Formative e-Assessment in Engineering Education

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Abstract: This paper presents a pedagogical practice introduced to second-year undergraduate Electrical and Electronic Engineering students to enhance learning and understanding during the classes. The practice consisted of four formative, objective-type e-assessments taken in two months. Each assessment followed a two-week teaching period. During the e-tests, the students used their notes and worked in groups or independently. Each test included a small number of problems in Electronics uploaded at the course's web page. The assessments were not competitive, and the students were allowed to discuss the solutions with the tutor during the problem-solving session. After the fourth test, the students evaluated the practice by answering a survey. The responses showed high satisfaction with the e-assessment, student retention during classes and active participation. The e-assessment increased students' engagement through interactive learning in a non-competitive environment, followed by a moderate improvement in the final examinations' grades. This paper highlights the opportunity to mobilise students' active participation in the lectures and bring closer teaching, learning and assessment with the help of the Learning Management System (LMS).

1 INTRODUCTION

Tutors and educational institutions are concerned with student performance manifested in grade distribution, completion of the studies and student retention. Student engagement is a complex construct that makes student success more probable. It accounts for students' connectedness to the institution, and it is related to self-regulation of learning. Engagement and self-regulation in learning are considered to positively impact student performance and retention (Kahu & Nelson, 2018; Gourlay et al., 2021; Carmona-Halty et al., 2021). Fine-tuning of the student-institution interface increases feelings of acceptance, support and belonging and positively affects engagement. However, engagement is not the only construct linked to student performance. Interest and caring for the students have also been proposed to drive student success. Interest increases student motivation for learning and positively impacts academic performance (Harackiewicz, Smith & Priniski 2016). Caring for the students mobilises their willingness to learn and enhances participation in classroom activities (Miller & Mills, 2019; Miller 2020). If student success is the desired outcome, engagement, care for the students, and interest are equally probable antecedents, although the first has attracted the most attention. However, student engagement requires a more holistic intervention at the level of the institution while cultivating a friendly, supportive and inclusive learning environment lies in the hands of the tutor. Classroom-based interactive activities have a more local character, facilitating co-regulated learning. Formative e-assessment asks the students 'to do' rather than passively listening during classes.

Recent literature reviews conclude that formative e-assessment results in co-regulation of learning and motivation (Andrade et al., 2021). However, it is still not clear whether self-regulation (Allal, 2019) or co-regulation (Yang, 2019) is the outcome of this classroom student-centred activity.

Besides, e-assessments provide feedback to instructors and students (Kearney, & Perkins, 2014; Farrag, 2020; Andrade et al., 2021), which is particularly useful in evaluating the quality of teaching and learning (Black & Wiliam, 2006).

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Formative e-assessment gauges students' development and has been characterised as "assessment for learning" (Biggs, 1999).

Wiliam and Thompson (2007), inspired by strategic planning, linked formative assessment to the following questions: "Where am I now in terms of learning?", "where I must go?" and "what needs to be done to get there?". They proposed that formative assessment consists of five key strategies resulting from the above questions: 1. Clarifying and sharing learning intentions and criteria for success; 2. Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding; 3. Providing feedback that moves learners forward; 4. Activating students as instructional resources for one another; and 5. Activating students as the owners of their learning.

Feedback is helpful to the student, but it does not necessarily lead to good results. Only the students who use feedback to self-regulate their learning (Perrenoud 1998, Black & Wiliam 2009) or proceed to corrective activities, e.g. revision (Chaktsiris & Southworth 2019), are more likely to succeed. The spatial and temporal distance between feedback and the corrective action requires the student to have an adequate level of interest, engagement, or self-motivation to invest time and effort in more studying. Giving time to the students to test their understanding, identify misconceptions and learn during the classes can enhance their self-efficacy, cognitive engagement and self-regulation. The skill of self-regulation is acquired through social interactions, which enhance students' self-efficacy (McInerney & King, 2018). Making the formative e-assessment a non-competitive classroom activity allows instant feedback and correction during the assessment. This strategy is attractive even to the students who are not high performers.

Relative to the five critical strategies suggested by Wiliam and Thompson (2007), our conception of the formative e-assessment suggests that:

1. It creates an environment that resembles summative assessment but is less stressful and more supportive. It supports the students to realise the learning objectives of the course through collaborative problem-solving.
2. It allows the students to receive support from the tutor and cooperate with peers to enhance rather than merely evaluate their understanding.
3. Students do not receive feedback after the assessment; it is available as they try alternative problem-solving strategies. It provides feedback for understanding.
4. It removes competition between students or groups of students. The students have a common objective: to understand.
5. Students use their class notes and cooperate with peers. They start thinking of teaching, learning and assessment as a whole.

