techniques. They offer the ability to practice a task in the virtual world in such a way that skills can be transferred to the real world as well as the opportunity for richer engagement to apply and communicate with other users. A virtual environment (virtual environment - VE) is usually described as a form of human-computer interaction (HCI - human-computer interaction) consisting of computer-generated visual and audio simulation in three-dimensional space (i.e. 3D graphics), in which users have interactive experiences (ie they communicate with each other and/or have the ability to react to experiences in the environment or even the ability to change those aesthetic experiences of the environment, such as controlling the movement of the avatar or changing some feature of the environment). It is often called virtual reality, virtual landscape, virtual space or virtual world [5].

As human beings, we base our perception of the world on rules developed by our experience. We believe in what we see, hear and feel. VR designers use the basic rules of perception and ideas about how we interact with the world to create an environment that is as authentic as the world around us.

VR devices are, in fact, just machines created to replace our environment with something created in software. They contain gyroscopic sensors, accelerometers and magnometers that determine how you move and track your reaction with virtual space. The devices also connect to external cameras and computer systems to access VR experience software or connect to additional programs.

Today's VR technology is constantly evolving to offer new, more immersive experiences. Currently, the most impressive VR experiences are built on the following functionalities: field of view and frame rate, sound effects and head tracking.

The human field of vision is still significantly wider than what VR devices can provide. The average person can see about 220 degrees of the content that surrounds him, while VR devices provide only 180 degrees. Aside from field of view, frame rate is the visual element that defines VR. Experts believe that the human eye can handle up to 1000 frames per second. It is considered that anything less than 60 frames per second causes disorientation and nausea, so in VR technology we try to achieve at least 120 frames per second. Spatial sound lets you simulate the unique kind of scenery you'd expect in the real world. It also helps the user navigate through the VR experience the way the developers intended, showing you where to turn and supporting a sense of realism as you move through different environments and experiences.

The third functionality, tracking the head position, allows the user to move in the virtual space while the environment adapts to your position. Head and position tracking functions are measured in degrees of freedom. VR devices that use 6 degrees of freedom can check your position in the room and show the direction your head is pointing. Sensors outside the VR device can help you stay safe while moving around the room.

VR technology is becoming more and more impressive. VR devices are becoming sleeker and more mobile, with fewer wires and more pixels. Haptic sensors and tracking gloves are replacing clumsy control systems, while machine learning and the development of artificial intelligence are changing the way VR technology tracks our interactions. From a technical perspective, VR is a simple concept made up of connected wires, screens and computer systems [15].

3. Types of Virtual Reality Environments

There are many types of Virtual Environments, but some basic division is into:

1. Multi-user distributed Virtual Environments – mDVEs
2. Collaborative Virtual Environment systems - CVEs
3. Immersive Virtual Environments

3.1. Multi-User Distributed Virtual Environments

Multi user distributed VR refers to a specific type of Virtual Environment in which the user, represented by a digital avatar, has the ability to interact with the environment and other users, also represented by avatars.

MUVEs are used in education to create online communities for pre-service teacher training and professional development, engaging in science-based activities while promoting socially responsible behavior, and helping students understand and experience history by immersing them emotionally and politically in historical context, promoting social and moral development through cultures of enrichment, providing an environment for programming, creative exploration of new mathematical concepts, and engagement in scientific inquiry [7].

3.2. Collaborative Virtual Environments Systems

CVE systems are distributed virtual reality systems that offer graphically realized, digital landscapes, potentially infinite. Within these landscapes, individuals can share information through interactions with each other and through individual and collaborative interactions with data representations. Virtual environments offer the potential for great flexibility in how landscape(s), data, and individuals are represented. For example, representations of data or individuals can use sophisticated 3D graphical representations, be 2D "flat" representations, or simply be text streams pasted onto a plane [8].

3.3. Immersive Virtual Environments

Immersive Virtual Environments (IVEs) provide a tightly coupled human-computer interface: input to the human participant's sensory organs is directly generated via computer displays, in visual, auditory, tactile and haptic modalities. The participant works in an extended virtual space, created by the interaction between the human perceptual system and computer-generated screens [9].

4. Development of Virtual Environments

Recently, various higher education courses have appeared, which partially solve the issue of designing virtual environments. It is important to note that most courses are organized within the faculties of IT, Art, Design and Architecture. Although the existence of these courses confirms the previously identified need to educate people in the design and development of 3D interactive content, the knowledge they offer is still seen as a supplement to traditional architectural or computer education.

4.1. Design of Virtual Environments

Interactive modification of surface representations can allow designers to perform modeling of objects and surfaces and therefore the design of real environments while immersed in a virtual environment. By modeling and designing while in the virtual environment, designers can approximately experience the approximate result of their design in real time while actually manipulating elements of the virtual environment. In this way, designers can carry out the modeling process while being in very direct contact with the model.

Virtual environments are by definition built on the principle of imitating the spatial experience provided by real environments. People experience virtual environments as a kind of three-dimensional space that includes several objects and events, which do not necessarily have a duplicate in the real world. The synthetic environment defined by these objects and events is a setting, which can accommodate human activities such as: navigation, interaction and communication [11].

4.2. Virtual Reality Modeling Language

To develop an interactive virtual environment, it is necessary to use 3D modeling, VRML (English Virtual Reality Modeling Language) and now X3D (successor of VRML). Today, VRML is mainly used to display static 3D models. Maintaining compatibility with VRML, among the usual options for displaying 3D and 2D static and animated graphics, it is possible to place sound and film as parts of the scene, then "sensors" and hyperlinks to other objects, whereby their interactions can be controlled by scripts within the file itself. Currently ECMAScript (JavaScript) and Java are supported for this purpose. It is also possible to assign physical characteristics to objects [11].

4.3. eXtensible 3D

Instead of focusing on specific problems that surfaced, since in some parts the specification remained vague or ambiguous, which led browser manufacturers to seek solutions at their own discretion and thereby deviate from the standard which is not defined in that part, in order to catch up with the general XML-ization on the Web. The main goal becomes the elaboration of an XML syntax for VRML. The characteristic of X3D is that, in addition to being able to be created in classic VRML code, X3D also uses XML to display VRML forms. Based on the XML language, X3D allows easy creation of reading and writing tools, as well as great extensibility [11].

4.4. Scripting Language

A scripting language is a programming language that is executed by interpretation. It is most often used for writing small programs (scripts). Scripts are quick to write and are used to perform small tasks. Because of their portability and ease of writing, scripting languages have become popular in web programming. The three basic types of scripts are: Connection scripts, movement scripts, and activation scripts. [11]

4.5. Avatars

Avatar represents the embodiment of the user or the so-called alter ego of the user in the two-dimensional and three-dimensional world. Avatars are used in computer games, on Internet forums and other places. The aim is to create a perfect avatar model as it will be a representation of the user both in a video game and in a virtual world [11].

5. Application of Virtual Reality in e-learning

The application of VR is very widespread, but if we stick to education and e-learning, the application areas can be applied to:

1. Application in schools and colleges
2. Virtual museum
3. Use for training (children or adults)

There are also smaller sub-areas of application, but we will stick to these basic ones.

5.1. Application in Schools and Colleges

The virtual world combines interactive 3D graphics, technological simulation, technological reality, Internet telephony or Internet voice transmission to provide users with unlimited ability to communicate, collaborate and explore. During the development phase, virtual environments were mainly based on the gaming community and over time they were adapted to meet the needs of the increasing number of educators connecting using virtual worlds for course delivery.

Environments in virtual worlds can be used as a digital classroom, a virtual place to hold a lecture, which can look like a traditional face-to-face lecture. It is clear that virtual worlds can be used in a variety of innovative ways. Virtual worlds can also provide an environment for role-playing activities aimed at immersion in the assigned role and visually seamless 3D simulation. Some of the most popular virtual worlds are Second Life, Active Worlds and There [2].

VR applications in schools and colleges can be divided into two categories. The first category is where teachers use pre-developed applications. The second category represents applications in which students themselves build virtual worlds to test hypotheses. Pre-developed applications consist of a virtual environment, supporting software and hardware in which students perform the required task.

Previous implementations include MaxwellWorld. MaxwellWorld has great applications in sciences such as physics, by teaching students about electrostatic forces and electric fields by allowing them to position electric charges and see and interact with the resulting electromagnetic field.

There is also Atom World which has been used to help students learn about atomic and subatomic particles and PhaseWorld used in chemistry to teach students about changes in state of matter and how this depends on volume and ambient temperature and pressure. VR has technology where students make changes to planets etc. to answer specific questions. They have also developed a virtual gorilla designed to allow students to reproduce the movements and behaviors of gorillas placed within the appropriate habitat. Other areas where VR techniques are actively applied for educational purposes are cultural heritage and archaeology. For example, Learning Sites has developed numerous desktop systems for researching archaeological reconstructions of buildings and sites in Europe and the Middle East [3].

5.2. Virtual Museum

Figure 2: Virtual Museum

The development of the Internet, multimedia technology, databases and other information and communication technologies have enabled the existence of virtual museums. Digital technology has introduced changes in the way museum collections are preserved, and thus also in the way they are

displayed. X-ray imaging and 3D laser scanning are some of the modern ways of scanning museum exhibits that have enabled their display in virtual space.

Digitization of museums is a joint project created by joining forces and finances of museums, cultural institutions and governments around the world. The goal of the project is to preserve heritage and create new sources of information, and thus knowledge.

Virtual museums consist of a collection of digitized images, drawings, photographs, sound and video recordings, newspaper articles and various museum objects that are not connected in the physical world by the place where they are located, but are somehow connected to the context of the real heritage to which they refer.

A virtual museum does not have digitized exhibits and that is precisely why it differs from a museum in the traditional sense. In addition to viewing and searching for URL addresses found in virtual museums, the visitor is also enabled to add content to the virtual museum and thereby participate in the creation of the virtual museum. Students and pupils are frequent visitors of virtual museums, and in addition to visiting them, they also create their own virtual museums.

