Continuous Summative Assessment Sessions in Vocational STEM Education

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***Abstract*—Continuous approach to learning is essential for mastering course content in STEM education. Research results regarding students' learning habits show that students usually learn in a non-continuous way, adopting surface instead of a deep approach to learning. Lack of students' motivation was identified as one of the causes that contribute to the observed problem. In order to motivate students for continuous learning, weekly organized summative assessment sessions were introduced for vocational STEM students in higher education. These sessions were conducted throughout the semester within a typical STEM course. Obtained research results showed that this approach to summative assessment encouraged the majority of students to start to learn continuously. Also, students were motivated to solve more math-based tasks during the preparation for the exam than they would usually do. Encouraging students to learn in a continuous way affected their motivation, thus helping them to move from the surface toward a deep approach to learning.**

Keywords—ELARS, formative assessment, continuous summative assessment, STEM, online evaluation system

I. INTRODUCTION

Students' motivation is one of the essential elements of a successful educational process [1]. In previous decades, a great body of research has focused on exploring motivational strategies for STEM education [2, 3]. Also, the theory of learning styles for STEM education was formulated [4] and implemented in real educational environments [1, 5].

In order to master the course material and gain a deep understanding of its' concepts, students' should approach their learning activities in a continuous way [6]. Previous research showed that the majority of students learn in a non-continuous way [7, 8]. When task with a deadline is presented to them, the majority start to learn just prior to the deadline. As for the cause of this, students mostly stated that they lack the necessary intrinsic motivation but also that they expect to be additionally motivated for learning by their teachers [9].

The observed problem of a non-continuous approach to learning among students was additionally explored and a model for an online evaluation system for STEM education was designed [10]. Based on the designed model, a prototype of the system was built and tested in a real educational environment.

The objective of this research is to explore the ways of using summative assessment as a motivational tool among vocational students. Since the vocational study is usually more oriented toward practical application of knowledge, additional motivation can help students whit their obligations that are less practical (such as classical summative assessment). A model for conducting proposed continuous summative assessment sessions was designed, and it was implemented in a real educational environment through an online educational recommender system with evaluation capabilities. Results gained through the conducted research are presented in this paper.

II. THEORETICAL BACKGROUND

This section of the paper presents a theoretical background of the related work regarding the following topics: assessment strategies, learning approaches, and motivation.

In STEM courses formative and summative assessment sessions are usually carried out [11, 12]. Both types of assessment can be conducted in a traditional paper-based way or through the use of the online evaluation systems. *Summative assessments* in STEM courses usually encompass two or three midterm exams with a final exam at the end of the semester. The results of these exams are used for grading students' achievements. These results can have a significant impact on students' future academic and, consequently, career opportunities [13]. On the other hand, *formative assessment* is usually conducted in a continuous way [14]. The main aim of the formative assessment is to generate quick feedback information regarding students' current level of knowledge [15, 16]. With that information, students can focus their learning activities on specific elements within course content that they have to additionally master in order to achieve the desired level of knowledge.

Carrying out assessment sessions should be carefully planned and implemented [17, 18]. Elements that should be considered during the planning phase are a number of students [11], specifics of the learning environment and learning approaches observed among students [19]. Each of these elements contributes to the effectiveness of the conducted assessment session, regardless of the technical way in which the assessment is conducted (classical paper-based or through online system). Also, assessment sessions can be used as a motivational tool within a STEM course [20, 21].

Approaches to learning that can be observed among students can be divided into three main approaches: surface, strategic and deep approach [22, 23]. The *surface approach* can be defined as an approach in which students focus their learning activities on memorizing information without deeper understanding [19, 22]. In the surface approach, students do not try to connect course content with other knowledge outside the course in question. When learning in a non-continuous way, students usually use surface approach. Research regarding students' approach to learning showed that first-year students usually adopt the surface approach to learning [7]. If they are not encouraged to change their approach to learning, there is a high probability that they will retain this approach throughout their studies.

