Using Continuous Online Assessment of Learning Outcomes for Grading: a Case Study

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Abstract: In recent years, the problem of the number of students enrolled in STEM courses falling below the minimum required to carry out the courses has worsened. This situation, which used to occur primarily in degree programs at the end of their life cycle, is increasingly happening in active STEM degree programs as well. The declining attractiveness of traditional STEM degree programs and negative demographic trends are seen as the main causes of this problem. To assist students and their teachers in this situation, a novel approach to grading student work based on the level at which students achieve learning outcomes in an online system was explored. Since the focus was on STEM students, math-based tasks were used to assess student knowledge within the online system. In addition to the accuracy of the final results of the tasks, the accuracy of the intermediate results was also monitored. Each result was linked to the corresponding concepts, which in turn were linked to the corresponding learning outcomes. By entering correct intermediate and final results, the online system was able to monitor student success in mastering concepts and learning outcomes. The implemented online system utilizes fuzzy inference to calculate the levels at which students have achieved the learning outcomes. These levels are continuously recalculated during the semester and presented to the students through generated recommendations after each solved task. The proposed approach has positively impacted students' motivation to learn during the semester, as confirmed by an anonymous questionnaire. Additionally, the results have shown that the final level at which students have achieved the learning outcomes within the online system, calculated at the end of the semester, can be used for grading and is comparable to the grades students would achieve in traditional midterm and final exams, thus helping teachers with their workload.

Keywords: E-assessment system, Education recommender system, Learning outcomes, STEM

1. Introduction

In public higher education, a fixed minimum enrollment is often required for ministry funding to support courses. In the Republic of Croatia, this number is set at 10 students. Special permission must be obtained from the Ministry of Science and Education for any study program with fewer enrolled students. If more than 10 students are enrolled in a study program, but the number of students in some courses within that program is less than 10, the courses can be held during the semester, but in this case, the faculty must provide financial resources for them from its own income (Government of the Republic of Croatia, 2019).

Generally, the problem of fewer students enrolled in STEM courses has been observed at the end of their life cycle. When enrollment in the program is discontinued, the faculty is obligated to allow students already enrolled to complete their degree and receive a diploma. Since there are no new students, the number of students in these courses usually drops below the specified minimum of 10 students. This situation can pose a problem for students and teachers in organizing and running a traditional class during the semester. Typically, a consultative teaching approach is used in these cases, where each student works alone and has a set number of meetings with the teacher during the semester. In the past, these consultations were held in person, but today it is more common to organize online consultations. However, online consultations cannot provide the same level of personal experience as face-to-face consultations (Praskac-Salcin, I., 2023). Also, students have to wait for feedback from their teachers until the scheduled consultation session.

With the further development of the Internet, various online systems have been developed to provide the necessary support in such situations. Education recommender systems (ERS) can reduce teachers' workload by helping students with personalized recommendations during their studies (Maphosa, V. and Maphosa, M., 2023). On the other hand, online e-assessment systems (EAS) can help students through formative assessment sessions where quick feedback on their learning performance can be determined (Topuz et al, 2022). In addition, these systems can be used to conduct summative assessments within their current limitations.

In the case study presented here, a hybrid system combining the features of ERS and EAS was used to reduce teachers' workload. The system was designed to provide feedback on the current status of learning outcomes achieved by students during the semester. This information was used as part of the generated recommendations to help students work independently. The data collected through the students' use of the online system was compared with their final results. The main focus of the research was to investigate the possibility of using this online system for grading students based on the level at which they have achieved the learning outcomes during the semester. At the end of the semester, an anonymous questionnaire was administered to get feedback from students about the impact of the designed online system on their motivation to study during the semester.

This paper is structured as follows. After the introduction, the theoretical background for the research conducted is presented. The research design and methodology are then described in detail, including the participants, the research design, and the approaches to data collection and analysis. Next, the research findings are presented and discussed. The paper concludes with a summary of the research conducted and the results obtained.

