

# A Technology Enhanced Assessment System for Skill and Knowledge Learning

Enosha Hettiarachchi<sup>1</sup>, Enric Mor<sup>2</sup>, Maria Antonia Huertas<sup>2</sup> and M. Elena Rodriguez<sup>2</sup>

<sup>1</sup>*Internet Interdisciplinary Institute (IN3), Universitat Oberta de Catalunya, Barcelona, Spain*

<sup>2</sup>*Computer Science, Multimedia and Telecommunication Studies, Universitat Oberta de Catalunya, Barcelona, Spain*

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**Abstract:** This paper presents a technology-enhanced assessment system that can be used for both skill and knowledge learning. For this purpose, a general technology-enhanced assessment system is designed and developed for an online logic course at a fully online university, taking into account e-learning standards and specifications, which can be easily adapted to any institute and subject requiring a high level of skill learning. Through this system, both learning and formative assessment facilities are provided to students. To evaluate its effects on student learning process, the system is applied in a real logic course at the Universitat Oberta de Catalunya (UOC). Based on the evaluation, it shows that students' are more engaged with the system and, as a result, their performance in the subject had improved. Also, based on the feedback obtained through the evaluation, it shows that students are satisfied with the facilities and assessments provided by the system. Overall, the introduction of the technology-enhanced assessment system for skill and knowledge learning has yielded some interesting results.

## 1 INTRODUCTION

Nowadays, e-learning systems have become a common form of media for providing education transparency in society (Krishnamurthy & O'Connor, 2013). E-Learning systems that provide higher interactivity and feedback makes students motivated and engaged to learn more efficiently (Bull & Mckenna, 2004; Sadler, 2013). As a result, new challenges have arisen for educators and technologists and, among them, providing student engagement and assessment can be noted.

Technology-enhanced assessment, also known as e-assessment, deals with methodologies, tools and processes where information and communication technologies are used for the delivery of assessment activities, the recording of responses and the provision of feedback (Cook & Jenkins, 2010; Daly et al., 2010; JISC, 2007). Traditionally, e-assessment has been used for testing the acquisition of declarative knowledge where students are required to select a predetermined response based on factual recall like, for example, the simple multiple-choice question types (Bull & Mckenna, 2004; de Bruyn et al., 2011). However, cognitive skills where students

have to apply their analytic, creative and constructive skills cannot be assessed via multiple-choice tests and equivalent forms (Gruttmann et al., 2008; Majchrzak & Usener, 2011). As Crisp (2009, 2010) stated, in order to test higher order capabilities, it is needed to design sophisticated assessment tasks, but the difficulty and workload in designing such tasks are considerable. Skill e-assessment when offered is, usually, subject dependent and technologically complex because of the computational difficulties to represent and simulate higher order cognitive questions and its automatic marking. Hence, most of the technology-enhanced assessment tools that are currently available are either developed specifically for the particular subject content or only offer a simple type of questions that can be used only for the assessment of knowledge acquisition. Therefore, one of the main disadvantages is that there is no general type of tool that can be used for assessment of both skill and knowledge activities (Hettiarachchi, et.al, 2013)

Another challenge is associated with the software used for e-assessment systems. According to Bull & Mckenna (2004), several issues have been identified as critical when it comes to the decision-making process. They can be noted as interoperability,

integration with existing systems, scalability, performance level, limitations associated with upgrading procedures, support and maintenance and security and accessibility.

Considering the above, this paper introduces a technology-enhanced assessment system, which goes beyond just the combination of existing assessment systems, for both skill and knowledge learning and assessment in an online educational environment. In addition to that, the system is designed and developed as a standardized and a general system that can be easily adapted by any domain or subject. The goal of this paper is to evaluate whether the developed e-assessment system works correctly and this was evaluated through a real online Logic course at a fully online university.

The rest of the paper is organized as follows. Section 2 presents a general introduction to the skill and knowledge assessment with some of the common e-assessment tools and systems. Section 3 explains the proposed technology-enhanced assessment system. Section 4 presents the data analysis and results based on the evaluation of the system. Finally, the paper ends with the conclusions.