The research questions of this publications are:

a) Which are the students' attitudes towards the studies and the proposed practice?

b) To what extent do the students consider the particular practice appropriate for other courses?

2 THE PEDAGOGICAL PRACTICE

Analogue Electronics II is a second-year course delivered during two 3-hour sessions per week. The course introduces the students to linear and high-frequency amplifier models, multistage amplifiers, AC and DC coupling of amplifiers, op-amps and advanced op-amp applications, power amplifiers, thermal analysis, distortion and noise, feedback topologies, oscillation criteria and multistage amplifiers' feedback analysis. It includes circuit analysis and design using circuit simulation software.

In October 2021, a formative e-assessment practice was introduced. The proposed practice was designed to bring closer teaching, learning and assessment trigger dialogue and cooperation between the students and between the students and the tutor. It was considered an opportunity to increase students' interest in the lectures, ignite active participation and make learning and understanding a classroom activity. There was no restriction to the resources used, allowing the students to work in groups and consult the tutor. Giving time to the students to experiment during the classes would make them realise that learning is highly valued. The tutor's presence and support during the formative e-assessment demonstrated caring for their understanding (Miller & Mills, 2019; Miller 2020). It also showed the students that learning and understanding are not tasks of the lonely learner that take place a few days before the exams, but part of teaching and the tutor's interest. The proposed practice aimed to improve student retention, motivate them to follow the classes actively and increase students' success in the final exams.

Every second week the students dedicated one hour to the practice. At the end of the fourth week, the tutor presented the project outline and explained its objectives. Each e-test consisted of three to four problems presented in multiple-choice, multiple correct or right-wrong questions. Before each e-assessment, the problems were uploaded to the course's LMS in the form of objective questions. The students accessed the problems using their mobile phones and submitted the number-answers electronically. Answering the questions demanded calculations, circuit drawing and extended thinking. Marking was done automatically, and the students received feedback immediately after the e-assessment.

Problem-solving is central in engineering education. Problems in electronics involve circuits, power sources, conventions regarding the currents and the potential, etc. A circuit is not merely a drawing of interconnected devices but involves visualising imagery, extended thinking, and other non-routine activities. The topology of a circuit intervenes with the "canonical object frames" (Chi, Feltovich, Glaser, 1981) of the various devices and the current and voltage interrelations. Overcoming misconceptions on physical quantities and using correct approximations is necessary for successful problem-solving in engineering studies. Good knowledge of theory alone is not enough to solve problems, and problem-solving is an effective way for students to exercise their understanding of electronics (Photopoulos, Triantis, 2022).

The students were allowed to work in groups or individually. They used their class notes and asked for help from the tutor. However, the students could consult the tutor after completing a solution. The problem solutions became available to the students immediately after the e-assessment on the course's web page. The first e-assessment was introduced at the end of the sixth week. At the end of the semester, the students evaluated the practice using a questionnaire. Apart from demographic information, the questionnaire collected information in two directions. The first had to do with students' attitudes concerning their studies, namely what they do during the classes, how they learn, how much effort they put into studying independently, and years to complete duration. The second was on the evaluation of the applied practice.

3 COLLECTION OF DATA

During the 12th week of the course, the participants were invited to evaluate the pedagogical practice. The participation was voluntary, the responses were anonymous, and consent was obtained before the 56 participants (50 male and six female) entered the research. One of the authors created the questionnaire hosted on the Google platform. There were no incentives for completing the questionnaire. The items were written in Greek, and the link to the survey was communicated to the participants via e-mail. The demographic questions collected information on age, gender and year of enrolment. Half of the participants were in the second year of their studies. In the first section of the questionnaire, the students gave a snapshot of themselves as learners. For example, the item 'As far as my studies are concerned, I am a self-disciplined person' recorded students' beliefs on self-control. Other items asked the students what they do when following lectures, (take notes, focus on what is said or focus on the blackboard), hours of home study, and whether they mostly learn studying at home or during the lectures.

The second section of the questionnaire recorded students' experience of e-assessment (Table 1). The responses were on a Likert-type scale ranging from 1 = 'I totally disagree' to 10 = 'I totally agree' (Table I). The questionnaire included a free text answer on the evaluation of the practice. Ninety per cent of the respondents considered the e-assessment "a positive experience."

Table 1: Questionnaire scoring.