2. Theoretical Background

Two basic approaches can be used to assess knowledge: formative and summative (Sri, R. L. and Muthuramalingam, S., 2016). Both approaches can be carried out in the traditional way (tests on paper) or with the help of an EAS.

Formative assessment of students' knowledge is usually conducted continuously during the semester (Hamidi et al, 2013) to provide students with rapid feedback on their mastery of the learning content (Petrovic, J., Tralic, D., and Pale, P., 2015). Using this feedback, students can target areas of the course they haven't yet mastered. Properly designed and implemented formative assessments can positively impact their motivation to continue learning (Shafeek et al, 2019).

On the other hand, summative assessments evaluate students and their work. Because of their purpose, summative assessments can significantly impact both academic progress and future career development (Hernández-Leo, D. and Oliver, V. M., 2014). In STEM higher education, summative assessments typically consist of two to three midterm exams along with a final exam.

Ongoing research explores effective online formative and summative assessment methods, leading to the development and adoption of numerous EAS in higher education. Their main feature is the ability to quickly assess the accuracy of results and provide feedback. Furthermore, teachers can use them to track student progress and tailor teaching activities to individual or group needs (Topuz et al, 2022).

EAS typically consists of five basic parts: User Model, Domain Model, Adaptation Module, Evaluation Module, and Interface. The User Model, essential for the system's operation, stores both modifiable and non-modifiable data, which are updated during system use. The Domain Model contains the tasks used to evaluate user knowledge. The Adaptation Module selects tasks tailored to each user based on predetermined rules, including knowledge, skills, and preferences. The Evaluation Module checks the correctness of the entered task solutions and provides feedback to the user. The Interface facilitates communication between the user and the system (Lukashenko, R. and Anohina, A., 2009).

ERS have been developed to help students find the information they need within the vast amount of available information (Roy, D. and Dutta, M., 2022). These systems enable students to build their own personalized learning environment based on their unique characteristics and needs (Göksel, N. and Mutlu, M. E., 2021).

The basic structure of ERS consists of four parts: User Model, Domain Model, Recommender, and Interface (Wu et al, 2020). As in any online system, the User Model describes the user for the system's operation. It usually has dynamic properties, with data about the user's activities and progress constantly updated (Muhammad, A. H. and Ariatmanto, D., 2021). All recommended content is stored in the Domain Model with additional information about how it can be linked to the user's needs. All algorithms and rules used to generate individual recommendations are part of the Recommender. The generated recommendations are presented to the user via an Interface.

Learning outcomes (LO) are defined as written statements expressing what students should know, understand, and/or demonstrate after completing a learning process. In a study program, LO are determined at the level of the entire program, individual courses, or each lecture. Critical to LO implementation is aligning them constructively with educational elements such as activities, teaching, and assessment methods (Kovac, V. and Kolic-Vehovec, S., 2008). Ensuring constructive alignment requires understanding the relationship between activity time and students' ability to achieve defined LO.

Additionally, appropriate teaching methods and techniques must be chosen to ensure students achieve LO (Njuguna, J., 2020). Assessment of the level at which students have achieved LO is done through appropriate formative and summative assessment approaches (Zhang et al, 2022).

Students benefit greatly from understanding and utilizing LO during their studies, helping them organize study time and anticipate course content for assessments (Pokorni, S. and Kuleto, V., 2022). Ignorance or misunderstanding of LO can lead to weaker results in examinations (Sweetman, R., 2017).

3. Research Design and Methodology

The study explored using an online system combining ERS and EAS features to grade students at semester's end. The system provides individualized recommendations with progress bars and percentages showing LO levels. These levels are based on formative assessment data compared to actual grading levels from two midterms and the final exam.

The research, a quasi-experiment in three courses, used a between-subjects design. This method was chosen due to the small student enrollment, making it impractical to form control and experimental groups. Instead, comparison groups were created from students in the previous academic year. Two research questions (RQ) were proposed:

RQ 1: Did the introduced mandatory formative assessment activities conducted using the online system motivate students to learn continuously during the semester?