Within the creation of the interior of the museum, different types of elements were used, which created a workspace where all the necessary elements for its functioning are available. Also, visitors can be represented in these virtual museums through animated 3D characters (avatars) [13].

5.3. Training

The final and most prevalent field of application of VR in education that we will mention is training. We could consider training as a special case of education because it usually involves teaching specific knowledge related to manual tasks rather than general knowledge. VR training provides a safe environment for training tasks that would otherwise be impractical or even dangerous to perform in real life. VR training has been applied to the general fields of transportation, medicine, engineering, and military and security [3].

5.3.1. Transportation

When it comes to transportation, the application of VR started a long time ago. Transport Flight simulators were one of the first applications of VR technology. Modern VR flight simulators use high-resolution computer graphics that provide a 180-degree field of view, real instrument panels, and movement platforms that have translation and rotation capabilities. These motion platforms provide motion cues that are correlated with auditory and visual events providing highly realistic feedback.

Specific simulators are now used for specific types of aircraft that allow training and retraining of commercial pilots when transferring from one aircraft to another and databases of real airports around the world giving realistic take-off and landing scenarios. Pilot training is expensive from both a financial and environmental perspective, as well as dangerous. VR simulators therefore provide a commercially viable and safe alternative and can be used to prepare pilots to handle demanding and dangerous situations that would be difficult if not impossible to perform in the real world.

VR simulators are also used in other areas of transportation. For example, driving simulators can be used to train people to drive cars and to deal with specific driving conditions, including fog and heavy rain. These simulators are similar to flight simulators in that they can be placed on real cars that are on a moving platform to provide feedback. A number of car manufacturers are adopting this technology [3].

5.3.2. Medicine

Like pilot training, medical training is an expensive process and involves risk to patients. Conventional medical training therefore required students to use cadavers in the initial stages of, say, surgical training, followed by long sessions of supervising qualified surgeons performing a specific task.

Surgical training has benefited most from the development of haptic feedback devices that provide a realistic sense of control and manipulation of soft body tissue. Most of the development of VR in medicine is in the training of a new range of non-invasive or minimally invasive endoscopy techniques.

Endoscopy has many applications including laparoscopic, thoracoscopic and hysteroscopy. The method involves an indirect approach to the operative part and therefore causes many disadvantages for the surgeon, including limited vision and difficult hand-eye coordination and handling of instruments with limited mobility. Surgeons require a lot of training and experience to perform surgery successfully and safely.

These systems are usually of the desktop type where real endoscopic equipment is used with video camera power being replaced by a computer generated display. The computer display shows simulated body parts, tissue membranes, organs, etc. New developments include attaching an endoscope arm to a robot arm that provides haptic feedback. The endoscope thus becomes a haptic end effector that provides tactile feedback when the simulated instrument comes into contact with the internal surfaces of the simulated body. Again, this multi-sensory simulation increases the realism of the display and enhances learning by providing interactive control [3].

5.3.3. Military

Of course, a large area of application in training is for military purposes, primarily because it allows us to introduce the application of a multi-user 3D environment. These multi-user systems are otherwise known as distributed interactive simulation. DIS is a standard for running multi-platform real-time wargames using computers distributed around the world, and is especially used by military organizations. The standard was developed through a series of workshops at the Interactive Networked Simulation for Training symposium. The standard was created based on SIMNET's distributed interactive simulation protocol. SIMNET could potentially handle hundreds of online players and while realism, in the form of high-fidelity graphics, was not available, realistic interaction between 10 or even 100 participants was possible. For military purposes, the benefits are that users benefit from role-playing, planning and operations in a more secure environment. [3]

6. Adventages and disadventages of Virtual Reality

The advantages of using virtual environments in e-learning bring different possibilities. In virtual environments, students, even though they are geographically distant, do not have this barrier. The possibility of various simulations and training was provided so that students could experience firsthand how something works.

Interaction is at the highest possible level. Different forms of communication are provided, chat, live audio and video are present. Socialization is one of the primary goals and the ability to share content is of great importance. Different forms of work allow you to get to know your colleagues better, and in this way you get an insight into different solutions and different opinions on a given problem. Emphasis is placed on collaboration and cooperation.

Another advantage of using virtual environments is learning through play. The use of computer games and games in general for educational purposes offers different presentations of knowledge and creates opportunities for basic knowledge in the virtual world, thus supporting and facilitating the learning process.

When it comes to the disadvantages of applying virtual environments in education, one of the main disadvantages is the necessary access to a computer and the Internet, as well as the problem caused by insufficient knowledge of the technology to access virtual environments. Students may feel that they

will not be able to achieve good results due to insufficiently invited technologies and may try to avoid using such technologies and tools.

Also, one of the disadvantages is the loss of human contact, body language (non-verbal communication) and the appearance of misunderstanding. Although the student will communicate through the avatar, it cannot be expected that the avatars will behave as we do in the real world, that they will make the same gestures and behaviors. Although some students have good written communication and test-taking skills, there are always students who will miss the absence of face-to-face oral exams.

The biggest disadvantage is the isolation from the real world, where the user of the virtual environment relies more on the interactions that take place in the virtual world than on the experiences in the real world [4].

7. Conclusion

In the future, we will increasingly expect the merging of real and virtual environments in order to develop virtual environments to support learning. The main goal is to achieve cooperation with as many remote users as possible, and this will be achieved by bringing the virtual and real environment closer together.

The Virtual Environment provides support for audio and video, animations, hyperlinks and other types of data. In a virtual environment, benefits are not limited in time or space. Virtual environments are for creating, publishing and working. With the accelerated evolution of highly sophisticated computers, communications, services and production systems, a major shift has been made in the way people use and work with technology.

While the Internet and other digital technologies continue to evolve, the evolution itself is happening so quickly that it is difficult for both scientists and IT professionals to keep up with the latest developments in digital domains. The field of virtual environments emerged about 40 years ago as an extremely expensive technology whose use is difficult to justify.

The term has been defined and redefined by scientists, humanitarians and everyday users. Large differences in time and space are one important attribute for defining virtual environments. The term virtual environment itself can refer to a web-based management space, learning management content/applications, or a three-dimensional social virtual world, a massively multiplayer online world, or just a virtual reality environment.

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An Approach to Studying Impedance of a Series *RLC* Circuits

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Abstract
The paper presents one of the educational approaches to the study of impedance and resistance in alternating current circuits, a *RLC* circuit in particular, having a resistor, capacitor and coil connected in series. The possibility of using digital simulation and the way in which students can independently discover the laws of impedance dependency on the frequency of alternating electric current are presented. Being involved in independent activities, students construct *RLC* circuit models, choose the values of the capacitance of the capacitor, the inductance of the coil, the resistance of the resistor and the frequency of alternating current. The range of frequencies that can be selected enables the detection of frequency change and extraction of the value at which a resonance in the serial RLC circuit occurs. In addition, the paper informs about alternative concepts with which students study the topic of alternating current and the effects that arise from the educational approach with up-to-date digital technologies described in the paper when conceptual change of knowledge is explored.

Keywords
Digital Simulation, *RLC* Circuit, Impedance, Educational Approach

1. Introduction

Availability of information technologies ensures overall modernization of the teaching process. Digital contents become part of curricula in general within many teaching programmes. Exploring the available literature it is noticeable that students very often construct their knowledge based on intuitive prediction, or that they draw certain conclusions using mathematical formulas, when they show great skills in using the maths operations. However, sometimes students fail to grasp full understanding of the explored phenomenon. Teaching content described in this paper is not detectable by senses in everyday experiences. Teachers, apart from curricula, include occasionally digital contents in their lectures and exercises. Often, those contents provide learning by exploration and are conducted with working in digital labs. In this paper, an overview of digital contents for learning impedance and resistance in an AC (alternating current) circuit is given. Several interactive simulations, appropriate to be applied at almost any level of education, are described here. Also, it is suggested here that these digital labs, can help students to better adopt reasoning and skills in physics and electrical engineering, even when math knowledge is arguable.

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2. Theory Considerations

Serial *RLC* circuits consist of a resistance, a capacitance and an inductance, that are connected in series and to an AC power source. The listed element are presented in Figure 1.

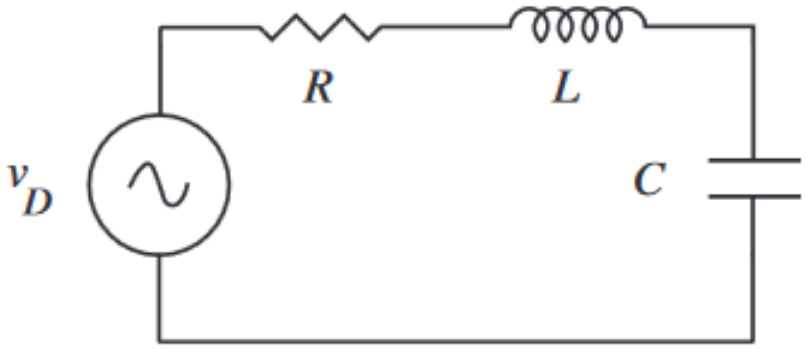

Figure 1: A *RLC electric circuit with resistor, capacitor and coil connected in series*

The impedance of a resistor is a real nonnegative number and the impedances of the inductor and capacitor are complex or rather pure imaginary numbers. The total impedance of the circuit shown ih Figure 1. is a sum of these three impedances and is, therefore, a complex number.

Expression of Ohm's law and effective voltage values of a resistor, coil and capacitor of a serial *RLC* circuit are:

$$V_R = IR\,, \qquad V_L = IX_L\,, \qquad V_C = IX_C \tag{1}$$

$$V_S = \sqrt{(IR)^2 + (IX_L - IX_C)^2}\,, \tag{2}$$

$$V_S = I\sqrt{R^2 + (X_L - X_C)^2}\,, \tag{3}$$

$$V_S = IZ\,, \qquad \text{where} \qquad Z = \sqrt{R^2 + (X_L - X_C)^2}\,. \tag{4}$$

For an ideal resistor the voltage and current waveforms are "in-phase". While for an ideal inductive load the voltage waveform "leads" before the current waveforms by 90°. And for an ideal capacitor the voltage waveform "lags" behind the current by 90°.