	Item	Mean	SD
1	The e-assessment allowed me to understand better.	8,14	2,28
2	The e-assessment helped me to clarify aspects I had not understood.	8,05	1,85
3	The e-assessment made me pay more attention during the lectures.	8,32	1.85
4	During the e-assessment, I worked productively.	8,18	1.61
5	The e-assessment motivated me to learn.	7.68	2,12
6	The e-assessment showed me that the tutor cares for our learning.	8,68	2.13
7	The e-assessments were carefully prepared.	8,54	1,57
8	The e-assessment took place at the right moment.	8,32	2,02
9	The fact that we were all working together created a sense of "community".	7,89	2,10
10	I would like to have e-assessments in other courses.	8,18	2,33
11	If there are e-assessments in other courses, I will attend more lectures.	8,21	2,01

4 RESULTS

The first section of the questionnaire recorded students' attitudes regarding their studies. The item 'As far as my studies are concerned, I am a self-disciplined person' recorded students' beliefs on self-control. The average score was 6.4 out of 10 (S.D.=2.2). The students also reported a high degree of self-determination 'When I set a goal in my studies, nothing distracts me from achieving it' (Mean=7.4, S.D=2.0). The quantitative data showed that the majority (64%) of the students consider that most of their learning happens during the lectures. Only 57% of the respondents take notes during the classes, 16% focus on the blackboard, and the rest 27% just listen. Only 36% replied that they mostly learn "studying at home."

A Chi-squared test examined whether there was an association between what the students do during the classes, i.e., take notes, look or listen and how they learn, i.e., in the classroom or studying at home. The result ($\chi^2(2,56)=1.86$, $p>.05$) showed no statistically significant association. A high percentage of the students (43%) follow the lectures rather passively, and the majority of them (64%) expect to learn during the classes.

Students reported on average 8.2 (S.D.=4,5) of home-study hours per week and an expected average duration of studies equal to 6.4 years (S.D.=2,2) when the degree duration is five years. We divided the respondents into two groups depending on the expected years of graduation. The students of the first group expected to get their degree in 5 or 6 years and the second group in 7 or 8 or more than eight years. The students who 'mostly learn studying at home' reported an average of 10.7 hours (S.D.=4,6, N=20) of study per week, while the students who 'mostly learn during lectures' reported 6.9 hours (S.D.=3.8, n=36). The 2X2 Chi-square test showed a significant association between the categorical variables $\chi^2(1,56)=7.45$, $p=.006<.05$ indicates that the mean study hours difference is not a sampling artifact. We identified a weak association between the 'hours of study category' and the self-control over the studies variable $\chi^2(1,56)=4.83$, $p=.028<.05$. Therefore, studying harder is associated with the perception of higher self-control.

We performed a Chi-squared test to examine the association between the "duration of studies" and students' learning habits, i.e., whether they learn by studying at home or during classes. We concluded that there is no significant association between the two variables ($\chi^2(1,56)=0.51$, $p>.05$). Similarly, there was no significant association between the expected duration of the studies and what the students do during classes, i.e., whether they are note-takers, listeners, or focus at the board ($\chi^2(2,56)=1.54$, $p>.05$).

We divided the respondents into two groups depending on the expected years of graduation. The first group of students declared that they expected to get their degree in 5 (the minimum duration of studies) or six years, while the second group of students expected to obtain their degree in 7 or 8 or more than eight years. Sixty-six percent (66%) of the respondents expect to receive their degree in 5 or 6 years, and the rest 34% in more than six years. Higher self-control over their studies was weakly associated with expectations of faster graduation $\chi^2(1,56)=4.37$, $p=.037<.05$. Finally, higher self-determination over the studies was associated with fewer years to graduation $\chi^2(1,56)=5.39$, $p=.02<.05$.

To explore the factor structure of the second section of the questionnaire, an exploratory factor analysis with oblique rotation (Direct Oblim) was performed. The Kaiser-Mayer-Olkin measure of sampling adequacy was found equal to .89, above the recommended value of .6, indicating that the variables were adequately correlated for factor analysis. This result was verified by Barlett's test of sphericity, which was found to be significant $\chi^2(56)=472$ $p<.001$. The communalities were all greater than .6, confirming the shared variance between the items. Kaiser's criterion for eigenvalues greater than 1 yielded a two-factor structure. The first factor labeled "attitudes" included eight items (items 1 to 8 in Table I) and explained 63% of the variance. The second labeled 'prospects of the proposed practice' (items 9 to 11 in Table I) explained 11% of the variance. The correlation between the two factors was 55%. Cronbach's alpha for the 'attitudes' factor was .91, and for 'prospects of the proposed practice ' .80 indicating the internal consistency of the two subscales.