RQ 2: How do student grades achieved through the online system compare to traditionally produced final grades (through midterm and final exams)?

3.1 Participants

The research involved courses in Electrical Power Networks, Electrical Substations Equipment, and Power System Protection from the vocational undergraduate program in Electrical Engineering at the Faculty of Engineering, University of Rijeka. Conducted in the 2022/2023 academic year, the experiment included 44 male students (ages 21-23). The comparison groups, from the 2018/2019 academic year, comprised 128 students (123 male, 5 female, ages 21-23), chosen to avoid COVID-19 pandemic-related influences.

Students in both groups were compared based on GPA and final grades from four previous courses. The GPA data distribution was normal, so a parametric t-test with a significance level of $p < .05$ was used. The t-test results showed no significant statistical difference between the groups (Electrical Power Networks: $p = .1417$; Electrical Substations Equipment: $p = .7819$; Power System Protection: $p = .2930$).

Final grades in the four courses did not follow a normal distribution (confirmed using the Shapiro-Wilk test with a significance level of $p < .05$; each dataset had a p-value of $< .005$). Therefore, a non-parametric Mann-Whitney U test with a significance level of $p < .05$ was used for comparison. The results presented in Table 1 show no significant statistical differences between the groups of students analyzed.

Table 1: The results of Mann-Whitney U test

Course	Electric Power Networks	Electrical Substations Equipment	Power System Protection
Mathematics 1	p = .764	p = .271	p = .322
Mathematics 2	p = .204	p = .060	p = .289
Electrical engineering 1	p = .689	p = .112	p = .516
Electrical engineering 2	p = .795	p = .589	p = .928

3.2 Study Design and Procedure

At the University of Rijeka, each course awards 100 assessment points (AP) for the final grade: 70% from semester activities (midterms, lab work, group work) and 30% from the final exam. Teachers assign AP for each activity, and students need over 35 AP from semester activities to qualify for the final exam. Final grades are based on total AP: 0-49.9% (F), 50-59.9% (D), 60-74.9% (C), 75-89.9% (B), 90-100% (A).

The semester has fifteen weekly lectures, each followed by a formative assessment requiring students to solve at least three math-based tasks online within fifteen days. Failure to do so disqualifies them from completing the course that year.

The online system provides individual recommendations and updates on LO achievement through progress bars and percentages. At the semester's end, students see their final LO achievement levels.

Each course includes three midterm exams after specific lectures. The exams match the difficulty of online tasks, with AP distributed as 20 for the first, 30 for the second, and 20 for the third, totaling semester AP. To pass, students need at least 15 out of 30 AP on the final exam.

3.3 Implementation of the ELARS Online System

To implement the proposed approach to assessing student work using learning outcomes (LO), an online system was developed that combines features of Education Recommender Systems (ERS) and E-Assessment Systems (EAS). An ERS called ELARS (E-Learning Activities Recommender System) (Hoic-Bozic, N., Holenko Dlab, M., and Mornar, V., 2015) served as the basis, and the system was extended to include assessment capabilities (Durovic, G., Holenko Dlab, M., and Hoic-Bozic, N., 2019). Given the focus on STEM students, the assessment was designed with math-based tasks for formative assessment.

Each course had a set of math-based tasks (52 for Electrical Power Networks, 95 for Electrical Substations Equipment, 97 for Power System Protection) divided into subsets corresponding to lecture content. Students entered intermediate and final results for each task, linked to concepts and LO as defined by the teacher.

Formative assessments in ELARS allowed continuous monitoring of student progress. Quick feedback indicated correctness, with corrections for errors. Achievement levels for LO were updated and presented in ELARS after each task, and recommendations for the next learning steps were given. Students could choose to ask peers for tutoring, review material, solve more tasks, or move to the next topic. These options were paired in ELARS recommendations, allowing personalized learning.

