SUPPORT FOR KNOWLEDGE ASSESSMENT IN STEM EDUCATION USING ELARS RECOMMENDER SYSTEM

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Abstract: *Education in STEM disciplines (Science, Technology, Engineering, and Mathematics) is very important for today's students since they will have to be able to successfully deal with the challenges of technological society in the future. In the context of courses related to the STEM, practical application of theoretical knowledge often involves the implementation of complex mathematical procedures and calculations. To enhance the assessment of students' knowledge of such procedures in STEM courses, technology support can be provided to teachers within e-learning systems. This paper presents an approach to support teachers in assessment of learning outcomes in STEM education. The approach is implemented within the educational recommender system ELARS. The system enables teachers to design online assessment activities and monitor students' results, and provides formative assessment support. The paper also presents results of using the ELARS system to support the assessment process in a higher education course.*

Keywords: Educational recommender system, ELARS, STEM, formative assessment

1. INTRODUCTION

Educational recommender systems (ERS) are mostly used to support the learning process by helping students to focus their learning activities on the specific parts of the subject content. In order to do that, ERS could be combined with other digital and pedagogical resources [1].

Educational recommender system ELARS (E-Learning Activities Recommender System) is used to promote the advantages of using digital tools for collaborative learning [2] and STEM education [3], to personalize e-learning activities [4] and motivate students to actively participate in e-learning activities [5]. Since recently, the support for online assessment is implemented within the ELARS system.

Evaluation approaches (such as online assessment) can be either formative or summative. Formative evaluation is generally used in order to create quick feedback to both students and teachers during the semester [6]. Summative evaluation is used at the end of an instructional period (midterm and/or final exam) in order to grade students work and verify the overall effectiveness of the learning process [7], [8]. Using online systems for formative and/or summative evaluation can enhance their effectiveness by providing quick feedback regarding students' success, especially when a great number of students needs to be assessed at the same time [9].

In STEM (Science, Technology, Engineering, and Mathematics), theoretical knowledge is usually transformed into the practical implementation through the use of mathematical procedures and calculations that students need to master [10]. Use of online evaluation systems for conducting formative and summative assessment can help in avoiding surface-approach to learning among STEM students which can result in a lack of deeper understanding of the course content [11]. Also, research results show that students prefer to have access to online evaluation systems because they allow them to organize their study obligations according to their personal preferences [12].

This paper presents an approach to support teachers in assessment of learning outcomes in STEM education using the educational recommender system ELARS. Using the system, the teachers can design the flow of course learning activities that includes online assessments. The system enables teachers to monitor students' results achieved by solving online assessments and provides formative assessment support by generating automatic feedback to students. The paper also presents results and experiences from a higher education course during which the ELARS system was used to support the assessment process.

2. SUPPORTING ASSESSMENT IN ELARS RECOMMENDER SYSTEM

The ELARS recommender system is designed to foster personalization of online learning activities by recommending optional activities, possible collaborators (student peers), and digital tools [2]. In addition, the system offers advice during participation in online activities with digital tools. Recommendations are generated based on students' personal data and achievements during the e-course (preferences for digital tools and learning styles, knowledge level, activity level) as well as on well-defined course learning design where course activities are grouped into learning modules. Students and teachers interact with the system using the ELARS web application [13].

The system was designed, built and tested in real educational environments [14], [15], [5]. Since recently, the functionalities of the system have been amended to support evaluation in STEM education. The part of the system for supporting online evaluation is based on the idea that intermediate results in math-based tasks solved by a student can provide additional information regarding the student's knowledge [16]. Therefore, for each math-based task, the teacher defines as a set of subtasks (several intermediate results and a final solution) and relates each subtask with one or more concepts from the course learning domain. Mistakes in calculation of intermediate results can indicate which concepts were not mastered by the student. Incoorrect answers can also indicate that the student lacks expected foreknowledge about concepts from preceding topics of subject matter.

In the teacher interface, the teacher first defines the tasks for a module. The teacher specifies task text, uploads an image, and lists all subtasks. To enable students to solve tasks, the teacher defines online assessment activity within course learning design. When defining an online assessment activity, the teacher should link a set of tasks, define the maximum number of attempts, and the duration of one attempt. At each attempt, the student have to solve a random task and has limited time (defined by the teacher).

After the task solving attempt, the student can see the analysis with correct and incorrect answers (Image 1). Students can also view summarized feedback on their performance for the assessment activity in which he/she participated regarding solving tasks related to each concept. Presented performance (Image 2) is determined based on the ratio of the number of successful and unsuccessful attempts to solve subtasks associated with a particular concept.

The teacher can get insight into the distribution and the number of attempts made by students (Image 3) and their results. The performance data regarding the concepts of subject matter is also available to teachers.

