Continuous Summative Assessment Sessions as a Motivational Tool for STEM students: a Case Study

G. Durovic
University of Rijeka, Rijeka, Croatia
gdurovic@uniri.hr

Abstract - **While using a classical approach to summative assessment that was based on mid-term exams, it was observed that overall results for each consecutive generation of STEM students at the end of the semester failed to improve. To promote a deep learning approach among STEM students, that can be achieved through a continuous approach to learning, activities for continuous summative assessment were introduced. Students have been given the opportunity to take the test for each of the parts of the course twice in two week period with the best of the two results used for grading. A comparison of the obtained results and results of the previous generations of students was made and it showed that students that participated in the experiment achieved significantly better overall results and understanding of the course materials at the end of the semester. In order to expand the experiment into the online environment, a model for an Education Recommender System with assessment capabilities for STEM education was proposed. Based on the proposed model of the system, the prototype of the system was built, and online summative assessment sessions based on the offline experiment were designed for the next cycle of the research.**

Keywords - summative assessment; STEM; Education Recommender System, ELARS

I. INTRODUCTION

Student motivation for learning is one of the basic elements needed for achieving successful learning results [1]. In order to help students to maintain or increase the level of their motivation, a number of different motivational strategies for STEM (science, technology, engineering, and mathematics) education have been explored in the past decade [2, 3].

Within the education process, assessment sessions can have a great impact on students' motivation. Successful formative assessment results can further motivate students for future learning activities [4], while summative assessment results can have a great impact on career and academic opportunities of students [5]. With the advancement of ICT, the ways in which student knowledge is evaluated have been expanded from the traditional classroom environment toward the online environment. Online evaluation systems that have been developed and tested in real educational environments showed that these systems can also be used for motivational purposes [6, 7].

This paper presents three-year research about the possibility of motivating STEM students to start to learn continuously during the semester. A model of summative assessment that can be used to increase students' motivation for continuous learning is proposed. The model was used with STEM students at the University of Rijeka, Croatia. Two consecutive generations of students were evaluated using classical mid-term exams, while the third generation of students was evaluated using the proposed weekly organized summative assessment sessions. The obtained results showed that students included in the proposed weekly organized summative assessment sessions positively accepted such an assessment model and achieved significantly better overall results. The paper also presents a prototype of an online evaluation system that was build within Educational Recommender System ELARS to enhance the implementation of the proposed assessment model for larger groups of students.

II. PREVIOUS RESEARCH

One of the indicators that can be used for measuring the success of the students' coursework during the semester is the course points score that students have achieved at the end of the semester (before the final exam). Table I. shows the percentage of students with insufficient course points score in two STEM courses at the University of Rijeka (Undergraduate University Study program of Electrical Engineering and Undergraduate University Study of Polytechnics, in both cases for obligatory course *Electrical*

TABLE I. PERCENTAGE OF STUDENTS WITH INSUFFICIENT COURSE POINTS SCORE AT THE END OF THE SEMESTER

Academic Year	**Number of enrolled students**	**Number of students with insufficient** course points **score**	**%**
The University of Rijeka, Faculty of Engineering, Undergraduate University Study of Electrical Engineering			
2015./16.	175	66	37,71 %
2016./17.	171	54	31,58 %
2017./18.	162	64	39,51 %
The University of Rijeka, Undergraduate University Study of Polytechnics			
2015./16.	21	6	28,57 %
2016./17.	30	10	33,33 %

engineering 2.). From the presented data it can be observed that a great number of students in each generation haven't achieved at least minimal course points score needed for taking the final exam (roughly a third of students or more in each generation).

On the other hand, while conducting research on the use of digital tools for learning by STEM students [8], it was observed that students want to be additionally motivated by their teachers. Although the introduction of digital tools for learning within STEM courses was positively accepted by students, it did not significantly affect their motivation for learning the course content [9]. Without sufficient motivation, it was not possible to get students to start learning continuously and to adopt a deep learning approach as their learning practice. The majority of students continued to approach their learning with the aim to just complete the tasks and memorize the minimal amount of presented course content in a so-called surface approach to learning [10].

III. METHODOLOGY

The aim of the research presented in this paper is to explore the possibility of motivating students to start to learn continuously during the semester. Since summative assessment can be used as a motivational strategy [6], the classical approach through mid-term exams can be replaced with weekly organized summative assessment sessions. To organize these sessions, the teacher must predetermine the time required for solving a task (that can be different for each topic), number of attempts for each topic within course, and the time period during which each topic should be in the focus of students learning activities. Therefore, a classical approach to summative assessment through several mid-term exams was replaced by weekly organized summative assessment sessions. The following research questions were explored:

RQ1: Will the introduction of weekly organized summative assessment sessions motivate students to start to learn continuously during the semester?