## 2 SKILL AND KNOWLEDGE E-ASSESSMENT

Assessment activities can be divided broadly into two types such as skill and knowledge assessment (Crisp, 2009). Knowledge can be specified as the recall or recognition of specific items. It can be more elaborate as remembering of previously learned materials and contents (Bull & Mckenna, 2004; de Bruyn et al., 2011). This may involve the recall of a wide range of content, from specific facts to complete theories, but all that is required is the bringing to mind of the appropriate information. Knowledge e-assessment mostly uses simple forms of questions such as Multiple Choice Questions (MCQ), multiple responses, short answers and fill-in the blanks. They are generally easier to mark both as automatic and human means. This type of assessment is quicker in delivery, gives more specific and directed feedback to individuals and can also provide greater curricular coverage (McAlpine, 2002). At the same time, they can be limited in scope and can occasionally degenerate into a 'quiz' of facts about the area of study.

Skill can be defined literally as a practiced ability, expertness, technique, craft and art. Higher-order cognitive skills are typically required for

solving exercises encountered in the natural sciences, including computer science and mathematics (Gibbs & Simpson, 2004). Skill e-assessment activities are often associated with a constructivist view of learning and it is best suited when there may be a difference of opinion based on interpretation (Crisp, 2007) or to assess higher cognitive skills. However, they can be time consuming to set and mark. They also require greater marking proficiency than knowledge assessment activities, involving training markers or detailing criteria (McAlpine, 2002).

### 2.1 e-Assessment Tools and Systems

The main characteristics of an e-assessment system have been widely studied. The most important are (Bull & Mckenna, 2004; Sitthiworachart et al., 2008; Tselonis & Sargeant, 2007):

- monitoring student progress through frequent assessments,
- applying a variety of interactive question types and promoting student engagement,
- automatic marking, weighted-average grade calculation and immediate feedback,
- supporting flexible and adaptive learning, and personalization of assessment activities,
- monitoring question quality using statistical analysis and
- reducing the potential for cheating by randomizing questions along with timers, and sharing questions via question banks.

Some universities and educational institutes offer e-assessments; but they are mostly based on knowledge assessment rather than skill assessment activities (Marriott, 2009; Pachler et al., 2010). One of the reasons is that most of the tools support only simple type of the questions such as MCQ. At the same time, tools that are based on skill assessment activities usually depend on a specific subject context because of their complex semantics.

Since this research is focused on a logic course, the e-learning and e-assessment tools used for logic were analysed. Currently, there is a quite large sample of tools used for learning logic courses, many of them can be categorized as Intelligent Tutoring Systems (ITS); but not so much for e-assessment. The main characteristic of an ITS for learning is providing customized assistance and feedback to students while simulating the presence of an e-tutor, however, they lack many of the characteristics of an e-assessment system. There is an extensive discussion on e-assessment tools in Crisp (2007) and on ITS for teaching logic in

(Huertas, 2011). In the case of logic, many tools fall into the category of ITS, for example: Pandora (Imperial College London, 2013), Organon (Dostalova & Lang, 2007), and AELL (Huertas, 2011), but none was fulfilling all the general features of an e-assessment system, noted above.

### 3 TECHNOLOGY-ENHANCED ASSESSMENT (TEA) SYSTEM

The context of this research is a first year Logic course of a Computer Science degree in the Universitat Oberta de Catalunya [www.uoc.edu]. Logic is a good case study for this research because it requires a high level of skill and knowledge learning. In this course, an ITS for learning logic, AELL, was developed and used previously, with the aim of providing a tool to facilitate the learning process (Huertas, et.al, 2011). The tool assisted students in different kind of activities by guiding and informing them of the correctness of their solutions. The main aim of the ITS tool was to provide learners with more practice through automatically graded exercises, for learning purposes. For assessment, students had, as is traditional, a set of assessment activities, provided through the ITS, that were the same for all the students. Therefore, they had the possibility to copy answers from each other.

In order to provide a fully formative e-assessment experience, as mentioned before, it was needed to introduce both practice and assessment of skill and knowledge acquisition in order to motivate students and provide a rich e-assessment experience while minimizing copying and cheating. In particular, main characteristics of e-assessments, not present in the ITS tool used for practice, had to be introduced. Therefore, we decided to go a step forward the use of the ITS and design a new system to provide e-assessment and feedback in an interactive way.

