Journal of Universal Computer Science, vol. 21, no. 8 (2015), 1001-1021
submitted: 20/11/14, accepted: 30/6/15 appeared: 1/8/15 © J.UCS

Introducing a Formative E-Assessment System to Improve Online Learning Experience and Performance

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Abstract: E-assessment is the process where technologies are used for the management of the end-to-end assessment process. It involves the use of any technology-based method that allows systematic inferences and judgments to be made about the student's skills, knowledge and capabilities acquisition. In online learning, technology is used to facilitate the implementation of the appropriate models that can be used for both teaching and learning. In addition, e-assessment technologies allow creating tools able to improve student engagement and performance, offer possibilities to practice competences and skills, provide personalized feedback and improve student motivation. This paper presents a general e-assessment tool with a formative e-assessment model. The e-assessment tool under a formative assessment model is integrated into the learning process and provides aligned and authentic learning experience, focused on skill and knowledge acquisition. Results show that the e-assessment tool and its model had a positive effect on students' performance and learning. The tool itself is capable of providing students with personalized feedback, guidance and marks as well as automatically storing and tracking students' progress, competences and outcomes, going beyond the e-assessment approach based mainly on quizzes. The e-assessment tool and model offer innovative assessment approaches, mainly focusing on skill assessment where dynamic and interactive questions were provided with the guidance of personalized feedback and hints.

Keywords: Online education, E-assessment, Formative assessment, Teaching innovation, Education technology
Categories: L.0.0, L.2.1, L.2.7, L.3.0, L.3.5, L.3.6

1 Introduction

Assessment is perhaps the best way of identifying the support needed by learners. It can encourage the desire for students to progress further if linked to appropriate resources, good quality, timely feedback, and also challenging but stimulating ways of demonstrating understanding and skills [JISC, 07] [Cook, 10]. In other words, assessment can also be denoted as an appraisal (or judgment, or evaluation) of a student's work or performance [Sadler, 13]. In this case, especially when it comes to online education, the advances in technology offer interesting possibilities, if used appropriately, to build practice tools and can add value to any of the activities associated with assessment [JISC, 10].

There are several educational tools that can be used for either learning or assessment [Crisp, 07]. Most of the tools are originally developed for learning purposes through simulation based learning or intelligent tutoring systems. For assessment, most tools offer merely a transformation of paper-based assessment, where only predetermined questions such as Multiple Choice Questions (MCQ) are offered [Marriott, 09]. These types of questions are good for assessing knowledge levels of students, but when it comes to assessing skill competences dealing with high level cognitive skills, it is needed to go beyond these types of questions. Also, some of the current tools are used for assigning and submitting homework as essay-type assignments, where teachers evaluate and assign a grade or a feedback [Heinrich, 09]. As it is not a synchronous process, students have to wait a considerable amount of time to clarify their doubts, as a result they are not motivated to stay engaged in the course. Still, in most of the courses, as for the evaluation, a face-to-face examination is used. When it comes to courses which are carried-out in a fully online environment, this is not an easy task due to space and time constraints. Therefore, technology can offer a significant contribution to the online educational process. In this paper, we focus on introducing an e-assessment tool which can change the way, teaching and learning is carried-out in online by introducing a more dynamic environment where students can interactively engage and improve their skills and knowledge.

Based on the online learning phenomenon, educational tools should provide innovative methods for practice and assessment of high level cognitive skills. At the same time, these tools should be able to improve student engagement and performance in the subject, offer possibilities to practice, minimize the level of cheating by students, offer personalized feedback, and improve student motivation in the subject [Bull, 03] [Sitthiworachart, 08] [Tselonis, 07]. Also, appropriate e-assessment tools can be used to offer teachers with the facilities to track students learning process and achievements throughout the duration of the course which in turns can be used to improve the course and the overall teaching process. Although, assessment in online learning has been well established long time ago, with the popularization of several types of online courses such has MOOC (Massive Open Online Courses), scalable, embedded and formative assessment is even more important. At the moment, the common methods of online assessment are multiple-choice quizzes and peer-reviewed, written assignments [Sandeen, 13], which are not capable of reviewing students answers in detail and offering rich constructive feedback to motivate students. Therefore, with the introduction of e-assessment with

appropriate technologies can offer a rich assessment experience for students where personalized feedback and tests can be tailored to match students' answers.

Considering all the above, this paper presents a general e-assessment system and a formative e-assessment model, focused on skill and knowledge acquisition in STEM (Science, Technology, Engineering and Mathematics) in higher education. The system was designed and developed with a special focus on skill practice and assessment. The system and the model were evaluated in a real case scenario integrated into a traditional learning model, with special attention to track student learning outcomes and to improve student learning experience and engagement.

The rest of the article is organized as follows. Section 2 presents a review of the literature based on assessment and learning, formative e-assessment, students motivation and learning as a result of formative e-assessment, and technologies used for assessment. Section 3 describes the research design with the proposed solution of a formative e-assessment model and the development of an e-assessment system that supports it. Section 4 presents the evaluation procedure which includes the context of the research, participants and findings based on the data analysis. Finally, the paper ends with the conclusions and future work.