RQ2: Which form of the summative assessment (through classical mid-term exams or through weekly organized summative assessment sessions) will be better suited for students?

Participants of the research were three consecutive generations of students at the University of Rijeka enrolled in the Undergraduate University Study of Polytechnics that attended the obligatory course *Electrical engineering 2*. The course is taught through weekly lectures that encompass both theoretical part and math-based tasks developed for a deeper understanding of the presented theoretical concepts. In total 78 students were included in the research that was carried out offline in a traditional paper-based approach to conducting exams.

The research was conducted during the academic years 2015./16., 2016./17. and 2017./18. Knowledge assessment of students enrolled in obligatory course *Electrical engineering 2* in academic years 2015./16. and 2016./17. was carried out through the classical summative assessment approach using mid-term exams with math-based tasks. In the academic year 2017./18. knowledge assessment was conducted through introduced weekly organized summative assessment sessions. Starting from the second week of the semester, weekly organized summative assessment sessions started. These sessions were designed for grading smaller parts of the course content. They consisted of the math-based task related to the course content that was presented at the lecture a week earlier. Students had the opportunity to take the weekly exam twice for each topic of the course content during two consecutive weeks. The best result from both attempts was used for grading.

To answer the research questions, results obtained from the third generation were compared with the results obtained from the first and second generations of students. Also, at the end of the semester, the students from the third generation were surveyed using a paper-based questionnaire. Gained results were used for building the online prototype of the proposed system.

IV. RESEARCH RESULTS

When starting to attend universities, students tend to adopt a surface approach to learning resulting in a superficial accumulation of knowledge [11]. This approach can result in inadequate mastering of the course material since previously covered course content must be mastered at the expected level and used while learning the contents that follow. Previous research showed that one of the main contributing factors is students' habit of non-continuous learning [8].

To motivate students to approach their learning in a continuous way is one of the steps that can lead to achieving a deep understanding of the course material [9]. Since the summative approach can have a significant impact on students' career, exam format and number of exams must be carefully planned [5].

While comparing students' results achieved through three mid-term exams for the consecutive generation of students, it was observed that a significant number of students do not achieve enough course points during the semester. For each course, a minimal number of course points are set for the successful completion of coursework during the semester. If the student does not achieve at least a minimal score, that student is excluded from taking the final exam, thus having the obligation to enroll in that same course in the next academic year.

In Table II. the results for achieving at least a minimal course points score at the end of the semester for the three generations of students that participated in the research are shown.

TABLE II. COURSE POINTS SCORE OF STUDENTS AT THE END OF THE SEMESTER

Academic Year	**Number of enrolled students**	**Number of students with insufficient course points score**	**%**
The University of Rijeka, Undergraduate University Study of Polytechnics, obligatory course Electrical Engineering 2			
2015./16.	21	6	28,57 %
2016./17.	30	10	33,33 %
2017./18.	27	1	3,70 %

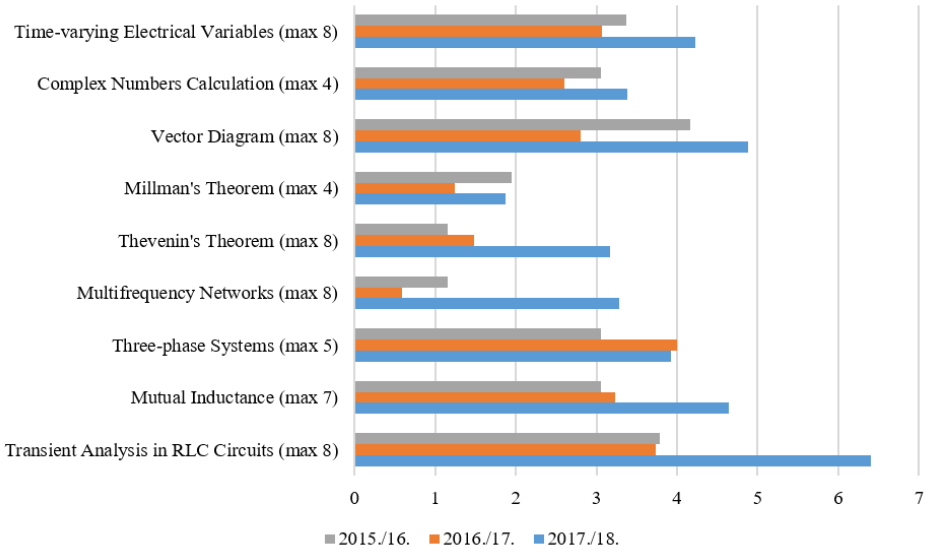

Figure 1. Comparison of overall mean score values of achieved points for nine topics of the course content.