A *deep approach* to learning includes students' intention to understand the underlying ideas of the course content in order to connect it with the knowledge from other courses [7,

19]. Related research results show that students do not tend to adopt a deep approach to learning within traditional learning environments [23]. When students do approach their learning in this fashion, there is a positive correlation between their learning habits and their academic achievements [7]. Also, learning in a continuous way during the semester is a prerequisite for the successful implementation of a deep approach to learning.

A *strategic approach* to learning is a combination of surface and deep approaches [7, 22]. In this approach students tend to organize their learning activities based on the course requirements, thus dividing their learning activities according to the task at hand and other obligations at that time period. When implemented, a strategic approach to learning can be a combination of both continuous and non-continuous way of learning.

Motivation with which students approach their learning activities fundamentally affects their choices, persistence, and performance within the learning environment [24]. Also, motivation is a prerequisite for engaging students to actively participate in the educational process [25, 26]. Although personal relevance, control of the learning process and a sense that students can master the course content are three main elements relevant to student motivation, feedback given to students is one of the most important parts of the motivational process [27, 28]. When planning the motivational strategy for STEM students, these elements must be taken into consideration.

Characteristics of the feedback that is planned for students regarding their coursework must be carefully designed in order to motivate students for future work. Feedback should focus on the effort students have invested in learning but also must give students information on how they can further improve their knowledge. Grading should also be in part in the service of planned motivational strategy and should focus on the course content that student has mastered at the desired level [29].

III. Materials and Methods

This research aims to explore the possibility of using continuous assessment sessions as a motivational tool within a vocational STEM course. Since previous research results showed that students lack sufficient motivation [9] and consequently usually adopt a surface approach to learning when entering higher education [7], the following research questions were explored:

RQ1: Will students be motivated to learn continuously during the semester by using the online evaluation system designed for carrying out organized online summative assessment sessions?

RQ2: Will additionally provided feedback information regarding results, concepts and learning materials be positively accepted and used by students during their learning activities?

A. Course information and participants

In order to conduct the research, STEM course *Electrical Power Networks* was chosen. The course is obligatory in the third year of the Undergraduate Vocational Study of Electrical Engineering at the Faculty of Engineering, the University of Rijeka. The course is taught through ten weekly held lectures that are composed of both theoretical concepts and math-based tasks used for achieving a deeper understanding of the course content. Knowledge assessment during the course includes mostly math-based tasks, which makes this course suitable for this research.

The research was carried out in the academic year 2019/2020. Participants were all students enrolled in the course *Electrical Power Networks* during that academic year (N=36).

B. Implementation of the continuous summative assessment sessions in the ELARS system

The continuous summative assessment was organized according to the model shown in Fig. 1.

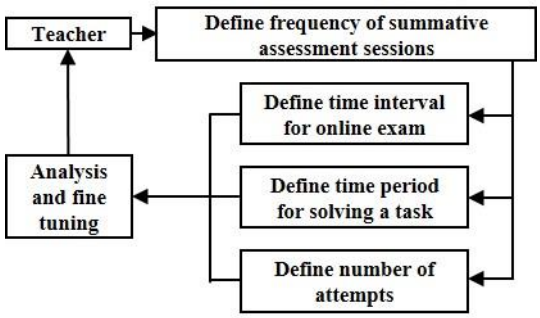

Fig. 1. Procedural model for implementation of continuous summative assessment sessions.

The defined frequency of summative assessment sessions was once a week. The time period defined for the online exam was set at two hours within which students had to initiate a session. The time period for solving each math-based task was initially defined at 30 minutes but was changed in some cases as a result of the analysis and fine-tuning using data collected during formative assessment sessions. For each course topic, a defined number of attempts was set to two.