2 State of the Art

E-assessment can be defined as the process where information and communication technologies are used for the management of the end-to-end assessment process [JISC, 07] [Cook, 10]. In other words, e-assessment involves the use of any web-based method that allows systematic inferences and judgments to be made about the student's skills, knowledge and capabilities [Crisp, 07]. E-assessment is an important aspect in online education, where students' active participation and engagement through practice is needed along with a continuous formative assessment carried-out during the learning process [Buzzetto-More, 06]. The overall assessment process takes a significant amount of time and effort for both students and teachers in the form of setting and responding to assessment tasks, marking or grading assessments. At the same time, assessments encourage learning and provide feedback on learning for both students and teachers. Therefore, it is interesting to have a look at the relationship between assessment and learning.

2.1 Relationship between Assessment and Learning

As [Biggs, 03] has stated, assessments not only determine the things students have learnt but assessment methods have also employed students to retain, reproduce, reconstruct and engage with learnt materials. According to him, assessment of learning is clearly distinguished from assessment for learning. "Assessment of learning" has a valid function for accountability and reporting purposes and "assessment for learning" acknowledges that systematic feedback from the teachers to the students informs the learning and teaching process itself [Headington, 12]. In this case, the teacher has to set up a learning environment that supports the learning activities appropriate to achieving the desired learning outcomes. The key is that the components in the teaching system, especially the teaching methods used and the assessment tasks, are aligned to the learning activities assumed in the intended

outcomes [Biggs, 03] [Santos, 12]. This research mainly focuses on “assessment for learning" as students are provided with the facilities to assess their own learning process and competences archived through formative e-assessment and feedback given. At the same time, to support teachers by allowing them to track student's learning process through the grades, outcomes and competences achieved for each learning activity.

2.2 Formative E-assessment Effects on Student Motivation and Learning

Formative e-assessment is carried-out during learning, which provides practice for students on their learning in a course and possible development activities they could undertake in order to improve their level of understanding [Lin, 13]. Formative e-assessment process and the learning outcomes should be aligned, to allow students to demonstrate the acquisition of skill and knowledge competences within a particular course [Biggs, 03]. Practice is an important aspect of formative e-assessment as it gives students the opportunities to act on the feedback [Sadler, 13]. In this case, immediate feedback and the possibility to track their competences acquisition are particularly useful as it helps students to monitor their own progress.

According to [Bull, 03], timely and constructive feedback motivates students to learn more effectively. Student motivation is connected to the desire to participate in the learning process, but it also concerns the reasons or goals that underlie their involvement or non-involvement in academic activities [Marriott, 09]. Assessment can be used as a means of channeling students' energies, and the feedback that it generates based on the learning outcomes can provide students with an opportunity for reflection; then, the frequency of assessment needs to be considered if it is to be of maximum benefit to students and teachers. Studies reported that frequent and timely testing and feedback increase motivation. Because the more students practice a subject and receive feedback on it, the more they tend to learn and the more engaged they become [Sadler,13]. Also, being able to track their own competences acquisitions is another factor for motivation. The importance of feedback and the possibility to track the acquisition of competences in the assessment process are significant as it is a conduit for facilitating student self-assessment and reflection, encouraging positive motivational beliefs and self-esteem, and yielding information that teachers can use to help shape teaching and learning [Nicol, 07].

2.3 E-assessment, Competences and Outcomes

Assessment of skill and knowledge competence acquisition is an important aspect in STEM courses in higher education. Therefore, the design of learning activities must be guided by the specific learning outcomes which can be mapped with the competences to be acquired by the learners in the course. Competences represent a combination of attributes (with respect to knowledge and its application, attitudes, skills and responsibilities) that describe the level or degree to which a person is capable of achieving the stated learning objectives or outcomes of a particular course [Biggs, 03]. Therefore, when selecting appropriate tools for e-assessment activities, they have to support the expected competences to be reached. Depending on the course, for both knowledge and skill competence acquisition, the type of activities and the related technologies that are needed have to be analyzed.

Knowledge represents the lowest level of learning outcomes in the cognitive domain and exercises that require knowledge to be memorized only account for a fraction of the overall examinations [Majchrzak, 12]. Therefore, for knowledge assessment activities and tools which offer simple types of questions such as multiple choice questions, multiple responses, short answers, fill in the blanks, matching and crossword puzzles can be used.

Skills are a practiced ability, expertness, techniques, crafts or art. Higher-order cognitive skills are typically required for solving exercises encountered in the natural sciences, including computer science, programming, mathematics and language learning [Gibbs, 04]. Assessment of skill competence is more authentic, therefore, it is needed to go beyond activities and tools that offer simple type of questions.

As [Santos, 12] mentioned, the use of appropriate technology enables the design of new assessment solutions, allowing the creation of more complex scenarios which allows the possibility to offer aligned assessment activities for skill competences and outcomes. As a result of technology, through the use of simulations, digital games, intelligent tutoring systems it is possible to increase students interaction and engagement with the information and authentic learning contexts which in turn makes students more participative in the assessment process [Santos, 12]

2.4 Technologies for Assessment

New approaches to assessment in STEM higher education can be informed by learning technologies [Heinrich, 09]. These approaches should emphasize the role of technology in supporting the human assessor, whose role is vital, especially for formative assessment [McGuire, 05]. Also, in this context, sharing of learning resources as well as communicating with similar systems has become a major challenge. Therefore, e-learning and e-assessment standards, specifications, and formats play an important role, as it helps to ensure interoperability, scalability, reusability, manageability, accessibility and durability [AL-Smadi, 09]. With respect to sharing information and communicating between different systems, some standards are needed to maintain the security and interoperability to carry-out a seamless communication. Therefore, standards and specifications such as IMS LTI (Learning Tools Interoperability) [IMS GLC, 14a], IMS LIP (Learner Information Package) [IMS GLC, 14b] and IEEE PAPI (Public and Private Information) [CEN WS-LT LTSO, 14] can be used. Additionally, there are some assessment formats whose main objective are the authoring and sharing of assessment resources. These assessment formats should include features such as response and outcomes processing, metadata capabilities, hybrid question management, correct response indication, and multiple responses related to one question [Gutiérrez, 10]. Some common and widely used formats are: IMS QTI [IMS GLC, 14c], MoodleXML [Moodle, 14], Blackboard [Blackboard, 14] and OpenMark [OU, 14] [Santos, 11].