The phasor diagram of a serial *RLC* circuit is drawn in figure 2.

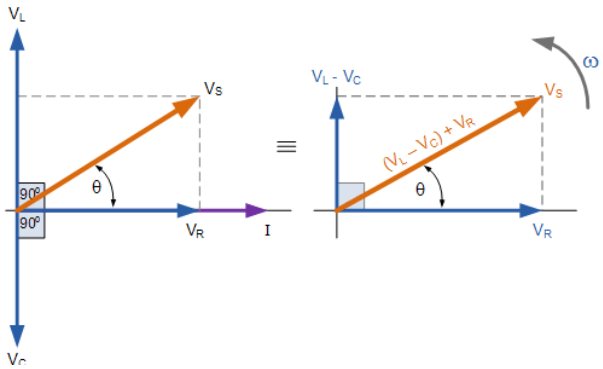

Figure 2: The phasor diagram for a serial *RLC* circuit

It is formed by combining the phasor diagrams of a single resistor, coil and capacitor (as shown in Figure 2). To create that drawing, it is necessary to establish dependences and relations between voltage and current of a resistor, capacitor and coil elements.

3. A *RLC* Circuit by E-Learning

The importance and gain from using various simulations can be successful compensation of the lack of real lab practice and absence of appropriate equipment, which is often too expensive for education institutions. Which simulation shall be used depends on the teacher's goals and accompanying factors within a certain group of students. However, keeping in mind that students learn the most when they are active, it is viable that, alongside adequate activities for each set goal, a digital simulation of a real physical system is chosen, or that their usage, to a certain extent, is combined. In any case, the basis of planning process should be adequacy and methodical justification. Here a three simulation applications are described and applied in teaching about a series *RLC* circuit.

3.1. Circuit Construction Kit: AC

PHET simulation of an AC circuit provides its construction by adding certain electrical or electronic components and elements, such as: wire, AC voltage source, resistor, capacitor, switch, coil or inductive load, voltmeter, ammeter, voltage chart, current chart, stopwatch, electrons, conventional direction of current flow, etc. (see Figure 3.).

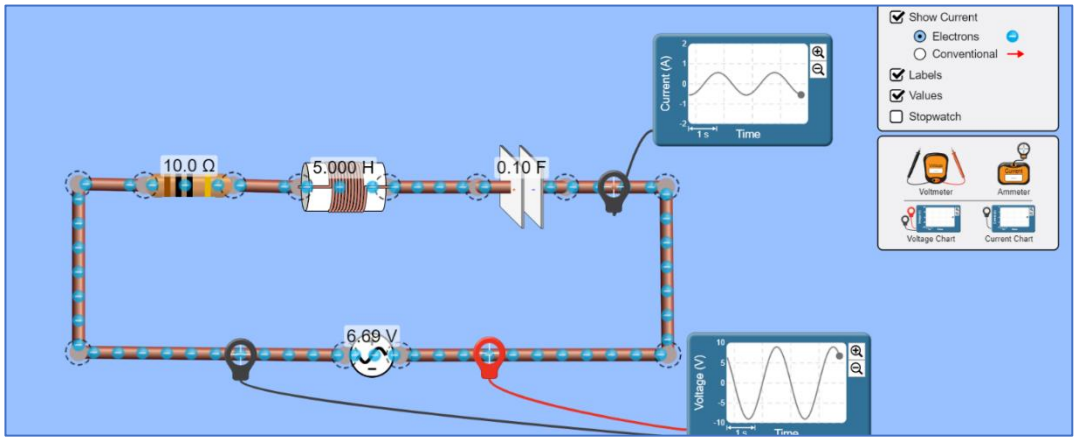

Figure 3: AC Simulation on PHET Interactive Simulations

In this environment the movement of the electrons is clearly visible. This visualisation is significant for understanding the term “alternate current”. However, in the realized simulation, accurate and precise positioning of elements is required, especially conductors. Determining the equivalent impedance or resistance can be reduced to calculating it, therefore it is important to know where the voltmeter and ammeter are to be placed. This lab simulation allows students to become understand how voltage and current are measured directly, and also how resistance is measured indirectly. Students can learn to recognize all important elements of a circuit, as well as the relevant relationships between voltage, current, and resistance.

3.2. A Serial *RLC* Circuit – Java Lab

Nowadays there are many open access or free-of-charge simulation applications for interactive learning of science. One of these which is written in JavaScript, simulates various natural phenomena, including problems in Physics, Chemistry, Astronomy, Biology, Mathematics and similar.

A Serial *RLC* Circuit simulation provides measurement in a previously built AC circuit. Certain physical quantities values are being selected using a slider in the simulation application within available range. The advantage of this simulation is the simultaneous visualisation of the three voltage phasors of all three circuit’s elements. Determining equivalent impedance or resistance is reduced to its calculation, or reading the value using option “equation” on lab-menu (presented on Figure 4).

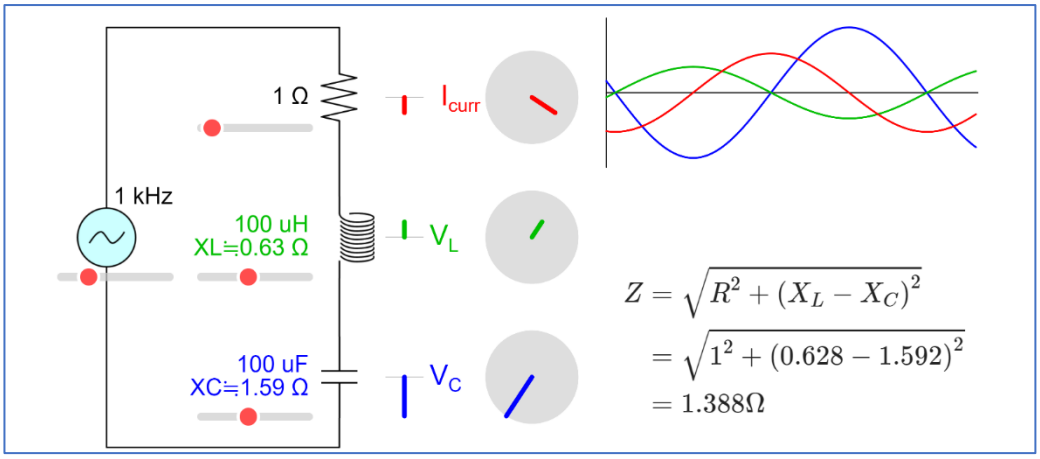

Figure 4: The simulation of Serial *RLC* Circuit in Java-lab application

3.3. Combinations of Resistors, Inductors and Capacitors on Apps for Physics - Walter Fendt

One of the authors of this article, from the methodical point of view, favours Walter Fendt's simulation, whose exploit has shown that students learn the most using this application, while being more motivated for learning when compared to other mentioned options.

In order to successfully finish lecture tasks regarding impedance and resistance in an electric circuit it is necessary to understand the concept of direct and alternate currents (DC, AC), as well as off characteristics of resistors, capacitors and (inductors. To add ti this it is important to know correct ways of measuring voltages and currents. However, an approach is also feasible, when essential properties of circuit elements can be discovered and studied precisely through their behaviour when they are connected in arbitrary way. This is a complex demand, but its importance lies in the fact that it encourages curiosity, asking questions and exploring deeper into observed phenomena.

To build a flexible knowledge regarding resistors in certain types of the electrical circuit, it was possible to model the circuit using specific types of components, tuning their parameters and it was available to choose their connections. This way overall circuit performance was digitally simulated and equivalent impedance and resistance were observed and used.

This virtualisation of the measuring process, and how the simulation looks like immediately after its start, is clearly shown in Figure 5.

The interactivity in the use of this simulation is made possible by choosing voltage values (the desired value is entered in the appropriate field), frequency values (the desired value is entered in the corresponding field), adding circuit elements - ideal resistor, ideal inductor and ideal capacitor (it is possible to add more than one of these elements). By choosing the numerical values of the appropriate quantities - the electrical resistance of the resistor, the inductivity of the inductor, the capacity of the capacitor, and by including the voltmeter and ammeter in proper places of the circuit, the simulation can be started. For the selected values of physical parameters and for the chosen topology of the *RLC* circuit constructed in the simulation window, it is possible to read the values of electrical quantities - voltage, current, complex impedance, impedance, phase angle. It was discovered that placing the ammeter and voltmeter in the proper places within the circuit is a tedious task due to numerous actions and recording the results.

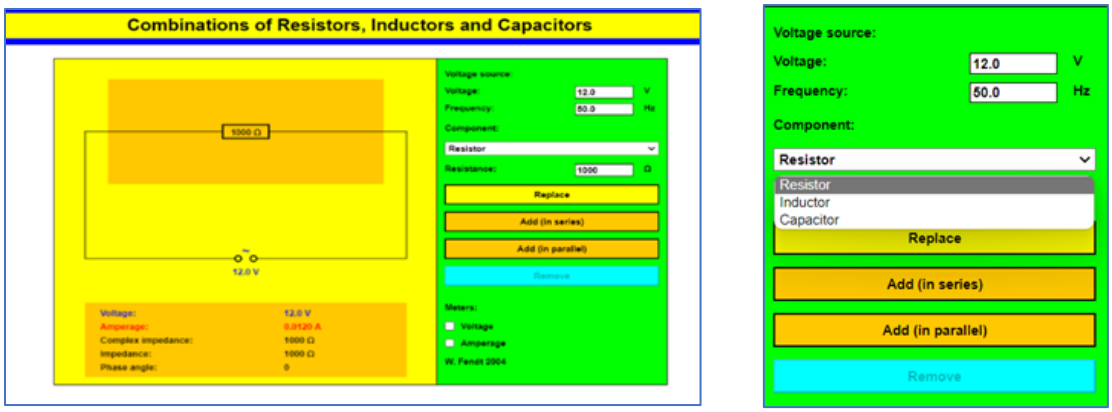

Figure 5: Combination of Resistors, Coils / Inductors and Capacitors on *Walter Fendt's simulator*

After the students explore menus of graphical user interface and become familiar with the possibilities of simulation, they start with their laboratory activities on the formation of a serial *RLC* circuit. Students observe what happens when the frequency of alternating current in the serial *RLC* circuit is changing. For that task, it is necessary to record the values of certain chosen parameters and quantities, according to the Table 1.