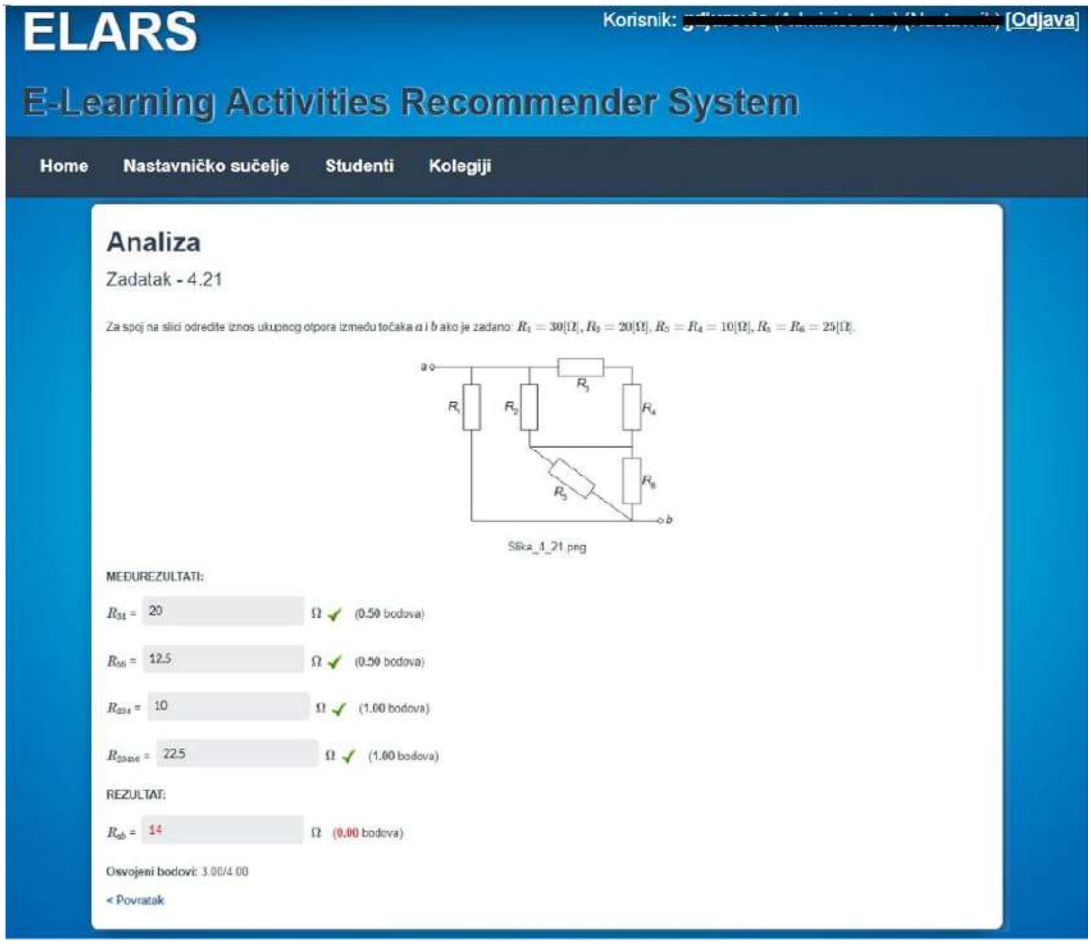

Image 1: An example of practical problem

3. DESCRIPTION OF THE CONDUCTED RESEARCH

The main aim of this research was to evaluate the effectiveness of the developed formative assessment support within a STEM course. The e-course “Electrical Power Networks” which is performed at University of Rijeka was chosen.

Course content and grading components

“Electrical Power Networks” is part of the curriculum in the third year of university undergraduate study program Electrical Engineering (single major) at the Faculty of Engineering University of Rijeka. The course is given 7 ECTS.

The course objectives, in terms of content, are achieving a physical understanding of the electrical parameters of components in electrical power networks, calculation of electrical parameters under particular operating conditions and capability to model and analyse electrical settings in electrical power networks. Finally, objectives include the ability to implement optimal advancements in electrical power networks.

The course is designed in the form of face-to-face (f2f) classes in which the students are expected to actively participate in analysing and solving the presented problems in the field of electrical engineering. Based on the acquired theoretical knowledge, students are expected to gain the ability to use this knowledge in practical applications (in the computational analysis of electrical phenomena and later in the practical work). The course materials used in the classroom, as well as additional materials, are available via LMS system Merlin – Moodle based system used at the University of Rijeka.

The course activities are organized in the following learning modules:

- Quadripoles
- Equivalent model of power lines
- Equivalent models of transformers
- Per Unit Method
- Admittance matrix
- Short circuit calculation (Per Unit Method)
- Electrical distribution power networks
- Reliability of electrical power networks

Regarding the grading components, students can collect up to 4 points on course attendance, 10 points on short tests during the f2f lectures, 16 points on construction projects and up to 40 points on two tests (Test 1 and Test 2) during the semester (20 points for each).