For each topic within the chosen course, two groups of math-based tasks were organized – one for formative and one for summative assessment sessions. These tasks were of a similar level of difficulty and they were randomly assigned to the assessment session initiated by a student. The number of math-based tasks within the group was high enough to ensure

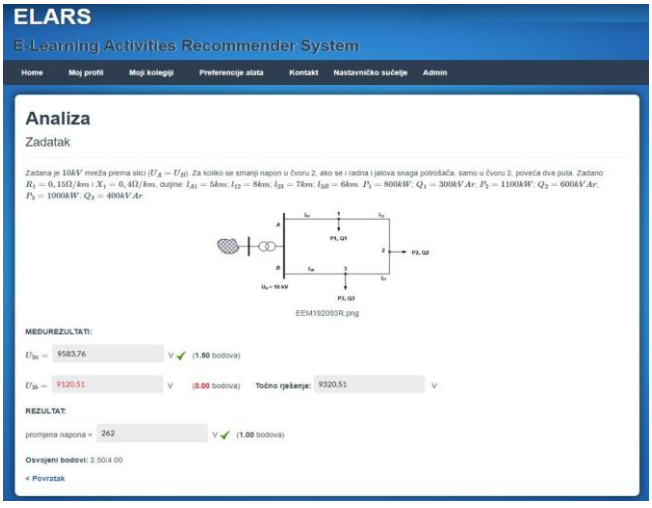

Fig. 2. Feedback information regarding correctness of the answers in the ELARS system.

that the same task is not to be given to the different students within a short time period. An example of the way tasks are presented to the students with feedback information regarding the correctness of the inputted answers is presented in Fig. 2.

The first group of math-based tasks was used for formative assessment sessions. These sessions were used by the students as preparation for summative assessment sessions. After the initial lecture has been finished, students were granted access to the group of math-based tasks connected with the topic of the lecture. Formative assessment sessions were in every aspect identical to the summative assessment sessions (the way in which math-based task is presented to the student, the way for entering intermediate and final results of the calculations, feedback information regarding their correctness and time period available for finishing the task). In this way, students were able to use the system for formative assessment that can prepare them well for summative assessment sessions.

Summative assessment sessions were organized in a two week period after the initial lecture. Due to the organization of all lectures from all courses during the semester, these lectures were given on Tuesdays and summative assessment sessions for that topic were organized on Thursdays in two following weeks (10 and 17 days after the initial lecture). Students were given two attempts for summative assessment of each topic. The better result of the two attempts was used for grading the students' coursework. If students achieved satisfactory results from the first attempt for a topic they were in no obligation to use the possibility of the second attempt.

Each time a summative assessment session was planned students were given two hour period for initiating two math-based tasks from two different topics (one for the first and the other for the second time). Students had to initiate a summative assessment session within that two hour period and to finish the math-based task within a time period defined for that specific topic. The time period for finishing math-based task was identical to the time period defined for formative assessment sessions for each topic.

Since students were unsupervised during the online summative assessment sessions, for this experiment classical paper-based mid-term exams were also conducted. In this way, it was possible to compare the grading points gained through online assessment sessions and corresponding grading points form the classical paper-based mid-term exam. If the results were not similar, it was a sign of fraudulent activities during online assessment sessions. In this situation, a teacher was able to warn the student and to decide if the grading points gained through the online summative assessment sessions will be used for final grading of the students' coursework.

Since formative assessment sessions were conducted prior to the summative assessment attempts, basic statistical capabilities incorporated into the system could have been used in order to verify the length of the time period defined for solving math-based tasks for each topic. If the initially defined time period was too short or too long, this information was used in order to prepare the correct time period for each topic for summative assessment sessions. Using this information teacher can conduct fine-tuning of the initially defined parameters regarding the general model of the procedure presented in Fig. 1.

Once formative and/or summative assessment sessions were conducted, students had the opportunity to revisit the math-based task they were randomly given. Among information regarding the correct intermediate and final results for each task, the students were given feedback information regarding the level at which they have mastered the course concepts associated with each of the results and a link for learning materials prepared for mastering those topics concepts. This feedback information was intended for the student to use in their future learning activities.