Table 1

The values for *RLC* circuit elements

Frequency [Hz]	Resistance [Ω]	Inductivity [H]	Inductive Reactance	Capacity [μF]	Capacitive Reactance	Impedance	Complex Impedance
50	500	2		1			
60							
70							
80							
90							
100							
110							
120							
130							
140							

The change in the teaching approach that occurred during the online classes was the omission of questions which students would have to answer. Instead, the aim was shifted to require that each Student should independently reach a conclusion by analyzing the data obtained either by simulated measuring or by calculating. After discovering and concluding that the equivalent impedance of the serial *RLC* circuit will increase with increase of frequency up to a certain maximum value and then will begin to decrease with further increase in frequency, Students need to explain the precise cause of this phenomenon.

When all three elements - resistor, capacitor and inductor - are connected in series within the AC circuit, calculating the impedance at different frequencies is not necessary, because the simulation shows its values. If students correctly fill out Table 1, they can conclude that a change in the growth trend occurs when something interesting happens with capacitor reactance/ impedance and inductor reactance/ impedance. If they analyze the changes in the two mentioned variables with increasing frequency, Students will notice an almost equalization of their values. Then it is possible to reach the exact value of frequency at which these two reactance values are cancelling each other. This further means that they can reach the exact value at which the equivalent impedance of the serial *RLC* circuit is the smallest, that is, the condition when resonance occurs in the AC circuit. In this way, students practically and experimentally reach the solution without directly applying Thompson's formulas. At the same time, this approach represents the possibility of introducing Thompson's formulas in a methodic content as well as to understanding it.

3.4. Simple AC Circuit on Walter Fendt Simulator

This application shows a simple circuit consisting of an alternating voltage source and, depending on the selected button, an ideal resistor (without inductivity), an ideal capacitor or an ideal coil (without resistance). In addition, there are meters for the voltage (blue) and the current (red) measurements. Below the equivalent scheme of the circuit, students can see on the left a phasor diagram; it is possible to read the time varying values of voltage and current oscillation phases from the position of the two phasors (voltage - blue, current - red). The projection of a phasor onto the vertical axis corresponds to the time varying value of voltage with respect to the time varying values of current. On the bottom right side of the window the dependence of voltage and current on the time is illustrated in a diagram.

The "Reset" button brings the circuit to its initial state. Students can either start or stop and continue the simulation with the other button. If they choose the option "Slow motion", the movement will be ten times slower. It is possible to vary the preselected values of frequency, maximal voltage and resistance, and either capacity or inductivity, respectively. The program will indicate the new value of the maximal current.

One approach to understanding the phenomenon of impedance minimization at a certain frequency is to measure the voltages on certain circuit elements and compare them using the previously described applet.

Students better understand the phase difference represented by phasors or rotating vectors. The representation of voltage and electric current by rotating vectors provides useful visualisation of their time-domain changing values. A graphic connection between phasors and amplitudes enables an understanding of the change in the current values of both voltage and current. Also, considering each of the three impedances individually helps students see the role of individual circuit elements in causing the phase difference. Below are pictures, 6 to 8, that illustrate certain segments of the simulation and changes in the voltage and the electric current values, when the ideal elements are used: resistor, inductor and capacitor.

All three ideal elements have current flowing through them and all are firstly individually considered. It was found out that students often confuse which element exhibits the voltage lead over the current, while all students easily remember that the ideal coil or capacitor has a phase difference of $\pi/2$, but not everyone remembers which quantity "lags" by $T/4$ (one quarter of the period). This fact, confirmed by the survey on the way of learning, indicates that students rely on memorization and that students with better memory can create an illusion for the teacher that they fully understand the phenomenon they are learning about. The Simple AC Circuit simulation was intended to encourage thinking about the contribution of coils and capacitors to the overall impedance of a serial *RLC* circuit.

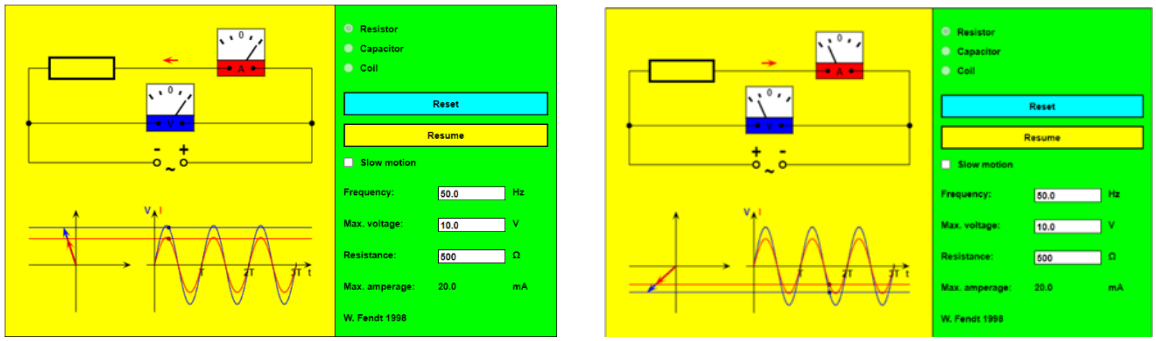

Figure 6. Phasor and sine graph for ideal resistor in AC circuit

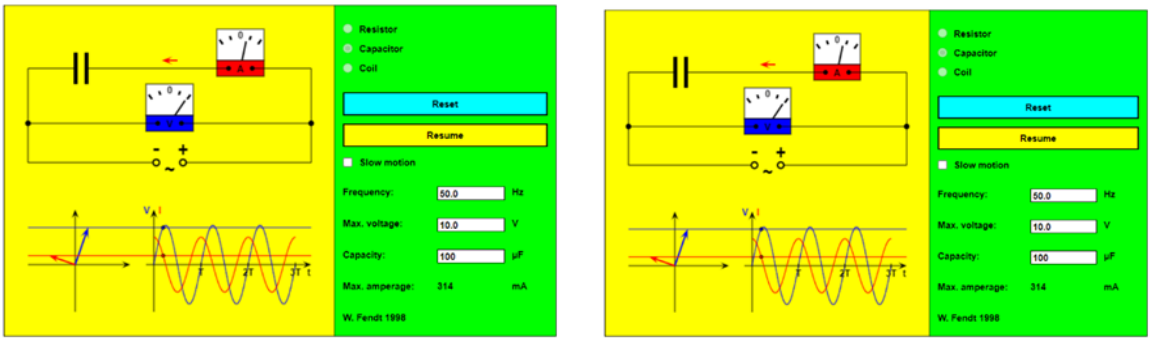

Figure 7: Phasors and sine graph for ideal capacitor in AC circuit

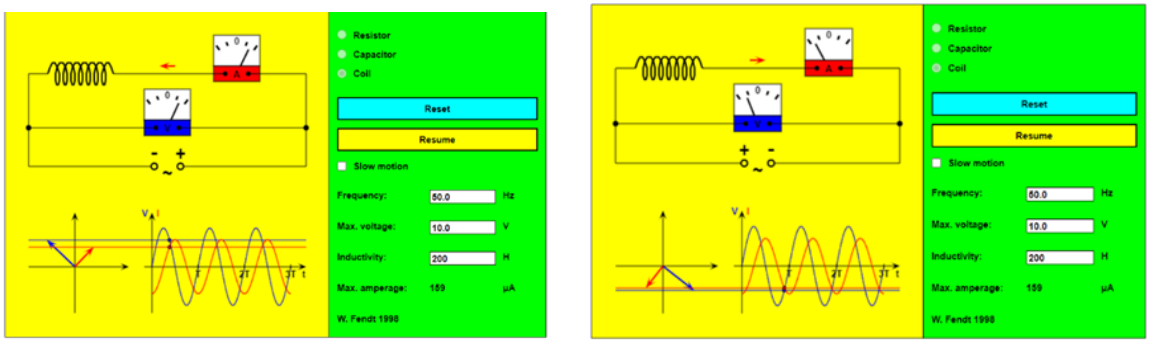

Figure 8: Phasors and sin graph for ideal coil or ideal inductor in AC circuit

4. Conclusion

The AC circuit discussed in this paper is a serial *RLC* circuit. It represents combination of resistor, capacitor and inductor in series, connected to an AC power source. The expressions of the Ohm's Law for the serial connection of resistor, coil and capacitor in the AC circuits was considered.

A phasor diagram involving circuit current, resistor's voltage, coil's voltage and capacitor's voltage, or $i(t)$, $v_R(t)$, $v_C(t)$ and $v_L(t)$ respectively was presented. It is irreplaceable for detailed time-domain analysys of the AC circuit.

The simulation of *RLC* circuit with AC power supply source is made in a special application available on the Internet. With digital platforms, the teaching of electrical engineering is being modernized.