3.4 Data Collection and Analysis

Both qualitative and quantitative data were collected during the experiment. Information on students' grade point average and final grades in four core courses was used to compare the two groups. Based on the data distribution, both the t-test and the Mann-Whitney U-test were employed.

System logs in the online system tracked students' activities and progress. To calculate the current level at which students achieved learning outcomes (LO), the accuracy of intermediate and final results, as well as the number of solved tasks and average solution time, were analyzed. A fuzzy inference system was designed to model the approach a teacher would take when assessing math-based task solutions. After each attempt to solve a randomly assigned task, the system calculated the current level at which students achieved the LO. This level was continuously presented to them as part of the generated recommendations.

At the end of the semester, an anonymous questionnaire with 15 questions was administered. The questionnaire included a Likert scale (1 - strongly disagree, 2 - disagree, 3 - no opinion, 4 - agree, and 5 - strongly agree) to gather responses for statistical analysis.

4. Research Results

Out of 44 participants, 39 qualified for the final exam. Their total AP were compared with results from the comparison groups. Table 2 shows the results in terms of AP earned for the experimental and comparison groups.

Table 2: Comparison between experimental and comparison groups using earned AP

Course	Academic year	N	Earned at least 35 AP		Number of students who failed the final exam	Mean value of earned AP (overall results)
			N	%		
Electric Power Networks	18-19	36	20	55.55	2	77.06
	22-23	11	10	90.91	1	75.30
Electrical Substations Equipment	18-19	47	21	44.68	0	78.24
	22-23	14	12	85.72	0	78.12
Power System Protection	18-19	45	26	57.78	3	76.74
	22-23	19	17	89.47	0	77.15

System logs were used to monitor the time dynamics of students' work during the semester. To utilize the final results of the levels at which students have achieved LO within the system, it is crucial that students work continuously throughout the semester. Data on daily task completion was collected, as students were required to solve three tasks per lecture within a fifteen-day timeframe. Figure 1 illustrates the time dynamics for all three courses observed.

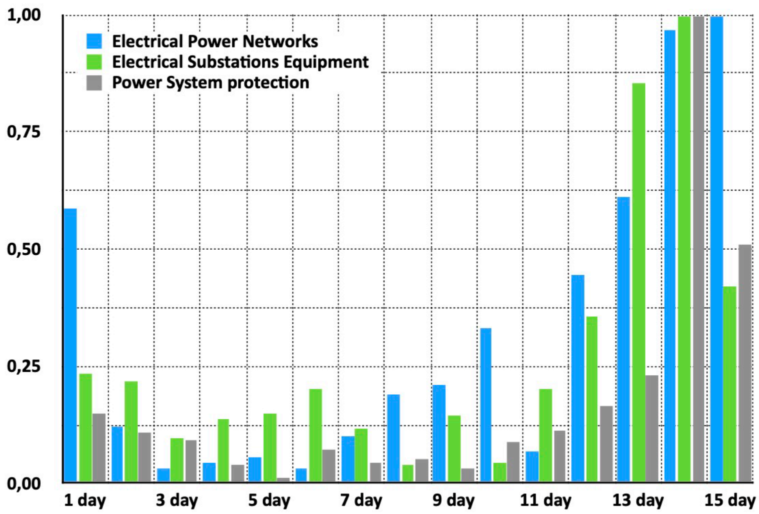

Figure 1: Time dynamics of the students' work during the semester

The online system monitored progress on learning outcomes (LO) by displaying the current percentage completion. Final results were subsequently compared with Assessment Points (AP) earned in midterm and final exams. As mentioned earlier, AP reflect the percentage of grades earned by students throughout the semester and in the final exam. Therefore, the percentage of LO achievement in the online system was converted to points (LO achievement points) and compared with the actual AP earned by each of the 39 students. This comparison is shown in Figure 2.