There are some interesting tools available for e-assessment in online education [Crisp, 07]. Some of them can be noted as; Moodle Quizzes [Moodle, 14] and Maple T.A. [Maplesoft, 14]. Most of the available tools support only predetermined questions such as MCQ, true/false, short-answer and fill in the blanks questions [Marriott, 09]. However, cognitive skills and application of methods cannot be assessed via multiple-choice tests and equivalent forms of basic assessment items [Gruttmann, 08]. Therefore, it is needed to provide a more complex kind of

assessment activities, especially when it comes to assessment of higher-order skill competences.

Currently, there is a large sample of tools used for learning skills in higher-order cognitive courses. Many of them can be categorized as Intelligent Tutoring Systems (ITS) for learning, but they are not e-assessment systems. The main characteristics of an ITS for learning are providing customized assistance and feedback to students while simulating the presence of an e-tutor or learning assistant [Huertas, 11]. ITS facilitates skills learning through interactivity by monitoring each step carried-out by students in an exercise and providing some guidance such as error messages and feedback. By integrating the assessment facilities such as personalization and adaptive assessment, it is possible to enhance an ITS into a skill assessment tool to offer dynamic and interactive question items.

To provide embedded assessment experience for students, in addition to technical support, pedagogical support is also needed. The pedagogical support takes advantage of pedagogical design patterns, promotes designers' awareness of the potential risks and opportunities of assessment plans [Villasclaras, 13]. To provide technical support, an e-assessment system should be designed and developed in a way that the system should be easily integrated with any learning management system to support and create a link between learning, assessment and competences.

3 Research Design

The action research approach [Oates, 06] is followed in this work. Action research is a method which has been used for those who want to investigate and improve their own working practices. Also, it is characterized by focusing on practical issues, an iterative cycle of plan-act-reflect, an emphasis on change, multiple data generation methods and the action outcomes plus research outcomes.

The research presented in this paper consists of designing and developing the e-assessment system and its evaluation in a real case scenario. The evaluation process was defined to verify the quality and the performance of the system and the model and whether the expected educational requirements and user needs were satisfied. To evaluate this methodology, a mixed-mode evaluation technique comprised of both quantitative and qualitative techniques was used [Frechtling, 97]. This was carried-out through a pilot study in the real online environment.

3.1 Proposed Approach: Formative E-assessment Model

The use of a proper formative e-assessment model is important to enhance students learning experience by providing facilities to assess their own learning process via the feedback given. Several formative e-assessment models such as [JISC, 07] [Al-Smadi, 09] [Almond, 02] [University of Southampton, 06] were reviewed and out of them, the one proposed by [JISC, 07] was selected as the foundation because it clearly highlights the relationship between e-assessment and effective learning. In this model, learning and e-assessment has to be integrated together, which we found suitable for the context and the needs of our proposal, focused on skill and knowledge acquisition of STEM in higher education. [JISC, 07] model also highlights the importance of feedback as well as practice, an important element of STEM skill practice and, one of

the key areas of online education and assessment [Sadler, 13]. As stated in [Rountree, 87], "one of the main drivers for learning has long been acknowledged as the assessment that students must undergo during the course of their studies". However, in a formative e-assessment process, frequent feedback is a vital component as formative e-assessment assists the on-going learning cycle. Also, students must have the opportunity to act on the feedback [Sadler, 13]. This underlines the importance of allowing students the opportunity to practice before moving into the assessment. Considering these factors, the model outlined by JISC was enhanced into the proposed formative e-assessment model. This model was introduced with the goal to provide more benefits for students to improve their learning process through practice. Thus, in our proposed model, after completion of each Learning Module (LM), students are provided with a new type of test: Practice Test (PT), in addition to the Assessment Test (AT), presented in the JISC model.

In our proposed model, for the practice test, students are provided with an unlimited number of attempts and time to practice each test as it allows students to interactively engage in the assessment system while acting upon the personalized feedback given "then and there" to solve the problem. Feedback is provided both in the cases of being successful and unsuccessful. If unsuccessful, based on the feedback students are directed to the revision module. In the case of being successful, where students have obtained the required pass mark, they are directed to the assessment test. The restriction of a pass mark was imposed with the intention to motivate students to practice more before moving to the assessment test [Salder, 89].