The Shapiro–Wilk test of normality showed that the compound variables' attitude' and 'prospects of the proposed practice' do not follow the normal distribution. Kruskal-Wallis tests showed no significant association between the scores of the two factors and the various categorical variables. Therefore, no particular subgroup is differentiated regarding the two compound variables.

5 DISCUSSION

This section discusses the research questions of the present study, namely: a) Which are the students' attitudes towards the studies and the proposed practice? b) To what extent do the students consider the particular practice appropriate for other courses?

5.1 Student's Attitudes

The majority of the students (90%) considered the e-assessment a positive experience. They gave high scores to all the items examining their attitudes towards the new practice. Their positive attitude was also profound in the free-text answers they gave. One can explain the enthusiasm considering that the new practice gave purpose to class participation and directed students' effort towards more effective learning.

The survey showed that only 57% of the respondents take notes during the lectures. It appears that students hope that being present during the lectures will result in learning. They spend hours in amphitheatres, considering that by doing so, they fulfil their academic duties. Their answers indicate that passive learning is not uncommon among the respondents. Passive learning relies on the false belief that receiving information during a lecture will somehow increase the individual's knowledge and abilities to perform specific tasks. Many students adopt a passive stance during the lectures, which does not result in learning (Chi & Wylie 2014). The students do not activate their past knowledge for making comparisons or searching for its relation to the information they receive. Sooner or later, they realise that they do not learn and stop going to the lectures.

Moreover, 64% of the participants believe or anticipate learning during the lectures. Putting the numbers together shows that disappointment is just around the corner. The absence of association between "studying hours", "classroom behaviour", and "studying at home vs. following the lectures" indicate that many students do not design a strategy to learn effectively. For many respondents, following a lecture is not part of an organised learning process and has a ritualistic character. Overall, the data show that the students are optimistic regarding the length of the studies. However, the students who report a shorter duration of studies do not study more than the rest of the students. Although one would anticipate that those students who expect to complete their studies sooner do something extra for that, we found no association between the "expected duration of the studies" and the "studying at home" or the "classroom behaviour" variable. It appears that the students embraced e-assessment as an educational practice because they realised that it guided more effective learning, a question they had not considered before. Moreover, it was a practice completed in the classroom with the supervision and support of the tutor and it required no extra effort at home.

Learning requires the cognitive engagement of the learner in meaningful activities (Bonwell & Eison, 199; Kahu & Nelson, 2018). The survey results show that the students considered the proposed intervention as a meaningful learning activity. Emotional engagement centres on the positive or negative reactions of the student towards the tutor, the classmates, and it affects learning (Chi & Wylie 2014). Items 4 to 7 (Table 1) indicate that the students attained higher emotional engagement during the e-assessment. Feelings of high self-control or self-determination over the studies were associated with faster graduation. However, there was no association between these variables and the hours of study at home.

Overall the students reported a positive attitude towards the e-assessment reporting in all the items scores higher than 7.5 on a 10 points scale. The respondents expressed the highest agreement (lowest standard deviation) to items 2,3, and 4, i.e. "understanding during the e-assessment", "paying attention during the lectures because of the e-assessment", and "working productively during the e-assessment". Item 6 was the item with the highest score "the e-exams showed that the tutor cares for our learning," indicating that in particular cultural contexts, the tutor's role is indispensable. The assessment allowed the students to apply theories and models to solve problems in a supportive environment. They increased their understanding of the taught material (Items 1 & 2 in Table I).

Extensive focus on cognitive gains has been criticised for reflecting lower cognitive development. Solving real-life engineering problems is a suitable way for higher-level cognitive development. While learning to apply models in solving standard textbook problems in electronics may draw criticisms as rote learning, good knowledge of them is an antecedent to real-life engineering problems, which require more complex decisions. Therefore, achieving a high level of theoretical mastery is a vital outcome independent of the targeted cognition level (Say, Visentin, Cummings, Carr, King, 2022).

Students' satisfaction with the pedagogical practice improved intrinsic motivation and resulted in more meaningful class participation (Say, Visentin et al., 2022). The positive outcomes of students' satisfaction affected positively their behaviours manifested in high class attendance, retention to the e-assessment practice and student-student cooperation (Hughes et al. 2020). Other outcomes were "more attention during the lectures", 'motivation to learn", "work productively", and "feelings of community".