Designed model of continuous summative assessment was implemented in Educational Recommender system ELARS (E-Learning Activities Recommender System) which was developed at the Department of Informatics at the University of Rijeka [30]. The system is used for promoting the use of digital tools among students and the personalization of collaborative learning activities [31] and in the last phase of development it has been upgraded with functionalities for knowledge assessment in STEM education.

Fig. 3. shows the way in which overall results gained from students' use of the system are presented in ELARS.

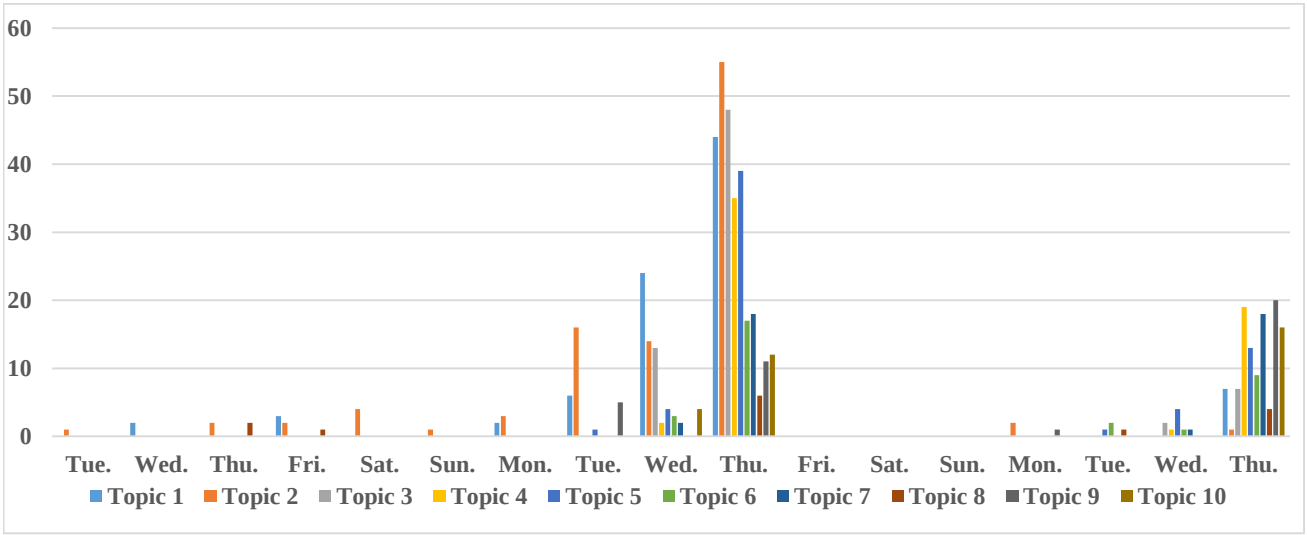

Fig. 3. Timeline with number of initiated formative assessment sessions for each of the topics.

C. Data collection and analysis

Research data was collected from two sources: log files regarding students' activities from the ELARS system and a paper-based survey.

Data collected from ELARS included time use of the system, the accuracy of the results, the number of initiated formative assessment sessions and time periods used for finishing math-based tasks during summative assessment sessions. Out of 36 students that participated in the research, 32 of them used ELARS during the semester.

The survey was conducted at the end of the semester using a paper-based questionnaire. The survey was conducted after the semester coursework was finished but before students take the final exam. Out of 36 students that participated in the research, 24 of them has completed the questionnaire.

IV. Research results

A. Data collected from ELARS

In Fig. 3. a timeline regarding the number of initiated formative assessment sessions within a time period defined for each of the ten topics is presented. Lectures were held on Tuesdays and in the following 17 days student were using the system for formative assessment sessions. Also, on Thursdays in the next two weeks, summative assessment sessions were organized.

As can be seen from the timeline presented in Fig. 3., students used the system for preparing for the summative assessment in roughly the same way for each topic. As the exam date approached, students used the system for formative assessment. For the initial attempt to solve the math-based task for each topic, the student initiates more formative assessment sessions. On the other hand, for a second attempt, the number of initiated formative assessment sessions was significantly lower. Since students were in no obligation to use both possible attempts, it can be concluded that the majority of students were satisfied with the grading points gained from the first attempt.