TABLE III. SURVEY RESULTS

I usually prepare for the mid-term exam as follows:	
I start studying just before the exam	60,87 %
I start studying more than a week before the exam	0,00 %
I study continuously throughout the semester	4,35 %
I start studying some of the course content just before the exam while I study other content continuously	34,78 %
The above-mentioned method of preparation for the mid-term exam is most influenced by:	
A perennial habit of learning that way	30,43 %
My colleagues' learning habits	4,35 %
The number of duties I have during the semester	52,17 %
Something else	13,04 %
Did the weekly organized summative assessment sessions encourage you to study continuously during the semester?	
It encouraged me	52,17 %
It did not encourage me	4,35 %
It did not affect my usual way of learning	43,48 %
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	100,00 %
It does not suit me	0,00 %
I don't have a preference	0,00 %
Which form of knowledge assessment, which is carried out in writing during the semester, is more appropriate for you?	
2-3 mid-term exams covering larger sections of the course material	13,04 %
Continuous weekly organized summative assessment sessions of the smaller content of the course material	82,61 %
I don't have a preference	4,35 %
Would you rather prefer that the knowledge assessment is conducted online through weekly summative assessment sessions or through classical mid-term exams conducted offline?	
Online weekly summative assessment sessions	52,17 %
Classical offline mid-term exams	17,39 %
I don't have a preference	30,43 %
If you can choose between online weekly summative assessment sessions and online mid-term exams what form of knowledge assessment would you choose?	
Online weekly summative assessment sessions	78,26 %
Online mid-term exams	4,35 %
I don't have a preference	17,39 %

In order to compare students' achievement within the course content, weekly summative assessment sessions were organized using the same math-based task used in classical mid-term exams carried out with the previous two generations of students. This approach enabled a comparison of results for each of the nine topics of the course content that is evaluated through summative assessments and is used for grading.

During academic years 2015./16. and 2016./17., when classical mid-term exams were used, three topics were part of each of the mid-term exams. Students had two hours to finish the exam and solve three math-based tasks, each corresponding to one of the topics. Each mid-term exam could have been taken only once, and the achieved results were used for grading. The same maximum numbers of points were assigned to the topics in the academic year 2017./18. when weekly organized summative assessment sessions were introduced. Students had the opportunity to take the tasks two times in two consecutive weeks that followed the week in which lecture for that topic has been held. The result from the better of two attempts was used for grading students. For each math-based task, students had half an hour at their disposal. Results for each of the course content topics are shown in Figure I.

At the end of the semester students that were part of the experimental group were asked to express their views regarding their experience with weekly organized summative assessment sessions. With the aim of getting feedback information, a paper-based questionnaire consisting of a set of single-answer multiple-choice questions was devised and conducted. Out of 27 students that were part of the experiment, 23 of them completed the questionnaire.

Detailed results obtained for each prepared question are presented in Table III.

A. Discussion of the results

As can be seen in Table II., respectively 28,57 % and 33,33 % of students in the first two generations have failed to achieve a minimal number of course points required

during the semester. A summative assessment for all students in those academic years was conducted through three classical mid-term exams. When weekly organized summative assessment sessions were introduced, only 3,70 % of enrolled students failed to achieve at least a minimal course points score at the end of the semester. From these results, it can be concluded that a significant improvement in overall results achieved by students through coursework during the semester can be seen.

When mean score values for each of the nine topics that were part of the summative assessment procedures are compared (Figure 1.) it can be seen that for seven topics the results obtained from the experimental group were higher than in two previous academic years. For two topics one of the previous generations of students achieved a slightly better overall mean score (0,07 points difference for Millman's Theorem and 0,08 points difference for Three-phase Systems). However, in topics in which the experimental group achieved better results over previous generations of students, the difference in mean score value ranged from 0,33 points difference (for topic Complex Number Calculation) up to 2,62 points difference (for topic Transient Analysis in RLC Circuits).

Survey results (Table III.) show that the majority of surveyed students start learning just before the exams, mainly because of their other obligations. Weekly organized summative assessment sessions prompted more than half of the surveyed students to start to learn continuously. All of the surveyed students stated that the possibility to take the tasks for each topic more than once suited them. Also, a great majority of them stated that they do like weekly organized summative assessment exams better than traditional mid-term exams. When asked to choose between online weekly organized summative assessment sessions versus offline classical mid-term exams, more than half of surveyed students chose online weekly organized summative assessment sessions. On the other hand, when surveyed students have been asked to choose between online weekly organized summative assessment sessions versus online mid-term exams, a majority of them chose weekly organized summative assessment sessions.