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Flipped Learning in Coeducation through Micro Text Messaging Within a Hybrid Learning Environment Opportunities

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Abstract

Mobile SMS is a short messaging service that is an electronic way of sending and receiving the messages. Micro learning is a technique to split contents of a course module in tiny pieces and used in small steps. Flipped learning is a method to send the educational contents to learners outside of a formal classroom through different ways, and face-to-face meetings in the classroom are used for discussions and sharing of understanding and ideas. Literature reveals that long protracted hours of teaching and learning affects the performance of teachers and learners towards the creation of in-depth ideas, and micro learning supports in this situation. Moreover, literature tells that female gender is shyer than male in pedagogical setups; therefore, female learners might have difficulties in asking questions, sharing their ideas and understandings, and discussing their unclear concepts during formal face-to-face lectures. This research had divided the contents of a course module in tiny pieces of less than two hundred and eighty characters using the scheme of twitter for a single tweet, and mobile messages (SMS) were used to send these tiny text messages to the smart devices of learners as micro learning contents through flipped learning approach. Total number of participants was twenty four, distributed in two groups, 'A' and 'B', representing female and male genders, respectively. Hybrid mode of teaching was used for the research. Both the groups had received micro text messages on their mobile devices earlier than their classroom meetings to understand the contents, in advance. Face to face sessions were used for exchanging their ideas and understandings and to discuss unclear concepts. After the experiment both the groups had attended an exam of the course module. Group 'A' (female group) performed with better outcomes of the exam with an average group mean of 1.74 marks that is equivalent to 13.92 percent. Therefore, results of this research are remarkably inspiring and have positively impacted on the learning outcomes based on gender diversity for female students.

Keywords

Flipped Learning, Gender Diversity, Hybrid Learning, Instructions, Micro Learning, SMS

1. Introduction

Education industry is using ICT (information and communication technologies) in the form of digital transformation that has plenty of benefits. Education supports a learner in the development of knowledge and skills through in-depth ideas, and technology works as a catalyst that stimulates the process of teaching and learning. The integration of technology with education results in hybrid learning environments where the traditional mode of face-to-face teaching and learning gets united with a technology.

Short Message Service is known as SMS that is used to send and receive the messages through portable electronic gadgets and this type of communication has a strong impact on learning outcomes [1]. Flipped learning is a technique in the pedagogical world that flips traditional classroom based learning with a practice of learning outside of the class, where study material is given to the learners for understanding, and face-to-face classroom based meetings are utilized for exchanging of ideas and collaborations [2].

The process of instruction is a pedagogical method where teachers transfer the knowledge to the learners through the creation of in-depth ideas. The formal process of instruction is centred on classroom lectures where teachers and students get engaged in the process of teaching and learning, and commonly each session is for a minimum duration of one or two hours; moreover, generally these classroom

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sessions get started in the morning and finishes in the afternoon. Consequently, most of the times these protracted hours result in challenges for both the parties towards delivering and receiving the knowledge with in-depth concepts of the course contents that results in compromised learning outcomes [3]. Micro learning is an educational technique that divides the contents of an educational course in small pieces and uses these small divisions for the process of learning in short steps [4]. Generally, in the educational setups, female students are being witnessed as shyer in comparison to male students [5]. Therefore, female learners might face problems in sharing their understandings and ideas, asking questions and discussing unclear concepts through the traditional process of face-to-face instruction. Primarily, female students encounter difficulties, when they are introduced to ICT centred technologies because of their limited disclosure; however, male students have better concepts about the use of ICT technologies. If female students get exposure to these technologies, they could perform better than male students at later stages [6]. Female students have encouraging attitudes in using the information and communication technologies [7]. The use of micro learning technique for the practice of learning through ICT helps female students in a better way as compared to male students [8]. Integration of technology with educational practices is a requirement of the existing pedagogical industry to enhance the teaching and learning outcomes [9]. Micro learning helps the learners in the creation of in-depth ideas and knowledge about a topic under study [3, 10, 11]. Twitter is a microblogging network; there are maximum of 280 alphabets to convey a message through a single tweet on twitter that restricts the tweet to be brief [12].

Hybrid learning technologies are vital for educational institutions. Nevertheless, these environments are expensive solutions because of the installation of technological software, trainings of students and instructors, devoted squad to manage the technology; consequently, there is a need of technological solutions those are easy on pocket and can improve the learning outcomes through hybrid learning technologies [8]. Therefore, educational institutions are in a continuous need of ICT supported hybrid learning environments those are financially economical and produce improved learning outcomes. Literature states that micro learning enhances the learning outcomes. In addition, literature also reveals that female students are shyer than male students that might hinder female learners from sharing their ideas and understandings and discussing doubtful conceptions during formal lectures. Moreover, female students perform better than male students if they are given a chance to experience technologies connected with teaching and learning. Flipped learning technique flips the formal way of classroom teaching with external classroom communications and classroom meetings are used for discussions about a significant topic. Therefore, this research had used short text messages (SMS) as a tool of micro learning through the division of course contents in small parts and utilized in small steps (messages sent on smart phones of students), using flipped learning approach within a hybrid learning environment. Existing literature revealed that the combination of this micro learning technique used for the research was innovative. It was assumed that this technique might help female students towards the creation of in-depth ideas and better understanding the course contents that was planned to be tested through examination of studied module.

Next sections of this paper are “Literature Review”, “Purpose of Study”, “Methodology”, “Results”, “Limitations”, “Conclusions and Future Work” and “References”.

2. Literature Review

2.1. Micro Learning

The method of micro learning is based on splitting the study material in small pieces those are used in small steps [4]. Dividing the material of learning in small parts and given to learners for the purpose of learning in small portions is known as micro learning [13, 14].

2.2. Flipped Learning

Flipped learning is a method of teaching that is based on flipped approach, where learning content is sent to the learners outside of a traditional class, using videos, audio podcasts, or small text based messages, and face-to-face meetings are used for exchanging of ideas and discussions [15]. Flipped learning is proved to be effective towards achieving the expected learning outcomes that could enhance the contribution and interaction of learners [16].

2.3. Short Text Messaging Service (SMS) and Twitter

Short text messaging service allows to send a text message from sender to receiver through a portable gadget such as a smart phone [17]. Teachers could get effective support as facilitators through the location independent short messaging service to motivate the learners towards the process of learning for better learning outcomes [18].

Twitter is famous as microblogging site that uses tweets, and each tweet is based on two hundred and eighty characters that provides brief and concise information in a short text message [19, 20, 21]. Field of education is continuously in a need of techniques those combine formal classroom based instruction with electronic based communicational technologies [22].

2.4. Hybrid Learning

A process where digital methods of teaching and learning are combined with formal classroom based teaching is called hybrid learning [23]. Learners' knowledge, skills and capabilities get improved within hybrid learning environments [24].

3. Purpose of Study

It is commonly known that mobile short messaging service (SMS) is independent of a computer network, unlike accessing e-mails, WhatsApp messages, Facebook and twitter through wired or wireless computer network; and social media applications divert the concentration of an end-user. There are a lot of benefits linked to short messaging service, including location independence, motivation of learners and effective learning outcomes. The maximum limit of the SMS is 160 characters that is not enough to shorten the content of a course topic in tiny pieces. However, the maximum limit of a tweet is 280 characters; additionally, the use of twitter as a tool of micro learning has produced effective results on the outcomes of learning, including in-depth understanding of course contents and better marks in the exam [25]. Therefore, this research had used the standard limit (280 characters) of a tweet to divide the contents of the course unit in small pieces and merged these tiny pieces of course information with SMS for sending the messages on smartphones.

Consequently, the purpose of this study was to gauge the effects of short messaging service (SMS) as a micro learning tool on gender diversity (female vs male students) through shortening the topics of the course module contents under study and usage of these short text messages within a hybrid learning environment through flipped learning approach. Female students were linked to group 'A' and male students were connected with group 'B'.

4. Methodology

This study had assessed the effects of SMS as a micro learning tool on the exam results centred on gender diversity through dividing the topics of a course module ('WWW, Network and Internet') of the subject Information Technology, within a hybrid learning environment through flipped learning approach. Total marks of the exam were 12.5 and the exam was conducted using Moodle through multiple choice and true or false questions. Total number of participants for this study was 24, belonging to similar pedagogical background and same age group.

The number of participants for this study was substantial, because; there was another study conducted by [25] that had used 21 participants for a similar type of research. This study had divided the participants in two groups; group 'A' for (9) female students and group 'B' for (15) male students. As mentioned in the literature review section of this paper that the maximum size of a tweet is 280 characters; therefore, the contents of module were divided in short messages of less than the maximum limit of a tweet. Both the groups had studied this module through hybrid learning mode, and received short text messages on their smart phones through mobile network for a period of two weeks, earlier than their lectures; to get an understanding about the topics. The participants were requested to read one message at a time and to have a minimum break of 10 minutes before reading the next message. Formal class meetings were used for discussions and exchanging of ideas about the topics of the module.

Analyses were done between the groups 'A' (female) and 'B' (male), focused on the outcomes (group means) of examination marks for the module. Results of the study are available in the next section.

5. Results

5.1. Comparison of Exam Results (Group 'A' vs Group 'B')

The outcomes of examination conducted on groups 'A' and 'B' are given in Table 1 and Figure 1. These results clearly validate that group 'A' connected to female students had achieved better examination outcomes in comparison to group 'B' of male students. Total marks of the exam were 12.5. The mean value of exam results for the group 'A' was 10.17, and mean value of group 'B' was 8.43. Therefore, mean value of group 'A' minus mean value of group 'B' is equal to 1.74 out of 12.5 marks. In percentage this difference is equal to 13.92 %. Hence, on average, every student of group 'A' (female group) had scored 13.92 percent extra marks as compared to every student from group 'B' (male group).