For assessment test, students are provided with a limited time and a limited number of attempts. The time allocated to complete the assessment test, depends on the curriculum and the difficulty level of the assessment. The reason for a restricted number of attempts is to allow students the possibility to obtain the required marks within given attempts. In most cases, students are allowed multiple attempts, with increasingly detailed and tailored prompt allowing them to act on the constructive personalized feedback whilst it is still fresh in their minds and to learn from it [Salder, 89]. This also gives a bit of pressure to students and at the same time, it motivates students to think carefully about their answers, but improve their mark through practice by paying more attention to their errors or mistakes [Fowler, 08]. This encourages an all-important "focus on form" for students [Fowler, 08]. Also, in the case of assessment tests, to discourage guessing, minus marks are given. The questions offered within a particular attempt are selected randomly from a large database of questions with different difficulty levels. In the case of questions where students have to select the correct answer, the answers are also shuffled within each attempt. These are done to minimize the facilities of cheating and copying the answers as expected with formative e-assessment [Clariana, 02]. The highest marks out of the given attempts are taken as the final mark. This is also done as a way to facilitate more practice as students tended to attempt several times in order to obtain a higher mark. After completing the assessment test, students can move to the next learning module. The proposed formative e-assessment model is shown in Figure 1.

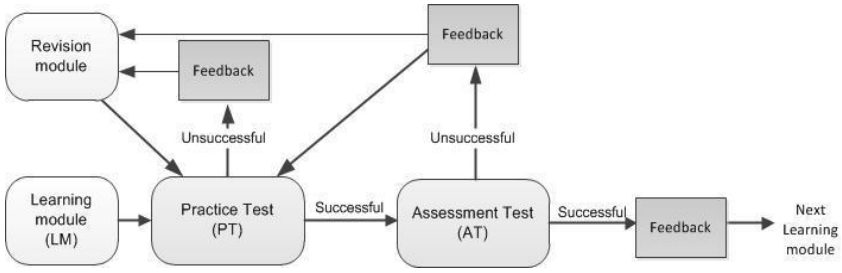

Figure 1: Proposed formative e-assessment model

3.2 Proposed System: Technology-Enhanced Assessment System

The proposed system known as the "Technology-Enhanced Assessment (TEA) system" has been developed according to a modular architecture which consists of five modules: skill assessment, knowledge assessment, progress bar, competences and gradebook.

Skill assessment module provides dynamic and interactive questions for practice and assessment tests, where students have to construct the answers with the guidance of personalized feedback and hints. Knowledge assessment module also provides practice and assessment tests through MCQ with personalized feedback for each step performed. Progress bar is a module that provides visual guidance for helping students to understand their progress with respect to the course. It shows the total progress obtained by each student along with the graphical presentation of activities completed, to be completed and not completed. Competences module allows teachers to track students learning process through skill and knowledge competences achieved for each learning activity in the course. These competences are selected based on the marks obtained by students for a particular activity. Students can view the competences they have achieved for each activity in the form of a progress bar and a table. Gradebook module is used to display grades and outcomes obtained by students based on the grades obtained for each test. These components help teachers to track students learning progress throughout the whole course. Out of the above modules, progress bar, competences and gradebook are taken as the standard modules of any TEA system. Both the skill assessment module and knowledge assessment module are domain dependent. Therefore, based on the subject that the TEA system is applied, these modules can be changed. The main reason for developing the system in this way is to make a general architecture which can easily be adapted to any subject.

The TEA system is mainly developed using PHP and MySQL, therefore, it can be easily connected with any Learning Management System (LMS) using IMS LTI [IMS GLC, 14a] specification together with OAuth protocol [OAuth, 14] while maintaining security and interoperability.

The users logged into the LMS can automatically navigate to the TEA system through the single sign-on facility provided by the IMS LTI specification. The principal concept of LTI is to establish a standard way of integrating rich learning applications (often remotely hosted and provided through third-party services) with platforms like LMSs, portals, or other educational environments. This allows a

seamless learning experience for students who gain access to rich applications that appear to take place inside the learning environment. Also, the modules within the TEA system are linked together using the IMS LTI specification. For transferring data such as user data, grades, time spent and attempts, between modules and, as well as to the LMS, OAuth protocol is used together with the IMS LTI specification. This protocol is used to secure its message interactions between the tools. The connections and the communications between tools are carried-out through both message-based and service-based connections. The proposed architecture of the system can be illustrated as in Figure 2.

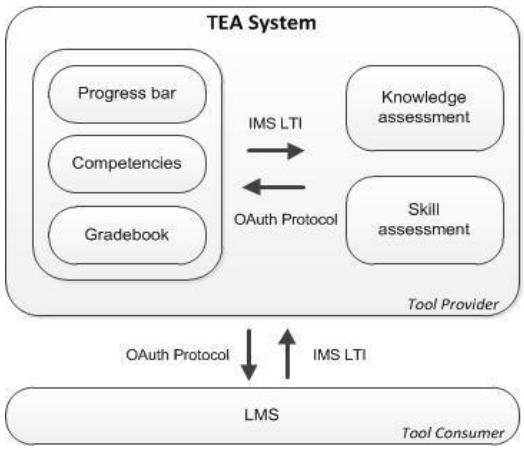

Figure 2: Architecture of the proposed TEA System

4 Evaluation

4.1 Context

For evaluation purposes, a first year Logic course of a Computer Engineering degree in a fully online higher education university, Universitat Oberta de Catalunya (UOC) [www.uoc.edu] was used. The Logic course was selected because it requires a high level of skill acquisition being a good example of a STEM higher education course.