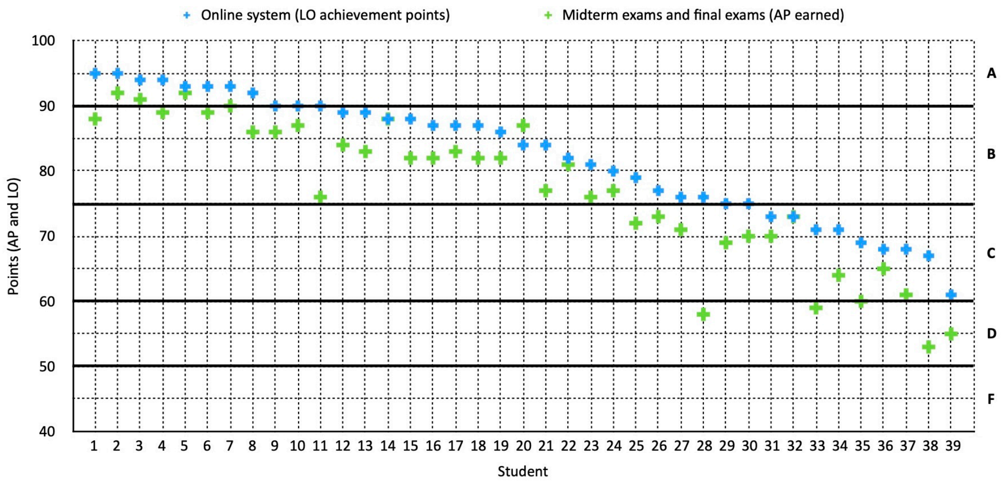

Figure 2: Comparison of AP earned through the exams and LO achieved in the online system

In addition, the earned AP and the achieved LO were compared using the Mann-Whitney U test. The results of the statistical analysis are shown in Table 3.

Table 3: Statistical analysis of the comparison of AP earned and LO achieved using Mann-Whitney U test

Course		Median	Min	Max	p-value
Electric Power Networks	AP	74.50	60	92	p = .405
	LO	79.50	68	93	
Electrical Substations Equipment	AP	82.00	55	91	p = .165
	LO	87.00	61	95	
Power System Protection	AP	77.00	53	92	p = .129
	LO	84.00	67	95	

An anonymous questionnaire was administered at the end of the semester to gather feedback from students on the impact of the introduced mandatory formative assessment on their motivation to study. Out of 44 enrolled students, 42 completed the survey. The most significant results regarding the impact of the online system on their motivation are presented in Table 4.

Table 4: Results obtained through anonymous survey

Question	Likert					Avg	Var	SD
	1	2	3	4	5			
The obligation to continuously solve tasks during the semester had a positive effect on my motivation to study.	0	0	2	6	34	4.76	0.28	0.53
Using the online system, I solved more tasks than I would solve otherwise (without using the system)	0	0	0	14	28	4.67	0.22	0.47

5. Discussion

The RQ 1 was: Did the introduced mandatory formative assessment activities conducted using the online system motivate students to learn continuously during the semester? As shown in Table 2, a comparison of students in the experimental groups with those in the comparison groups based on the number of Assessment Points (AP) achieved during the semester revealed a significant increase in the number of students eligible to take the final exam. Specifically, there was an increase of 35.36 percentage points for Electric Power Networks, 41.04 percentage points for Electrical Substations Equipment, and 31.69 percentage points for Power System Protection. These results confirm that the proposed method of motivating students to learn continuously during the semester by introducing a mandatory activity related to a minimum number of tasks to be solved within fifteen-day period after each lecture using the online system helped them to achieve better results at the end of the semester. This outcome was also validated through the survey. Students indicated that the introduced mandatory activity motivated them to engage in learning and solve more tasks using the online system (Table 4).

Figure 1 illustrates the time dynamics of students' work during the semester, showing their continuous approach to learning as observed by the daily number of tasks attempted. Students effectively utilized their study time throughout the semester rather than concentrating efforts solely near the mid-term exam dates.