Table 1

Exam Outcomes (Group 'A' vs Group 'B')

Exam Outcomes: Out of 12.5 Marks	
Group 'A' (Female students) Used short text messaging as a micro learning tool through flipped learning approach with in a hybrid learning environment *Exam results – Group Mean of group 'A'*	Group 'B' (Male students) Used short text messaging as a micro learning tool through flipped learning approach with in a hybrid learning environment *Exam results – Group Mean of group 'B'*
10.17	8.43

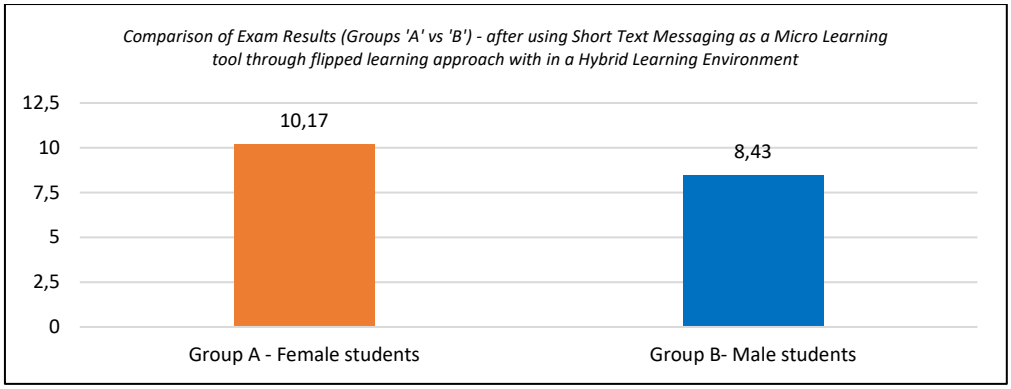

Figure 1: Comparison of Exam Results (Groups 'A' vs 'B')

Therefore, the results given in table 1 and figure 1 certify that this micro learning technique had supported female students of group 'A' in a better way as compared to male students of group 'B' in gaining high scores in the examination. Moreover, the used micro learning technique through mobile SMS was financially economical because of the nominal cost of the short messaging service.

6. Limitations

Overall, there were no major limitations during this study. The number of subjects (24) was considerable, keeping in view the research study of [25] with 21 participants with similar setup. Moreover, a healthy teacher-student ratio is required for this type of study at the tertiary level of education. There was a minor issue that students of male and female groups had used their mobile devices for reading the micro text messages; few participants had weaker batteries of their mobile phones, and sometimes they had to recharge the batteries before reading the micro text message.

7. Conclusions and Future Work

The results of this research confirms that the use of short text messaging (SMS) as a tool of micro learning through flipped learning approach within a hybrid learning environment affects the process of learning in a constructive way on female students as compared to male students, towards gender diversity through in-depth understanding of ideas and results in better learning outcomes through better examination results. Hence, the division of study materials in micro learning content through splitting in small pieces of not more than 280 characters, and using these chunks through flipped learning approach with in a hybrid learning atmosphere is assuredly supportive. When the course contents are divided in small chunks, these are easily digestible as compared to prolonged classroom lectures. Moreover, flipped learning technique flips the method of formal instruction, and students' endeavours to get an understanding about the topic, earlier than classroom meetings; and face-to-face classroom gatherings as a mode of hybrid learning are for the discussions, collaborations and exchange of understandings about the topics.

Furthermore, SMS is a renowned way of communications through sending and receiving text messages through smart phones using mobile networks; hence, there is no need to install any kind of special software or usage of any learning management system. In addition, instructors and learners do not require any sort of skills or trainings for sending and receiving text messages, and the charges of mobile's SMS are nominal, resulting as an economical solution. The results of this study are in agreement with [8, 25] that female students get better learning outcomes as compared to male students, if they participate under the atmosphere of micro learning technique, mixed with information and communication technologies within a hybrid learning mode. This environment creates an in-depth understanding of learned topics and results in better examination results for female students those are shyer than male students in asking questions or clarifying fuzzy ideas during formal lectures.

The initial probability shown in the start of this document towards the positive effects of SMS as a tool of micro learning through flipped learning approach within a hybrid learning environment has

moved to substantial. Moreover, literature reveals that female are shyer than male in educational setups and if female gender gets an opportunity towards the usage of technology, they perform better than male gender [5].

Consequently, this micro learning technique should be used by the teachers, in combination with formal face-to-face teaching because it has formed state-of-the-art results for female students.

Dear pedagogical experts, teachers and educational institutions; an easy on the pocket and state-of-the-art method of micro learning to support the female learners via short text messaging through the usage of flipped learning approach within a hybrid learning environment is in your hands. Do not delay in using it; get elevated outcomes to support female students. Real-time online chat sessions and Facebook might be used as micro learning tools for the future work.

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A Framework to Use Virtual Reality and Augmented Reality in Education; Future, Challenges and Opportunities

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Abstract

Education is the key of success and provides a bright future. Virtual Reality (VR), augmented reality (AR), and mixed reality (MR) are innovative technologies those are improving the learning outcomes, creation of in-depth ideas and skills development of learners through the process of teaching and learning. These technologies are considered as the future of education. However, electronic gadgets and development of educational contents for these cutting-edge technologies are expensive, and at present it is difficult to implement them entirely at a larger scale. Literature reveals that a wait time of at least one more decade is expected towards the full implementation of these technologies at their best. There are a lot of research studies and electronic resources, scattered at different electronic locations. Therefore, it is important to connect all these scattered dots to form a clear picture about the future of digital education, and to know the challenges and opportunities to use VR, AR and MR through active learning approach, looking towards the future. Blended mode of education is best suited for the use of these technologies. This paper joins the scattered dots to provide a complete picture of digital teaching and learning in the future, discusses challenges and opportunities, and offers a framework of instruction that provides a structure to answer the questions "Where and how to use these technologies in an economical way?". Educational institutions get a baseline through this paper to understand and apply these highly advanced technologies and to gear up for the future.

Keywords

Active Learning, Blended Learning, Challenges and Opportunities, Future of Digital Education, Augmented Reality, Augmented Virtuality, Mixed Reality, Virtual Reality

1. Introduction

In the field of education, learning is a process of gaining knowledge and skills, and lecturing is a famous method of instruction. Active learning is a teaching approach to students where the traditional face-to-face method of lecture delivery gets an addition of a pedagogical strategy that elevates and activates the students' engagement [1].

Technology plays a significant role in the field of education and brings innovative educational openings to the world. It is growing at a rapid pace and provides instant access to plenty of information that helps learners to develop their in-depth knowledge and skills. Literature reveals that fast growing technologies of virtual reality, augmented reality and mixed reality are increasing the quality of pedagogical practices [2].

VR, AR and MR are the technologies in education those are increasing the learning outcomes and are counted as the future of education. Literature reveals that these technologies will take one more decade to reach at their best. Blended learning is a known technique that is a blend of traditional classroom based education with electronic learning methods that is very helpful in the field of education.

Existing resources reveal that information about challenges, opportunities and future of the education sector towards VR, AR and MR (AR + AV) is scattered with irregular dotted patterns at different locations. These dots are required to be connected to get a clear picture about the future of digital teaching and learning, and to know what are the challenges and opportunities linked to these technologies; where and how these technologies can be exercised economically? The purpose of this paper is to join these dots to provide an insight about the future of digital education, challenges and opportunities linked to the usage of VR, AR and MR technologies, recommendations about the use of

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AR and VR technologies within an operational structure that is easy on pocket, and gaining of insights about AR, VR, MR and extended reality (XR) technologies. This paper uses TEAL (technology enabled active learning classroom) and provides a framework to integrate and practice the course contents of english, mathematics, information technology (IT) or any other subject as testers through freely available augmented reality and virtual reality materials with the minimum number of VR and AR based electronic gadgets. Consequently, educational institutions would gear up for the future through the offered framework via insertion of these technologies to instruct any subject (like english, mathematics and information technology as sample subjects in the offered framework) or any other subject in a technology enabled active learning classroom.

Next sections are related with "A Range of Realities (Reality-Virtuality Continuum)", "Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and their Impacts on Education", "Extended Reality", "Blended Learning", "TEAL Classroom", "Future of Education", "Challenges", "Opportunities", "A Proposed Framework for the Integration of VR and AR Materials with the Subjects of English, Mathematics, IT or Any Other Subject – Teaching in TEAL Classroom", "Conclusions and Future Work" and "References".

2. Literature Review

2.1. A Range of Realities (Reality-Virtuality Continuum)

There are many advancements in the field of education those have robust impacts on the educational industry. The areas of VR and AR are strongly influencing the field of education towards productive learning outcomes. To unfold and understand the differences between these areas, it can be started with the range of realities "reality-virtuality continuum", provided by [3]; figure 1 illustrates the reality-virtuality continuum that is a constant measure, fluctuating among real environment, augmented reality, augmented virtuality (AV), virtual reality and their combinations are forming mixed reality. According to the existing literature, augmented reality (AR), virtual reality (VR) and mixed reality (MR = AR + AV) are known terminologies, today.

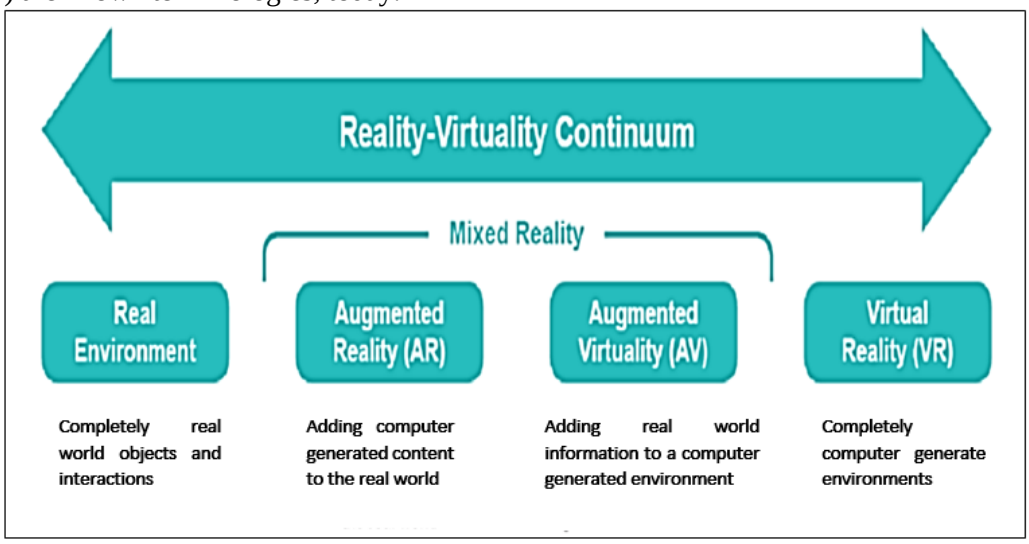

Figure 1: A range of realities - Reality-Virtuality Continuum

Figure 2 illustrates an in-depth understanding of reality, augmented reality, augmented virutaliy, virtual reality, mixed reality and extended reality as stated by [4].