Regarding RQ1, from results obtained through weekly organized summative assessment sessions, it can be concluded that the offline part of the proposed experiment has successfully motivated a number of students in a group to start learning continuously.

Through the conducted paper-based questionnaire used for getting an answer to RQ2, students' opinions showed that the majority of them do prefer the introduced weekly organized summative assessment sessions over classical mid-term exams. Obtained results are also the foundation for building a prototype of the online system based on the previously designed model [9].

V. AN ONLINE EVALUATION SYSTEM PROTOTYPE

The model for an Online Evaluation system for STEM education was designed using previously obtained research results [9]. Results of the offline case-study experiment that are presented in this paper were used in order to build a prototype of the proposed system.

Figure 2. Example of the math-based task in the system prototype.

The model of the proposed system and its' prototype were designed around Educational Recommender System ELARS that was developed at the Department of Informatics at the University of Rijeka. A standard Educational Recommender System (ERS) structure that ELARS was build upon was modified in order to add online math-based tasks testing [12].

Within the prototype of the online system, for each topic that is to be graded, two sets of math-based tasks were envisioned. The first set was planned to be used for formative assessment in preparation for taking the exam. The second set was designed for conducting weekly organized summative assessment sessions. In this way, the prototype of the system will be able to allow the students to use the system in order to practice for the exam by solving math-based tasks of approximately equal complexity as the tasks that will be used for grading.

In both sets of the math-based tasks, a task is randomly selected for each student in each session. The overall number of tasks that students can access is defined by the teacher, according to the overall number of tasks within the set. The same task will not be selected more than once for each student. In Figure 2., a screenshot of the math-based task in the system prototype is presented.

The prototype of the system enables the teacher to define the time period during which students will be able to access each topic, separately for each set of math-based tasks. Also, the teacher can define a time period for solving a task based on the tasks' complexity.

Since the prototype of the online system is built around the ERS structure, the system has the capability to present students not only with the information about the accuracy of the provided answers but also with feedback information about concepts that are graded through tasks. This feedback information that is available for students during the formative knowledge assessment within the practice set of math-based tasks can be used by students in order to identify the parts of the topic content that they have to master at the higher level.

The prototype of the online system is built with the basic statistical capabilities intended for teachers. These capabilities could be used in order to follow students' progress (individual students and the group as a whole).

Since one of the main problems with online testing is the possibility of fraudulent activities, the basic statistical capabilities of the system can also be used in order to detect these types of behavior. For example, since the teacher can see time periods used for solving the math-based tasks for each student and compare them, it can be seen if the student has entered the results in too short or too long a time interval relative to other students. In this case, the teacher can forewarn the student thus preventing the abuse of the system in future sessions, or exclude the suspicious results for selected math-based tasks from consideration when grading the students' knowledge.

VI. Conclusion and Future Research

Using classical mid-term exams for summative assessment for STEM students showed that overall results at the end of the semester were similar and unchanged for consecutive generations of students. Out of all enrolled students, between 30% and 40% of them didn't, through coursework during the semester, achieve minimal course points score needed for taking the final exam. In order to address the observed problem, weekly organized summative assessment sessions were introduced.

As the preparation for building an online prototype of the system for conducting summative assessments in the proposed fashion, the offline experiment was conceived and conducted. The results gained from the experiment showed that students were motivated to learn continuously throughout the semester and that almost all of them achieved at least minimal course points score needed for taking the final exam. Also, feedback information gathered through the paper-based survey at the end of the semester showed that the proposed way of conducting a summative assessment in a weekly fashion was positively accepted. Students also indicated that most of them prefer weekly organized summative assessment sessions over mid-term exam approach, especially if these weekly organized summative assessment sessions are to be conducted online. If conducted offline, weekly organized summative assessment sessions can be extremely demanding for the teacher, especially when a large number of students are enrolled in the course. In order to successfully implement the proposed assessment approach in a real educational environment, weekly organized assessment sessions must be conducted online using adequate online technologies.

Based on the initial results, a prototype of the online evaluation system was built. A prototype was designed around the Educational Recommender System structure based on the previously developed model of an Online evaluation system for STEM students. By combining the ERS structure with math-based testing capabilities, the prototype of the online system could be used for conducting weekly organized summative assessment session and to provide students with quick feedback information regarding their success. The system can be used both for formative and summative assessment, and the gathered data can be used for providing teachers with basic statistical analysis. A combination of recommendations and statistical analysis based on the students' achievements during formative and summative assessment sessions conducted through the system should provide both students and teachers with feedback information that can be used for fine-tuning their learning and teaching activities. In the next phase of the research, the prototype of the system will be used in the real educational environment. The prototype will be refined according to the feedback information gained from students and teachers that will participate in the research.

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