The Logic course consists of 8 learning modules. At the time of this research, based on the 8 learning modules, the assessment model of the course provided 4 continuous assessment tests, which they can complete throughout the duration of the course. The questions offered through these tests were the same for all the students. As a result of it, the students had the possibility to copy the answers from others. Additionally, at the end of the course, students had to do a 2 hour face-to-face examination. When calculating the final grade of the course, marks of both the continuous assessment and the face-to-face examination were used. In this case, students were not provided with facilities for formative e-assessment. When calculating the final marks, 35% was given for the continuous assessment mark and 65% was given for the face-to-face examination. An ITS for tutoring logic, developed at the UOC, was used for learning and practice purposes. It allowed students to build

the answers for skill activities in a step-by-step manner, with immediate feedback at every step. The ITS was also used to provide the continuous assessment test, however the questions were the same for all the students.

Considering the above, the TEA system together with the formative e-assessment model was introduced to the course, substituting the existing continuous assessment model but maintaining the 8 learning modules, the final face-to-face examination and the proportion of marks as 35%-65%. When adapting the proposed TEA system into the context of the Logic course, the TEA system was connected to the UOC LMS using the IMS LTI and OAuth following the general architecture of Figure 2. As in the online classroom, students' login to the LMS of the UOC, supporting administration, documentation, tracking, reporting and delivering of educational courses. After login into the UOC LMS system, they move to the Logic classroom where they are provided with necessary information, schedule and guidelines. From there, students are automatically logged into two modules which they can use for practice and evaluation purposes.

For knowledge assessment, MCQ questions are used and the data such as grades and statistics are stored within the module itself. An example of a question provided for knowledge assessment with feedback is shown in Figure 3; they were mainly MCQs.

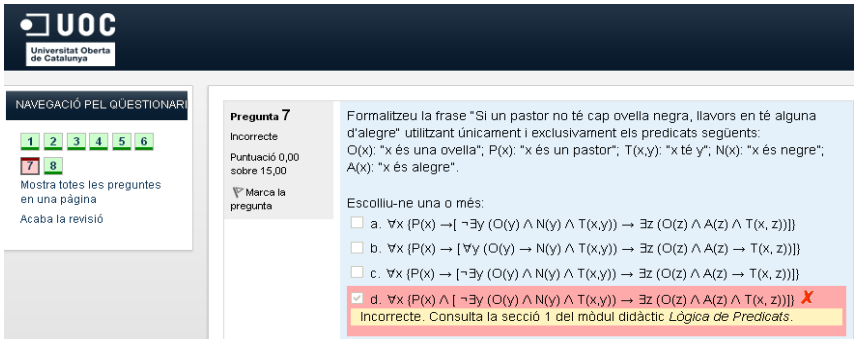

Figure 3: MCQ question with feedback and marks

For skill assessment, questions were provided using the ITS tool enhancing it into a skill e-assessment module by including functionalities such as a database of questions categorized into different difficulty levels, random generation of questions, grade storage and statistics. Skill assessment questions provided are interactive and dynamic where students have to construct the answers in a step-by-step manner with the guidance of personalized feedback and hints. In Figure 4, an example of a skill question with feedback is shown, it is an interactive step-by-step activity where a complete proof of a valid logic argument has to be built.

After completing practice and assessment tests, marks and grades are stored into the gradebook module. Based on the grades obtained through skill and knowledge assessment activities, competences, outcomes and progress of the activities were assigned.

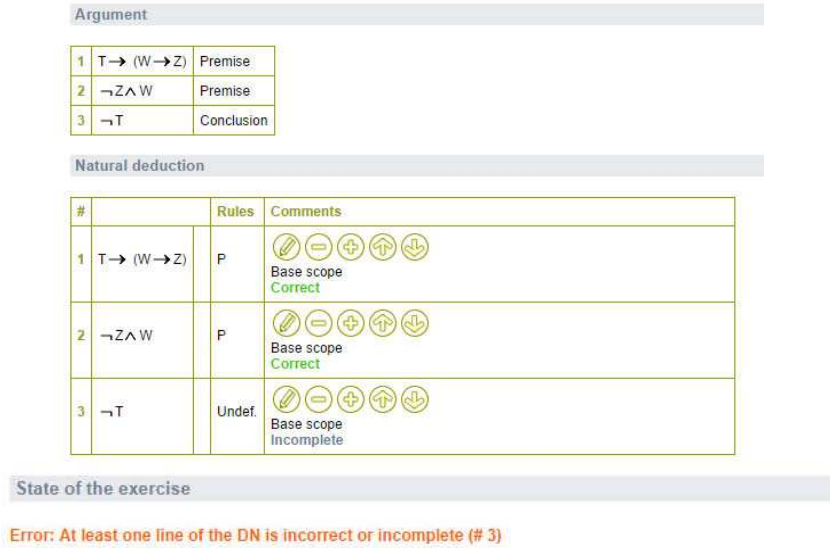

Figure 4: Skill question with hints, feedback and error messages

4.2 Participants

The participants in this research were two classrooms from the Logic course of the UOC. One classroom was taken as the pilot group (38 students), where the assessment was offered through the TEA system. The other was taken as the control group (28 students) which was the Logic course as explained before. The students in the classrooms were assigned on a first-come, first-serve basis. For ethical reasons and to maintain a balance in the classroom, students' ability was not evaluated when grouping the students.