When the semester ends, students should take the final exam and collect up to 30 points. After totaling all points earned, the final grade is given according to the following scale: A (90-100), B (75-89.9), C (60-74.9), D (50-59.9). Students with less than 35 points fail and must retake the course.

The introduction of formative assessment support with the ELARS system

The most important component of the assessment within the course “Electrical Power Networks” are Test 1 and Test 2. By taking those tests students can collect up to 40% of the points for the course. Therefore, activities for formative assessment were introduced before the two tests in order to motivate students to practice solving practical problems to the greater extent as well as to enable students to get insight into their level of success in solving problems similar to those expected in the tests.

Students could use the system for 10 days prior to taking the tests. Within each learning module, students could solve tasks in the pre-set time limits of 30, 45 or 60 minutes, depending on the complexity of the tasks. Also, they could make between 10 and 20 attempts, depending on the overall number of available tasks within each of the learning modules.

Research method and participants

The purpose of presented research was to determine is there any significant difference in students’ results after the introduction of formative assessment support. In addition, the aim was to gather students’ comments that will guide further improvements of the system.

A comparative study was used. For the experimental group, activities for formative assessment were included in the course, just before the Test 1 and Test 2 (that are part of the summative assessment and conducted in a paper-based form). Course points awarded from the Test 1 and Test 2 were collected for the students from the control and the experimental group and compared since they indicate the extent to which students achieved the expected learning outcomes. To select the appropriate test for comparison of two independent samples, the D'Agostino-Pearson test of normality was previously performed. For both Test 1 and Test 2 normality was concluded for the control group but not for the experimental group. Thus, the Mann-Whitney U test for nonparametric independent samples was used. Comments from students from the experimental group regarding performed activities for formative assessment and the ELARS system were collected using a couple of open-ended questions in an anonymous paper-based questionnaire.

The control group of participants consisted of students who participated in the course during the academic year 2017/2018 (N=39). The experimental group consisted of students who participated in the course after introduction of assessment support with the ELARS system, during the academic year 2018/2019 (N=58). The students from the experimental group participated in two activities for formative assessment.

Koncept	Broj točnih pokušaja	Postotak
Množenje matrica	19 / 64	29.69 %
Prijenosne jednadžbe	9 / 32	28.12 %

Image 2: ELARS system - List of concepts with progress results (available to students and teachers)

Red br.	Datum	Četveropoli	Nadomjesni model vodova	Nadomjesni modeli transformatora	Metoda jediničnih vrijednosti	UKUPNO
1.	15.4.2019.	0	1	0	0	1
2.	16.4.2019.	6	0	1	3	10
3.	17.4.2019.	0	4	0	2	6
4.	18.4.2019.	52	21	10	3	86
5.	19.4.2019.	20	26	27	8	81
6.	20.4.2019.	15	23	50	17	105
7.	21.4.2019.	28	20	43	24	115
8.	22.4.2019.	60	53	56	46	215
9.	23.4.2019.	11	6	13	12	42

Image 3: ELARS system - Data regarding the number of attempts made by students (available to teachers)

Results and discussion

Table 1 shows results of comparison of average results (points). A statistically significant difference is present in the case of both Test 1 and Test 2. From this, it was concluded that experimental group students who participated in the activities for formative assessment using the ELARS system achieved significantly better results.

Table 1: Comparison of average results (points)

	Control group AVERAGE	Experimental group AVERAGE	p
Test 1	9.99	13.95	.0003
Test 2	8.32	11.72	.0021

The results shows that ELARS system was useful in supporting the formative assessment during a STEM course. Students were motivated to practice solving practical problems before the test included in the summative assessment. By reviewing the performance data regarding solving tasks related to concepts, students could get insight into their level of success and focus their learning on the specific subject content (both from previously finished and recently taught learning materials).

In their comments, students expressed satisfaction with the system. The majority of them said that they would recommend it to other students and that they would like to use it in the future. Also, they pointed out that they would like to receive recommendations from the system in a form of written or video online materials related to the content of each task within learning modules, colleagues for joint work as well as simple tasks to be solved using digital tools that could help them to master the subject matter.

Student comments provide motivation and guidance for future work and system development toward defining rules for generating recommendations based on the results of online assessments.

5. CONCLUSION

The presented research contributes to field of computer-supported assessment by development of an assessment systems for STEM education within educational recommender system ELARS. The evaluation of the developed functionalities confirmed the effectiveness of the system in a real setting and students' satisfaction with it. In the future research, additional experiments will be carried out to confirm these findings.

In the next phase of the research, students' results collected during assessment activities will be used to generate individual recommendations for students. Recommendations will be based on students' feedback results from already conducted research, thus incorporating online written and video materials, the recommendation of colleagues for joint work and tasks that require the use of digital tools. Each of these recommendations will be tested in a real learning environment.

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