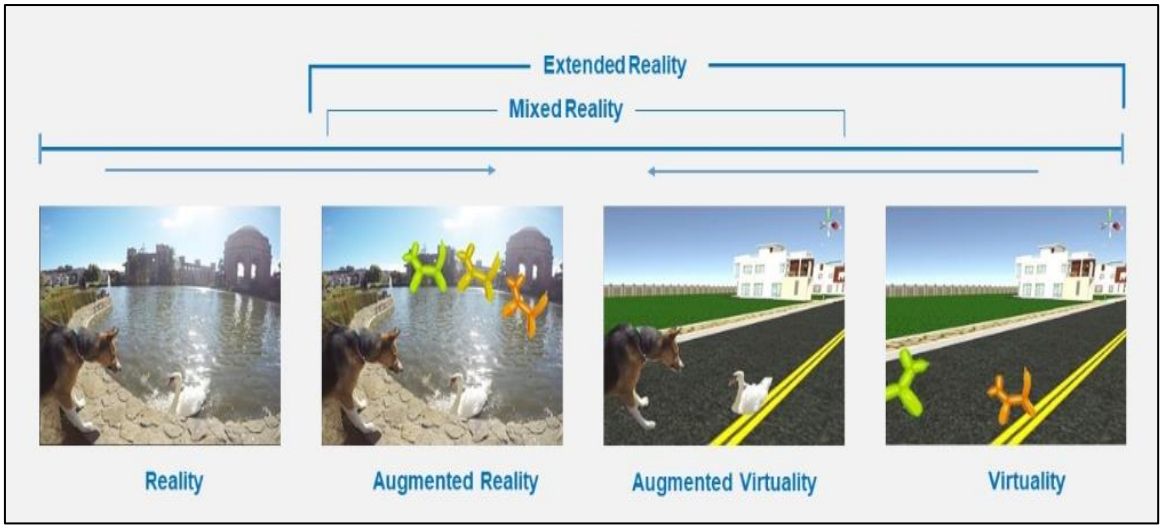

Figure 2: Reality, augmented reality, augmented virtuality, virtual reality, mixed reality and extended reality

2.2. Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and their Impacts on Education

2.2.1. Virtual Reality (VR) and Its Impact on Education

Virtual reality is a technology that permits a person to use a computer-based environment, which could be real or imaginary, and the real world is unseen because the person is immersed in a digital world [5]. Figure 3 illustrates the virtual reality environment.

Figure 3: Virtual reality (VR) - source [6]

The use of Virtual Reality has positive impacts on the process of instruction because it increases the learning experience of learners through guided discovery that makes them active and engaged [7]. VR can be used for the human anatomy instruction, virtual field tours, virtual reality laboratories, soft skills development, teaching medicine and coaching learners with special needs and many more. Moreover, some of the benefits are visualized learning and enhanced learner engagement. In addition, components of virtual reality are: VR headsets, extended reality system (XRS) that is essential for VR content to track VR learning requirements, production of VR content, and development of software such as mobile applications [8]. VR headsets are famous to watch '3D' and '360 Degrees' contents, with controllers for interaction or without controllers to watch the videos.

2.2.2. Augmented Reality (AR) and Its Impact on Education

Augmented reality is a technology that is a mixture of real surroundings with the virtual world; this blend is done through insertion of computer-based images with real world backgrounds [9]. Figure 4 illustrates the application of augmented reality.

Figure 4: Augmented reality (AR) – source [10]

Students become active through the use of augmented reality in education that results in the elevation of their motivation and engagement [11]. Students always like a lecture equipped with augmented reality [12]. Figure 5 shows a view of augmented reality through AR smart glasses.

Figure 5: Smart glasses – augmented reality glasses – source [13]

2.2.3. Mixed Reality and Its Impact on Education

Mixed reality is a setting where physical reality and computer-based electronic materials are integrated, so that interaction could be done through real world and digital entities [14]; hence MR is a mixture of AR and AV. Figure 6 illustrates an example of mixed reality.

Figure 6: Mixed reality (MR) – source [15]

The use of mixed reality in education produces higher levels of engagement for contributors, in comparison to formal methods of pedagogical instruction [16].

2.3. Extended Reality

Extended Reality (XR) integrates augmented reality, augmented virtuality and virtual reality [17]. Therefore, XR provides a solution that is a combination of AR + AV + VR into to a single gadget that offers all the features. HMD is a head-mounted display that is commonly known as a VR headset; however, augmented reality glasses and mixed reality headsets are also counted as HMDs. Nearpod, EON Reality and ThingLink are famous companies working towards AR and VR in education. Some regional companies are also available to setup AR, VR and MR based technological labs.

2.4. Blended Learning

Blended learning is a method of instruction where different electronic learning techniques are merged with formal face-to-face teaching [18]. Blended learning advances the skills of students through its practice of digital content integration with traditional classroom based teaching and learning [19].

2.5. TEAL Classroom – Technology Enabled Active Learning Classroom

TEAL is a technology enabled active learning classroom that is a pedagogical setup based on multi-media equipped workspace to support learners; moreover, this arrangement stresses on group based activities and collaborations [20]. Figure 7 shows a sample structure of a TEAL classroom.

Figure 7: A sample structure of a TEAL classroom - source [21]

2.6. Future of Education - Virtual Reality, Augmented Reality and Mixed Reality

The use of virtual reality and augmented reality in education has constructive effects on learners' engagement and understanding with improved learning outcomes, those are the future of education, and these technologies will take pedagogical practices at a different level of instruction [2]. If figures 8, 9, 10, 11, 12 and 13 are considered as dotted points and linked to each other under one umbrella; the future of digital education is obvious using VR for in-depth understanding and trainings of course contents, AR for augmented support, MR (a combination of AR and AV for the development of detailed ideas), virtual conferencing (virtual meetings), haptic gloves (using which virtual sense of touch can be felt, such as real world handshaking) and holoportation in real-time (that could be used by an instructor to be able to virtually appear in front of a student(s) for the practice of teaching), respectively. Therefore, altogether, figures 8, 9, 10, 11, 12 and 13 clearly draw the picture about the future of digital education. Moreover, for further details, links are available on these figures to watch them as videos in YouTube.

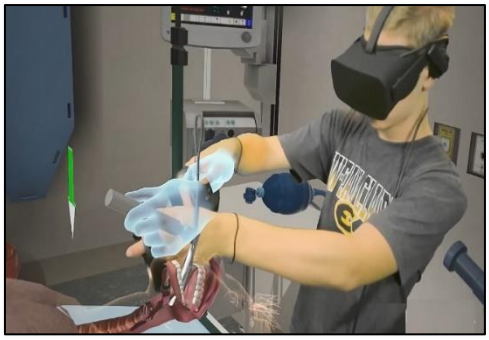

Figure 8. Virtual reality – source [22]

Figure 9. Augmented reality - source [23]

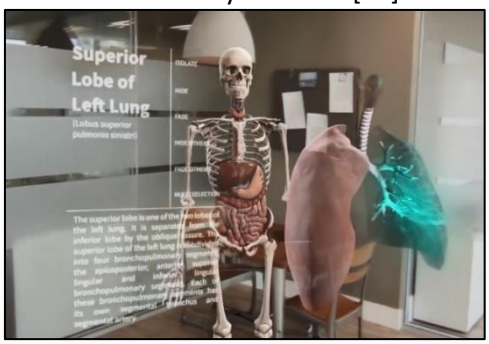

Figure 10. Mixed reality – source [24]

Figure 11. Virtual conference – source [25]

Figure 12. Haptic gloves – source [26]

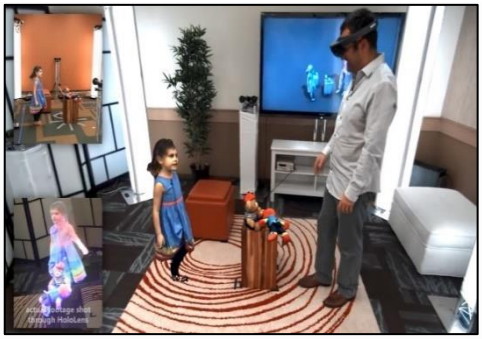

Figure 13. Holoportation: virtual 3D teleportation in real-time – source [27]

2.7. Challenges

High prices of developing new technology, prices of gadgets, digital fatigue and limited user experience are some of the major challenges hindering the development of augmented and virtual reality solutions [28]. Implementation costs, technology and skills gaps are few of the major challenges towards the implementation of technologies connected with augmented reality [29]. Tables 1, 2 and 3 show the prices of famous AR, VR and MR gadgets; overall the prices are high. In addition, related companies are charging a huge amount for the development of required educational contents.

Swiss cognitive, a famous network based on worldwide community of corporate leaders and specialists from the field of artificial intelligence has claimed that one more decade is required for the complete implementation of augmented and virtual reality [28].