In the pilot group, formative e-assessment was introduced through the proposed formative e-assessment model. There, students were provided with Practice Tests (PT) and Assessment Tests (AT). Both types of tests consist of questions for skill and knowledge assessment. Based on the 8 learning modules of the course, in the pilot group, students were offered with 8 practice tests and 8 assessment tests for continuous assessment worth 35% of marks. Therefore, for each learning module, students were first given a set of activities for both knowledge and skill as a practice with an unlimited number of attempts. In our application of the formative e-assessment model into the classroom, after obtaining a pass mark of 30% or more for each practice test, students were allowed to move to the corresponding assessment, where questions were offered through the skill assessment module. Here, the questions were offered in a randomized manner according to different difficulty levels and within a time restriction of 2 hours and 3 possible attempts. In addition to that, a final face-to-face examination worth 65% of the total marks were given as the final assessment. In the control group, the logic classroom, students were provided with only final assessment consisting of 2 hour face-to-face examination and continuous assessment tests which were not mandatory. The final assessment was the same for

both groups, and, therefore, it was possible to evaluate the effects of completing formative e-assessment on students' performance in the final examination.

4.3 Analysis and Results

The evaluation was used to determine the quality and the performance of the system in the real-world context. Both the system and the model were evaluated in the real online environment through pilot studies in the Logic course which was carried-out during the course period of 2012-2013. The objective of the pilot study was to analyze the effects of introducing the formative e-assessment model and the TEA system on students' performance, engagement, learning experience, and the possibilities for tracking of students learning process. The analysis of results is categorized according to the following propositions.

P1. The introduction of the formative e-assessment tool and model had a positive impact on students' performance and satisfaction.
P2. Student learning process can be tracked in terms of outcomes and competences achievement.
P3. Formative e-assessment improved student learning experience and engagement.

These propositions were analyzed following a mixed method evaluation [Frechtling, 97]. Mixed methods used combine quantitative techniques such as data obtained from the TEA system and closed questions in the form of Likert scale from the questionnaire, and qualitative techniques such as open questions from the questionnaire and observations of students' free entries and comments in the forums of the virtual classroom. The data gathering technique used for each proposition and the reasons for using those techniques are explained below in Table 1.

P1. The introduction of the formative e-assessment tool and model had a positive impact on students' performance and satisfaction.

To analyze this proposition several studies were carried out. First, a t-student statistical study was carried out to compare means of the final face-to-face examination marks in the pilot and the control groups. The P-value obtained was 0.027251 and, thus, it was proved that there was a statistically significant difference between means, where the mean of the pilot group (5.4) is greater than the mean of the control group (5.0). In addition to that, it was analyzed through the Pearson Correlation Coefficient carried-out between the final mark of the continuous assessment and the final face-to-face examination. Accordingly, students in the pilot group had a higher correlation of 0.702, whereas in the control group, it was 0.228. Therefore, assessment activities and outcomes using the TEA system and the formative e-assessment model proves to be more aligned with the final examination. It also showed more reliability in the formative e-assessment mark than in the traditional continuous assessment mark, as there was no copying among students due to a randomized selection of questions from a database of different difficulty levels. Additionally, students' final face-to-face examination marks were higher in the pilot

group compared to the control group. All together indicate that students' performance improved with the use of the formative e-assessment system.

	Technique	**Purpose**
P1	t-student analysis	Compare means of the final face-to-face examination marks in pilot and control groups.
	Pearson Correlation Coefficient	Evaluate the effect and alignment of using the TEA system and the formative e-assessment model with the final examination.
	Average marks between PT and AT	Evaluate the impact of the e-assessment model in terms of practice.
	Average marks between attempts in AT	Evaluate the impact of practicing using attempts.
	Likert scale questions in the questionnaire	Analyze students' satisfaction with respect to the implementation of formative e-assessment model.
P2	Competences, Gradebook and Progress bar data	Track student learning process, outcomes and the level of achievement.
P3	System Log data	Evaluate students' engagement in the course.
	Pearson Correlation between PT and AT	Evaluate students' improvement on their learning process based on formative e-assessment model.
	Likert scale questions in a questionnaire	Evaluate students' learning experience.
	Open-ended questions and forum entries in virtual classroom.	Analyze students' comments and suggestions about the system.

Table 1: Data gathering technique used for each proposition

To evaluate the impact of the e-assessment model in terms of practice, student data with respect to practice tests in the pilot group were analyzed. The number of attempts taken by all 38 students in the pilot classroom and the way their scores have improved during attempts were analyzed. At the beginning, some students had spent 8 attempts in the first practice test. This is because at the beginning, students had used the tests to get more familiar with the system. In most cases, students had spent a minimum of 2 attempts. Also, based on the analysis, students' marks have improved through these attempts. Therefore, it shows, more students practice using the formative e-assessment model, the more probability of obtaining a higher mark and improving their learning process. Also, to analyze the student improvements with respect to doing PT and then AT, the average marks obtained by the students for the given 8 tests were analyzed. These tests were related as students had to pass one to move to the other. As shown in Table 2, students' average marks in assessments had improved after doing formative practice using the TEA system. This was also proved before with a higher correlation of 0.915 between PT and AT.

Test No.	PT	AT
1	75.03	81.84
2	72.37	78.33
3	74.8	86.36
4	73.5	93.5
5	81.69	82.05
6	79.27	80.23
7	77.5	95.4
8	77.16	77.59

Table 2: Comparison of average marks between PT and AT

Then, the average marks between attempts for all 8 tests were analyzed. As shown in Table 3, the average marks had also improved through the attempts. Therefore, as a summary, the more students practice with the help of the automatic feedback had enhanced their learning experience.