Based on these results, it can be concluded that the answer to RQ 1 is affirmative: the introduction of the mandatory formative assessment activities using the online system motivated students to learn continuously during the semester.

The RQ 2 was: How do student grades achieved through the online system compare to traditionally produced final grades (through midterm and final exams)? At the semester's end, the percentages corresponding to the levels at which students achieved the Learning Outcomes (LO) were converted into LO achievement points. These points were compared with the total number of AP that students achieved after taking the final exam. The result of this comparison for the 39 students who earned the right to take the final exam shows that these scores follow a similar trend, with minor differences in certain cases (see Figure 2). The Mann-Whitney U test comparison (see Table 3) revealed no significant statistical difference between these two sets of data. This result further confirms that the levels at which students achieved the LO within the introduced online system can effectively be used for grading students.

Analysis of individual student data reveals discrepancies in final grades, which could differ if based solely on LO achievement levels in the online system. These differences are noticeable near the established grading thresholds (see Figure 2). However, for the majority of students, these discrepancies do not exceed one grade higher or lower than the assigned grade based on AP earned through midterm and final exams (only one student has a greater difference – student 28).

With these limitations in mind, based on the results obtained, it can be concluded that the answer to RQ 2 is affirmative: Students would achieve comparable final grades if grading was based on the achieved level of LO obtained through the developed online system (when compared with grades achieved through midterm and final exams).

There is a substantial body of research by authors such as Cigdem et al. (2024), Mushtaq et al. (2024), Popovska Dimova and Popovski (2024), and Sun (2018) regarding the use of continuous formative assessments to motivate students, which is directly related to RQ 1. The findings of the research presented in this paper are consistent with these results and build upon them to expand our understanding of the impact of continuous formative assessment on student motivation. However, there is limited research on the use of LO for grading. Authors Cifuentes Gomez and Santelices (2024) have provided a systematic review of institutional contributions to LO, where a small number of research papers connect LO with student grades. The findings presented in this paper enhance our understanding of this connection by exploring new possibilities in using the levels at which students achieve LO to determine their grades.

6. Conclusion and Future Work

When course enrollment is below the minimum required, teachers must adapt their course delivery methods. Online systems can be very useful in such cases. This research introduces an online system combining ERS and EAS features to grade students based on LO achievement levels. These levels, assessed by a fuzzy inference system, evaluated the correctness of math-based tasks completed by students. Continuous semester-long engagement with the system was essential for utilizing the achieved LO levels as proposed.

The research findings confirm that the developed online system effectively motivates students to study continuously throughout the semester and allows for the assessment of their overall performance based on their LO achievement levels. These levels were compared with the actual Assessment Points (AP) scores achieved by students in midterm and final exams, and the data analysis confirmed that there is no significant statistical difference between them.

However, there are limitations to the proposed approach. In some cases, grades based on AP scores differed from those based on LO levels. Additionally, without final exams, students would not have the opportunity to improve any weaker grades earned during the semester. Furthermore, since the proposed method relies on students' work in uncontrolled conditions, the issue of potential academic misconduct during student work also arises.

Future research activities will address these limitations and will be conducted within the project “Support for personalized learning in STEM based on learner personas and recommendations”. Different approaches will be tested, such as reorganizing classes to ensure that mandatory task-solving is carried out in a controlled environment, while still allowing students the option to take the final exam if they are not satisfied with their semester performance. Additionally, there are plans to create learner personas based on observed student work habits in the online system to provide more timely and accurate student descriptions. Also, since in this research a number of participants was relatively small, a larger number of participants will participate in future experiments.

By incorporating these improvements, it should be feasible to provide teachers with an online system that supports them by alleviating their workload, particularly in situations where adjustments to the entire teaching and assessment process are necessary due to low enrollment or course discontinuation. In this way, the research presented in this paper aims to expand understanding of the positive impact that continuous assessment of learning outcomes, conducted using appropriate online systems, can have on learning and teaching processes.

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