Table 1.
VR Headset Prices - source [30]

Name	Price in USD ($)	Image
Oculus Quest 2	387	
Valve Index	1150	
HTC Vive Pro 2	799	
HP Reverb G2	469	

Table 2.
Augmented Reality Glasses – source [31]

Name	Price in USD ($)	Image
Epson MOVERIO BT-300	699	
Google Glass Enterprise Edition	1800	
Toshiba dynaEdge AR100 Viewer	1899	
Vuzix Blade Smart Glasses	999	

Table 3.
Mixed Reality MR or MX – source [32]

Name	Price in USD ($)	Image
Magic Leap One	2295	
Microsoft HoloLens	3000	
Microsoft HoloLens 2	3500	

2.8. Opportunities

2.8.1. Use of Virtual and Augmented Reality in Education – for English, Mathematics, Information Technology or Any Other Subject

As mentioned above, the prices of VR, AR and MR gadgets, and contents creation are expensive. An educational institutional must have clear information about the requirements of gadgets, content creation for a subject(s) (how much contents are required for VR and AR, and how the contents will be taught); using this information a contract could be awarded to a related company for the establishment of VR, AR and MR laboratories, at later stages. Besides, this practice will reduce the overall cost of the project with a complete understanding of provisions.

There are several ready-made resources (videos) available on YouTube with 360 degrees. Moreover, normal YouTube videos can also be seen through Oculus Quest 2 or other headsets.

Following are some of the YouTube videos:

Link for English listening:

https://m.youtube.com/watch?v=gf0mpUS9vWI

Another Link:

https://www.youtube.com/watch?v=2b2mRNkSLSQ

Link for Information Technology:
https://m.youtube.com/watch?v=JwYFGMoWwyw
Link for Mathematics:
https://www.youtube.com/watch?v=bfsdSVGy-Hs

In addition, there are numerous applications available in the app store of iOS and google play store of Android devices those are used as virtual and augmented reality solutions. Through these applications, virtual reality and augmented reality can be used in education. Figure 14 shows an application (a sample) for learning mathematics through virtual reality.

Figure 14: Math VR application for iOS and Android devices

Figure 15 shows an application of augmented reality that is used for mathematics.

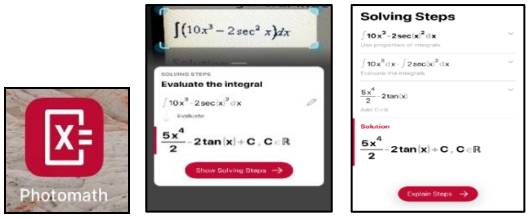

Figure 15: AR application (Photomath for mathematics) for iOS and Android devices

Figures 16 and 17 show applications of language learning for augmented reality for iOS and Android devices.

Figure 16. Learn language – Mondly (for iOS and Android devices)

Figure 17. Google translator AR

Figure 18 shows augmented reality solution using information technology based mechanism.

Figure 18. Healthcare training AR – source [33]

Moreover, there are numerous resources available online or in App Stores of iOS and Android those are available for free or at minimal cost.

3. A Proposed Framework for the Integration of VR and AR Materials with the Subjects of English, Mathematics, IT or Any Other Subject – Teaching in TEAL Classroom

As mentioned earlier that there are several available resources including 360 degrees and normal videos on YouTube (those can be seen through Oculus Quest 2 or any other VR headset) and applications (app store of google play or iOS) for english, mathematics, IT or any other subject. Therefore, at least one representative from each department: 'english', 'mathematics', 'IT' or any other subject can be assigned to find these resources, and to integrate with the educational materials of their subjects, as shown in the proposed framework (figure 19). Few topics could be selected from a subject to be taught in the TEAL classroom. A suitable or matching resource can be found on YouTube or App Store and the connected part of the course content can be changed (adjusted) according to the available resource. Teachers would use TEAL classroom for teaching with technology.

Time allocation in the TEAL classroom for different levels of classes and diverse courses for different teachers might be an issue that is required to be planned according to the requirements. Therefore, planning should be done actively, such as, for how many times a group of students or a specific teacher would use TEAL classroom in a week via active learning techniques and technologies because there would be only one TEAL classroom. Consequently, the ratio of TEAL classroom to different levels, classes and courses would be 1: n (where 'n' shows multiple number of levels, classes and courses).

Four 'Oculus Quest 2' headsets could be purchased initially, and the proposed framework (figure 19) can be used to test the searched VR resources from YouTube and iOS/Android play stores or from any other resource.

Likewise, four tablets (Samsung, Lenovo or any other company) could be purchased initially, to test AR applications according to the proposed framework (figure 19).

Figure 19 illustrates the proposed framework to find the available resources for the subjects of english, mathematics, information technology or any other subject and integration with materials for teaching in TEAL classroom.

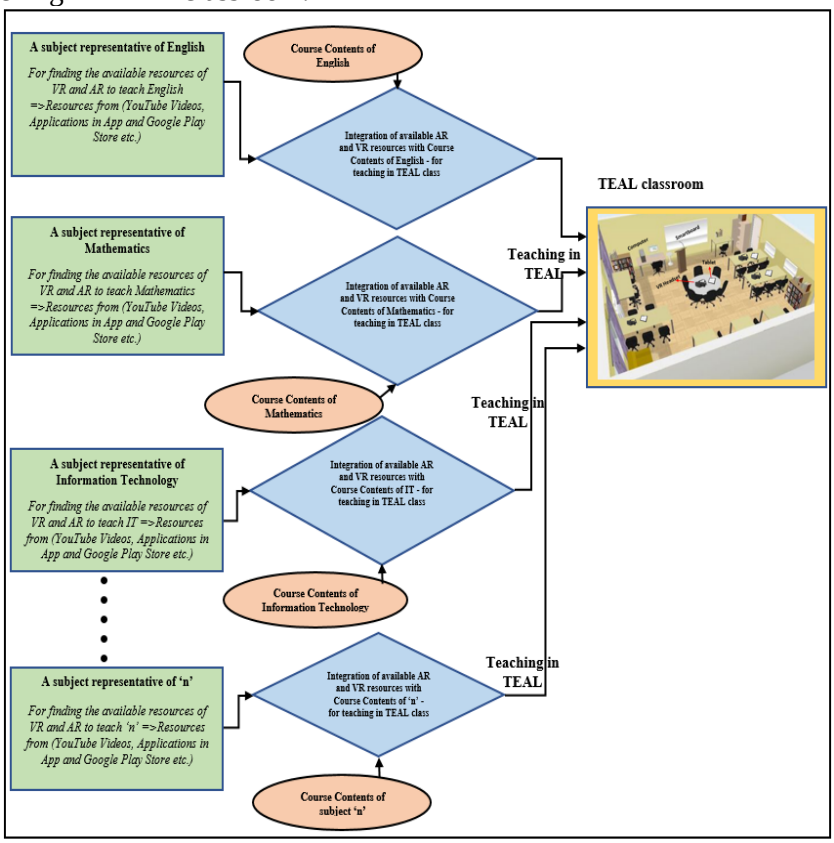

Figure 19: A proposed framework for the integration and teaching of VR and AR materials for different subjects

4. Conclusions and Future Work

The industry of education is in a continuous need of innovative methods, techniques and technologies to improve the process of teaching and learning. Virtual reality, augmented reality and augmented virtuality are pioneering technologies in education, boosting up the knowledge and skills of learners. Virtual reality is an immersive computer-based technology with a digital environment used in education to get the help in the process of knowledge transfer and skills development. Augmented reality is a blend of real world atmosphere with digital technology. Mixed reality is a combination of augmented reality and augmented virtuality to get the benefits of integration. Extended reality is a combination of augmented reality, augmented virtuality and virtual reality. Literature section of this paper reveals that AR, VR and MR technologies are extremely useful to achieve improved learning outcomes and enrich the level of learner's engagement.

However, financial burden in the development of course contents, high costs of AR, VR and MR gadgets, digital tiredness and limited knowledge and skills of teachers and students towards these technologies are some of the major key challenges; that is why, one more decade could be required to reach at the peak and maturity of these technologies. Moreover, all the subjects and study materials cannot be converted for these technologies, right away. At the outset, every educational institution has to understand and get a know-how about the future of digital education, connected challenges, opportunities and its own digital requirements linked to VR, AR and MR technologies.

As a pedagogical process, the comparison of formal face-to-face environment of teaching and learning is parallel to the future of VR, AR and MR; because after the full implementation of these technologies, altogether, virtual meetings would be possible, sense of touch would be working and participants could feel each other from distant locations like handshaking. Hence, similar to formal face-to-face classes, it would be possible in the future to conduct completely online classes as a successful e-learning or distance education system or in a case of any emergency; other options could be blended learning, or the eminent mode of HyFlex (hybrid and flexible) learning.

It is strongly recommended to use these VR and AR technologies for this framework within a blended learning atmosphere that is a combination of formal face-to-face and virtual methods of teaching and learning through active learning environment, like within the technology enabled active learning classroom (shown in figure 7). Keeping in view the current prices, it is difficult for every educational institution to convert all the curriculum or topics into digital contents and provide VR, AR and MR gadgets to every learner. Even, in case of an availability of a budget for an establishment of AR, VR and MR laboratories, it is highly recommended that the institution should know its requirements first, because direct out sourcing of a project to a company without having the enough knowledge could lead towards the project failure. The offered framework (figure 19) is an ideal solution that could support in getting an understanding of VR and AR requirements and help the educational institution to gear up for the future of digital education. Furthermore, this framework is economical with few numbers of VR devices (four) and digital tablets (four) for getting an experience about these technologies. After using VR and AR technologies through the presented framework, the institution would automatically have ideas about MR and XR because MR is a combination of VR and AV and XR is an integration of VR and MR. Any educational institution can use this framework for any number of subjects to teach in the TEAL classroom, keeping in view its feasibility (like number of students groups). It is projected that after few years, ready-made contents of VR, AR and MR will be available online for free, similar to the current availability of educational contents for all the educational levels at the YouTube channels like 'Khan Academy' and many others. Furthermore, VR, AR and MR gadgets will be cheaper in the future, and the whole world would benefit from it.

Dear educational institutions, managerial heads and teachers; do not wait any more. Use the offered framework within a blended learning environment, inside a technology enabled active learning classroom and integrate the VR and AR technologies with course contents to understand the future of digital education, evaluate the framework with teaching staff and students, and get ready for the use of these technologies in the future. Researchers could search and include electronic gadgets of mixed reality and available online materials of MR as a future work to expand the functionality of this framework.

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