Assessment Test No.	Attempt 1	Attempt 2	Attempt 3
1	65.11	71.82	83.89
2	70	78.57	91.66
3	72.38	76.67	90
4	46.25	52.30	67.78
5	66.11	74.98	76.67
6	49.54	57.14	66.67
7	53.33	65.38	75
8	40.73	67.62	70.38

Table 3: Average marks of AT between the three attempts

Overall, based on the above analysis, it shows that formative e-assessment could be introduced into the standard course (syllabus, learning modules and final face-to-face examination was the same for pilot and control group) and had an effect on students' performance in both the continuous assessment and the final examination. It shows that through the introduction of the formative e-assessment model with personalized feedback, students were more motivated and engaged in the course for both practice and assessment purposes and as a result, their performance had improved. Considering these, it is possible to implement formative e-assessment into the Logic course by replacing the previous assessment model.

In addition, students' satisfaction with respect to the implementation of formative e-assessment model was analyzed through Likert scale questions in a questionnaire, which was voluntary and given after the completion of the course. As a result of that, 19 of 38 students in the pilot group answered. The results of the questionnaire are displayed in Table 4.

Items analyzed through the questionnaire	Positive answers
It was helpful to practice before doing assessment tests	74%
Tests helped to evaluate the skills and knowledge acquired	74%
Automatic personalized feedback provided was satisfactory	89%
The marks obtained fit the knowledge and skills developed	89%
Tests were helpful for learning skills related to the course	79%
Tests helped to understand the topics covered in the course	79%
Tests helped to evaluate strengths and weaknesses in the course	79%
Preferred formative e-assessment instead of the traditional assessment	89%

Table 4: Students' feedback to the formative e-assessment model

Overall, students were satisfied with the TEA system and the formative e-assessment model.

P2. Student learning process can be tracked in terms of outcomes and competences achievement.

To track students learning process and level of achievement, modules such as progress bar, competences and gradebook (outcomes are provided within this module) were used. Data were obtained from these modules to track the acquisition of skill and knowledge competencies and outcomes obtained throughout the duration of the course. As for the competences module, 12 competences were assessed based on the 8 assessment tests. In order to obtain a particular competency, students had to obtain a minimum of 50 marks for the test. Overall, students had performed well in the Logic course with an average of 62% progress for all competences. Even for individual competences, students were able to obtain a progress of more than 50%.

Regarding outcomes, the data were obtained from the gradebook module. The average course outcome was equal to “Good", and for all learning modules, outcomes were either equal or above satisfactory. Based on the data obtained from the competences module and gradebook module for outcomes, it shows that students have performed well in the course. The statistics of the gradebook module with marks and outcomes for each activity and the overall average is displayed in Figure 5.

Additionally, the progress bar module was used to visually indicate the progress of each student as well as to provide teachers with the facility to track the progress of individual students and the overall course. The average progress of students in the Logic course was 71%. Also, as the progress bar is visible throughout the duration of the course, students had the possibility to evaluate their own progress and compare it with the rest of the classroom. Therefore, through modules such as progress bar, competences and gradebook, it is possible for teachers to track student learning process and the level of achievement throughout the whole course.

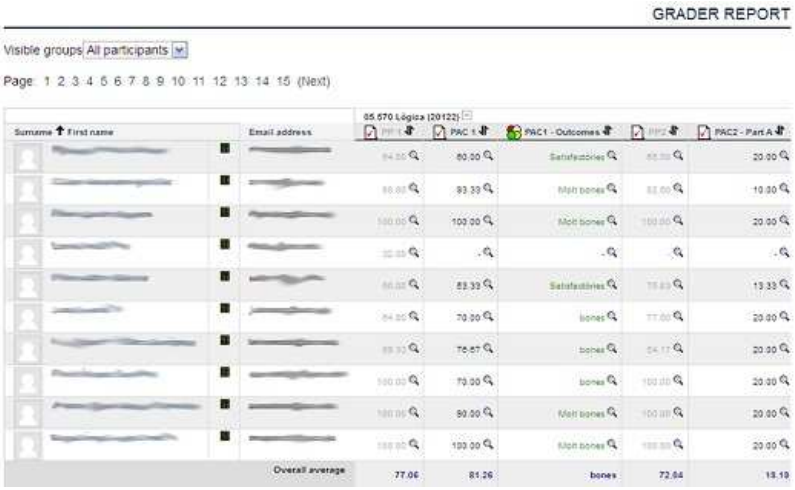

Figure 5: Statistics of the Gradebook

P3. Formative e-assessment improved student learning experience and engagement.

To evaluate students' engagement in the course, student participation data were obtained through the system logs. Based on these data, it can be seen that students had spent a considerable amount of time in the TEA system as shown in Figure 6. All students have accessed the system minimum 50 times during a particular day (this was taken as number of times they have logged into the system and used the content).

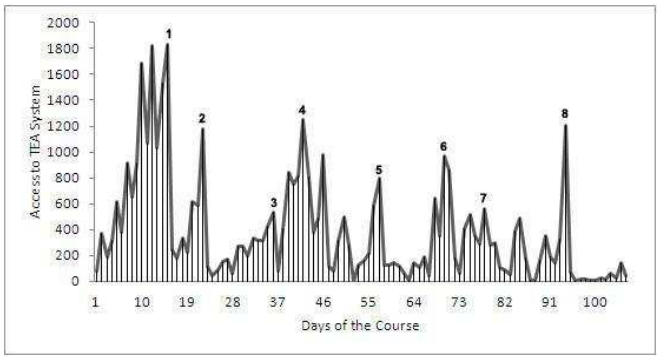

Figure 6: Students' participation in the course

The TEA system consisted of session time-out duration and therefore, students had to login to the system more than once during the day, if they were idle (without user input) for a particular duration. This can be taken as a reason for the high peaks in Figure 7. It is interesting to note that most of these high peaks had occurred when it was close to the deadlines of assessment tests shown as number 1-8 in the figure. At

the same time, after the last assessment test students had used the TEA system until the final examination for practice purposes. This is because, students had appreciated the authentic learning experience offered by the system through personalized immediate feedback. This is also due to additional facilities provided by progress bar, competences and gradebook, where students had the facility to evaluate their own learning. Overall, students in the pilot group the TEA system had been constantly used throughout the course duration for practice and assessment purposes based on the formative e-assessment model with personalized feedback. Therefore, it could be seen that students' engagement had improved with aligned formative e-assessment and personalized feedback.