The e-assessment affected the way students attend the lectures (Item 3). The lecture was no more a timetable duty but the means to perform well during the e-assessment. Groupwork presumably energised the group dynamics, giving a learning community feeling (Item 9). The e-assessments occurred in a non-competitive environment where the students shared ideas with their peers and the tutor. They reconsidered what they already knew and related past to present knowledge. Presumably for many of the students, it was an exciting experience to move from passive to interactive learning. Although beneficial to the student, active learning assumes that students are patient enough to work on their own. The interactive mode places the learner within a social context. Learning is not a personal activity, but it results from interaction with the teacher and fellow students. Within a group of peers, students learn through questioning, exchanging understandings, elaborating and challenging ideas (Molin et al., 2021).

The e-assessment introduced the students to a new environment where learning and understanding became the centre of the class activities (Items 6,7 & 8). This experience is in contrast with teacher-oriented classes. In a student-centred environment, learning results from what the students do. The tutor designs the learning activities and allows time for the students to rethink what has been taught, generate questions and identify difficulties that challenge their understanding. Student-student interaction flourishes in project-based (Čavić et al. 2022) or problem-solving classes (Hmelo-Silver, 2004).

Hsiao et al. (2022) found that the students who exhibited interactive, constructive, and active engagement behaviours are primarily found in student-centred learning environments, while passive engagement dominates in tutor-oriented classes. The e-assessments comprised a series of learning tasks to direct students towards desired learning goals, challenging their understanding and eliciting dialogue and argumentation. The learning activities (Chi & Wylie 2014) serve and reproduce the learning environment and influence how students engage with them. Problem-solving is a good activity for this purpose. Asking the students to plug a few numbers in an equation and make calculations serves a tutor-oriented environment, while problem-solving in groups promotes student-centred education.

5.2 Prospects of the Proposed Practice

The second composite variable, which resulted from the factor analysis "prospects of the proposed practice," explains 11% of the total variance. Seventy-one per cent (71%) of the respondents scored higher than 7 for the items "I would like to have e-exams in other courses" and "if there are e-exams in other courses, I will attend more lectures". As one student noticed and the free text question, "it would be nice if there was e-assessment in other courses. It motivates me to pay attention during the classes. Learning becomes easier and classes more useful."

The LMS added formality and flexibility to the e-assessment. It offered a systematic way to monitor student participation and performance. It provided a well-prepared framework that encouraged the students to work on activities aligned to the learning objectives. Apart from optimistic accounts of a total transformation of education using LMSs, the practice provided evidence of effective use of technology to enhance student motivation, participation, retention in a traditional campus-based setting (Coates, 2007). The survey results showed that the e-assessment was an opportunity for the students to consider metacognition issues concerning class participation and learning strategies.

The survey findings indicate that the students valued the assessment because it guided their learning. It responded to their beliefs and expectations that the classroom must be the place to learn. It assured them that the tutor cares for their learning and supports their endeavour, affecting positively emotional engagement. They realised that they worked productively during the e-assessment. The LMS allowed flexibility in assessment formats while the proposed practice increased their interest in the lectures and created a learning community.

6 CONCLUSIONS

This study examined students' attitudes of a pedagogical practice introduced in a second-year course in Electronics. The purpose of this intervention was to bring closer lecturing and assessment with the help of technology. The findings show that the students consider that the proposed practice motivated them to engage in more active class participation, student retention, and improved learning and understanding. We explain the high acceptance of the practice because it guided the students to take ownership of their learning in a supportive, non-competitive environment.

The findings of this research shows there is a gap between students' behaviour and the demands of University education. The students, especially those of the first years, find themselves in a new situation where they do not know how to navigate. Half of the students attend the classes without making notes; however, most anticipate learning during the classes and spend a limited amount of hours studying at home. The proposed pedagogical practice organised the active participation of the students and helped them feel productive and members of a learning community. It appears that such initiatives are necessary in order to make class attendance meaningful and learning more likely to happen.

Despite the students' positive views, the proposed practice had only a marginally positive impact on students' final examination grades. Seventy-one per cent of the student who participated in the practice obtained a pass mark in the final examination (Average=5.4 S.D.=1.9) compared to 65% for the rest of the students (Average=4.9 S.D.=2.2). The percentage of the high achievers, i.e. score greater than 7.5/10, was equal to 13 per cent in the first group and only 2% in the second. However, this may be because the more industrious students participated in the pedagogical practice.

Although the proposed practice did not significantly affect student performance, it highlighted the gap between students' attitudes and the demands of university education. Further research is needed to identify similar practices, which will take into count this usually forgotten gap and mobilise the students to become more active learners.

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