Also, from the timeline presented in Fig. 3. it can be observed that students concentrated their learning activities during one or two days before the date of the summative assessment sessions. This is consistent with the approach to learning observed during previously conducted research [22, 32], and is usually a result of a number of different causes (other obligations, learning habits, etc.).

Although this pattern resembles the usual non-continuous approach to learning during the semester, in this case, students were actively learning the course material each week, at least for a couple of times during one or two days. From this information, it can be concluded that the answer to RQ1 is positive and that the use of the introduced online evaluation system has motivated students to learn continuously during the semester.

B. Data collection from the survey

Questions in the questionnaire were divided into two groups: learning habits and ELARS influence on them with students' preference regarding the form for conducting exams during the semester, and the way students have used ELARS during the experiment.

As can be seen from the results presented in Table I., the majority of surveyed students approach their learning in a non-continuous way, thus adopting a surface approach to learning. The main reasons for this are their learning habits but also other obligations during the semester. On the other hand, the majority of surveyed students were motivated to start to learn continuously during the semester. These results have confirmed the positive answer to RQ1 that was concluded from the information regarding students' use of the system.

TABLE I. SURVEY RESULTS – LEARNING HABITS AND ELARS INFLUENCE ON THEM WITH STUDENTS' PREFERENCES REGARDING THE FORM OF THE EXAM

I usually prepare for the mid-term exam as follows:	
I start studying just before the exam	70,83 %
I start studying more than a week before the exam	25,00 %
I study continuously throughout the semester	4,17 %
The above-mentioned method of preparation for the mid-term exam is most influenced by:	
A perennial habit of learning that way	41,67 %
My colleagues' learning habits	4,17 %
The number of obligations I have during the semester	54,17 %
Did the weekly organized online summative assessment sessions conducted through ELARS motivated you to study continuously during the semester?	
It encouraged me	66,67 %
It did not encourage me	8,33 %
It did not affect my usual way of learning	25,00 %
Does it suit you that you can take the test more than once and that only your best results are used for grading your work?	
It suits me	91,67 %
It does not suit me	0,00 %
I don't have a preference	8,33 %
Which form of knowledge assessment, that is carried out in writing during the semester, is more suitable for you?	
2-3 classical paper based mid-term exams	20,83 %
Continuous weekly organized online exams	37,50 %
Cobination of classical paper-based mid-term exams and weekly organized online exams	41,67 %

Regarding students' preferences about the form in which exams during the semester are conducted, it can be concluded that the possibility to take the exam more than once with better results used for grading suits the majority of surveyed students. Regarding the form in which exams should be conducted, students tend to lean toward a combination of classical paper-based mid-term exams combined with weekly organized online summative assessment sessions. Since this research was carried out in this fashion, it can be concluded that students have accepted this approach but also that future research into this area is needed.

The second group of questions was referring to the way students have used ELARS. The results for the second group of questions are presented in Table II.

As can be seen from the results in Table II., the majority of students used ELARS during the semester but not for each of the topics. They have used the system mostly in a recommended way (solving math-based tasks within the system) and they combined individual work with teamwork when preparing for the online exams. The use of ELARS has motivated students to solve more math-based tasks than they would usually do when preparing for the exams.

The majority of students took advantage of ELARS capabilities. Feedback information that ELARS has provided has been used by students for focusing their learning activities on specific parts of the course content that they had to