Additionally, whether the students were able to improve their learning process as a result of the formative e-assessment model was evaluated. For this, the impact of doing the practice test and then doing the assessment tests was validated through Pearson Correlation Coefficient. Accordingly, there was a high correlation of 0.915, between completing the PT and then attempting the AT. Also, average marks of AT after the completion of PT were also high. Further, AT average marks had also increased in the subsequent attempts. As a conclusion, students learning process would have improved with more practice through attempts. Overall, practice and assessment using the formative e-assessment model helped students to enhance their learning process. To evaluate the learning experience, students' feedback was obtained through Likert scale questions in a questionnaire, which was voluntary answered by 19 students after the completion of the course. Questions were mainly about the satisfaction with the tool and the learning experience. A summary of the student's answers can be seen is in Table 5.

Items analyzed through the questionnaire	**Positive answers**
Instructions for questions were provided in a clear and concise manner	89%
Automatic grading offered through the system were satisfactory	84%
Questions provided were satisfactory	89%
Learning has improved as a result of assessment tests	89%
The progress bar was useful to see the progress in a graphical way	84%
The competency module was useful to evaluate the learning process	79%
Grades and outcomes provided useful information	100%

Table 5: Students' feedback to the questionnaire

Finally, an open-ended question was given to obtain students comments and suggestions about the system. Overall, students liked the system and few students have gone on to express their ideas as "*What I liked about the course is its planning: very well structured. In addition, the tools are very useful. As a final note, I do not know if it's personal or collective, the counterexamples are less strong than I thought. Otherwise, very grateful for the work you do: -)*" and "*A very interesting subject that helps to consider issues from a point of view. I have no complaints on the subject, personally I liked it and I learned a lot*".

Overall, based on students' feedback, they were satisfied with the authentic learning experience, support and facilities provided by the TEA system. Also, based on the evaluation data, it showed that students were constantly engaged in the system.

5 Conclusions and Future Work

The use of the TEA system and the implementation of the formative e-assessment model had a positive effect on students' performance and learning experience. Due to practice and assessment facilities, students were constantly engaged in the system and as a result, they were able to improve their performance in the final examination. It was also possible to control possible dishonest practices like cheating as the questions were generated randomly from a large database of different difficulty levels. Since the personalized constructive feedback was provided immediately after the completion of a test, students were motivated to stay in the course to achieve the required skills and knowledge needed. Also, the system offered facilities to keep track of students' achievements and learning process throughout the duration of the course with the aid of modules such as progress bar, competences and gradebook. These modules help both teachers as well as students. For teachers, to evaluate students' performance, competences, outcomes and progress in the course, identify the improvements needed, and to recognize the areas where special attention has to be given in the course. For students, to evaluate their own progress, compare it with the rest of the classroom, and identify their weak areas and give more focus to it. Based on the aligned assessment offered through the skill and knowledge assessment modules, students could evaluate whether they were able to achieve the required competences assigned for a particular learning activity. Also, teachers can identify the level of competences and outcomes achieved by students and based on that carry-out improvements needed for the course.

Teachers have a realistic chance to switch the previous traditional assessment model for a complete formative e-assessment model in an online learning environment. It means that, now it would be possible to introduce formative assessment activities with the TEA system in the Logic course and the final examination can be modified into an authentication test to validate that the online student is the same face-to-face student. We think that the system and the model can be implemented in other courses, which will be part of the future work. Overall, based on the evaluation, the proposed system with its general, flexible and standardized architecture together with the formative e-assessment model, can be taken as a good foundation for online learning and assessment of knowledge and skill in online courses which requires a high level of cognitive skills. Also, since the TEA system together with the formative e-assessment model is capable of providing students with personalized feedback, guidance and marks with no need of direct human supervision as well as automatically store and track students' progress and competences, it is possible to apply it to different types of online courses comprised of a small number of students or a large number of students such as MOOCs.

As future work, to provide personalization of questions and more detailed feedback, learning analytics techniques can be used. Also, the assessment process can be improved through techniques such as adaptive testing, where the questions given within a test are tailored based on student's previous answers. This can also be used to enhance the authentic learning experience of students. More detailed analytic

techniques can be used to improve the course and the methods used for tracking students' level of achievement and for increasing confidence in the authorship of the responses and preventing cheating, thus change the traditional ways of assessment.

Acknowledgements

This work has been partially supported by the Spanish Ministry of Science and Innovation funded Projects MAVSEL (ref. TIN2010-21715-C02-02), ICT-FLAG (TIN2013-45303-P) and LINHY (FFI2013-47126-P), the Department of Computer Science, Multimedia and Telecommunication and the eLearn Center of the UOC.

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