TABLE II. SURVEY RESULTS – THE WAY STUDENTS HAVE USED ELARS

Have you used ELARS in order to prepare for online summative assessment sessions by solving math-based tasks randomly given to you by the system?	
I have used ELARS	33,33 %
I haven't used ELARS	8,33 %
Sometimes I have and sometimes I haven's used ELARS	58,33 %
Have you used ELARS in a recommended way or have you extracted a number of math-based tasks from it and then solved them in a classical way without using the ELARS capabilities?	
I have used ELARS as recommended	50,00 %
I haven't used ELARS as recommended	4,17 %
Sometimes I have and sometimes I haven's used ELARS as recommended	45,83 %
Have you prepared for the online summative assessment sessions conducted through ELARS on your own or with other collegues in a group?	
I have prepared on my own	33,33 %
I have prepared with other collegues in a group	20,83 %
Sometimes I have prepared on my own and sometimes with my collegues in a group	45,83 %
Have you solved more math-based tasks then you would have usually solve while preparing for the exeam because of the possibility to use ELARS?	
I have solved more math-based tasks	75,00 %
I have solved approximately equal number of math-based tasks	16,67 %
I have solved fewer math-based tasks	8,33 %
Have the feedback information regarding correctnes of the results you have entered in ELARS helped you to focus your learning activities on specific parts of the course content that you had to master at a higher level?	
It helped me to focus my learning activities	83,33 %
It didn't help me to focus my learning activities	8,33 %
I haven't used that feedback information for my future learning activities	8,33%
Have you used feedback information regarding level at which you have mastered course content (provided for you by ELARS) for future learning activities and preparation for exam sessions?	
I have used feedback information	75,00 %
I haven't used feedback information	16,67 %
I didn't know that ELARS provide that feedback information	8,33 %
Have you used online learning materials (PDF files) available through ELARS?	
I have used online learning materials	58,33 %
I haven't used online learning materials	29,17 %
I didn't know that I can access that kind of the learning materials through ELARS	12,50 %
Would you recommend ELARS to your collegues for its online testing capabilities?	
Yes	87,50 %
No	12,50 %

additionally master. They have used the information regarding the level at which they have mastered course concepts and have used online learning materials connected to these concepts. Only a small number of surveyed students have stated that they didn't know that ELARS have these capabilities. Also, a majority of students have stated that they would recommend ELARS for its' online testing capabilities to their colleagues.

These results give the answer to RQ2 as positive: provided feedback information regarding results, concepts, and learning materials have been positively accepted and used by students during the semester.

V. Conclusion and Future Research

Helping students to stay motivated during the semester is one of the main goals within the educational environment. Students tend to learn in a non-continuous way due to the number of different factors (such as the number of obligations they have, their learning habits developed before entering higher education study programs, etc.) and they also lack sufficient motivation. To address the observed problem continuous summative assessment sessions were introduced among students enrolled in vocational STEM education.

Introduced continuous summative assessment sessions were organized on a weekly basis and were conducted online using ELARS as an educational recommender system with integrated knowledge evaluation capabilities developed for STEM education. ELARS provided students with possibilities for both formative and summative assessments during the semester. Formative assessment was conducted entirely online, and summative assessment was divided among online environment and classical paper-based mid-term exams. Students have used these capabilities of the system and the results gained through the system logs and conducted the paper-based survey were explored.

From the presented results, both from the students' use of the system and from the paper-based survey, it can be concluded that students have positively accepted ELARS and have used it continuously during the semester. Introduction of ELARS and weekly organized summative assessment sessions have motivated students to start to learn continuously during the semester, thus encouraging them to move from the surface toward a deep approach to learning. Students have retained their learning habit characterized by active learning only a day or two before the exam, but because of the weekly organized online exams have actively learned the course content continuously during the entire semester.

ELARS have been positively accepted by students and the majority of them have used all of its capabilities in order to focus their learning activities on specific parts of the course content. It can be concluded that the introduction of continuous weekly organized summative assessment sessions through ELARS motivated students and helped them to learn continuously during the entire semester.

In the next phase of the research, course concepts will be connected with learning outcomes in order to further develop the capabilities of generating recommendations for students by ELARS. Also, some form of gamification will be implemented (such as digital badges or experience points) to further motivate students for learning.

By introducing new features and using all the available data that can be collected through ELARS and continuing to use weekly organized online summative assessment sessions, it should be possible to additionally influence students' motivation and to help them to spend their learning time more efficiently.

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