The proposed Technology-Enhanced Assessment (TEA) system was designed and developed iteratively following a user centered design approach (Bevan, 2003). To identify the features and functionalities of the system, data were collected in the form of surveys, focus groups and interviews. Also, interfaces were tested and prototypes were built in order to evaluate the system and make it match teacher's goals and student's learning and assessment needs.

The TEA system was designed to provide both practice and assessment in both skill and knowledge

acquisition. For practice, students were provided with facilities such as learning materials and practice tests. For assessment, the system provided assessment tests. Both practice and assessment tests included interactive feedback and based on the feedback students were able to attempt the tests till they obtain the required marks needed to master the knowledge and skills required. For assessment to be effective, feedback must not only be provided, but also understood by students and acted on in a timely fashion (Jordan, 2009). Therefore, the feedback provided through the system was immediate and detailed with guidance. Based on that, students should be able to interactively learn their errors or mistakes and obtain a higher mark in the subsequent attempt. For assessment test, some restrictions were imposed with time and attempts to motivate students as well as to offer individual questions and the assessment atmosphere.

#### 3.1 Architecture of the TEA System

In this section, the architecture for a general TEA system, from which the case of the TEA system for the Logic course is developed, is presented. It consists of five modules: skill assessment module, knowledge assessment module, progress bar, competencies and gradebook.

Skill assessment module provides dynamic and interactive questions for both practice and assessment tests where students have to construct the answers with the guidance of feedback, errors and hints. In the case of the TEA for the Logic course, this module uses an ITS for Logic practice. In the case of a different subject, a tool of the type of an ITS can be used. Knowledge assessment module also provides both practice and assessment tests with simple knowledge type of questions such as MCQ. Also, for these questions, feedback is provided for each step performed by the student. 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. Competencies module allows teachers to understand the competencies achieved by students in a particular course. These competencies are selected based on the marks obtained by students for a particular activity or test. Students can view the competencies they have achieved as a progress bar and a list of tables. Gradebook module is used to display grades and outcomes obtained by students for each activity or test. These components help

teachers to track students learning progress throughout the whole course period.

Out of the five modules mentioned, progress bar, competencies and gradebook are taken as the Basic TEA System as these are the basic functionalities of the main general TEA system and they are not subject dependent. In addition to that, the Basic TEA system is capable of storing log data related to students' participation in the activities and statistics.

Both the knowledge assessment and skill assessment modules are independent modules, where the skill assessment module is, usually, subject dependent. They are connected with the Basic TEA system using a plug-in, developed for this research purpose.

As shown in Figure 1, the users log into the LMS of the educational institution and automatically navigate to the TEA system through the single sign-on facility provided by the IMS Learning Tools Interoperability (LTI) specification (IMS GLC, 2013). The principal concept of LTI is to establish a standard way of integrating rich learning applications with platforms like learning management systems or other educational environments. Also, skill and knowledge assessment modules are linked with the Basic TEA system with the aid of the developed plug-in. For transferring data such as user data, grades, time spent and attempts, from the two modules to the Basic TEA system and from the TEA system to the LMS, OAuth protocol (OAuth, 2013) is used together with the IMS LTI specification. This protocol is used to secure its message interactions between the tools.

The connection and the communication between tools are carried-out through both message-based and service-based connections (Hettiarachchi et al., 2012).

In the case of the Logic course, an MCQ module was used as the knowledge assessment and our previously developed Logic ITS tool, enhanced into an assessment tool with the features of incorporating a large database of questions based on different difficulty levels, randomized selection of questions, immediate and detailed feedback, limited time and limited attempts, was used for the skill assessment. Since both the skill and knowledge assessment modules are independent modules, instead of these tools, any other tool can be taken and easily connected with the Basic TEA system using the developed plug-in in a secure and interoperable manner. Therefore, depending on the context, any other tool can be used.

#### 4 EVALUATION

The goal of this paper is to evaluate whether the developed e-assessment system works correctly. Also, the impact of the system in students' performance and engagement in the classroom was evaluated.

To evaluate the proposed TEA system and analyse its impact on students, the system was used in a Logic course of the Universitat Oberta de Catalunya. The course duration was 14 weeks with the participation of 38 students.

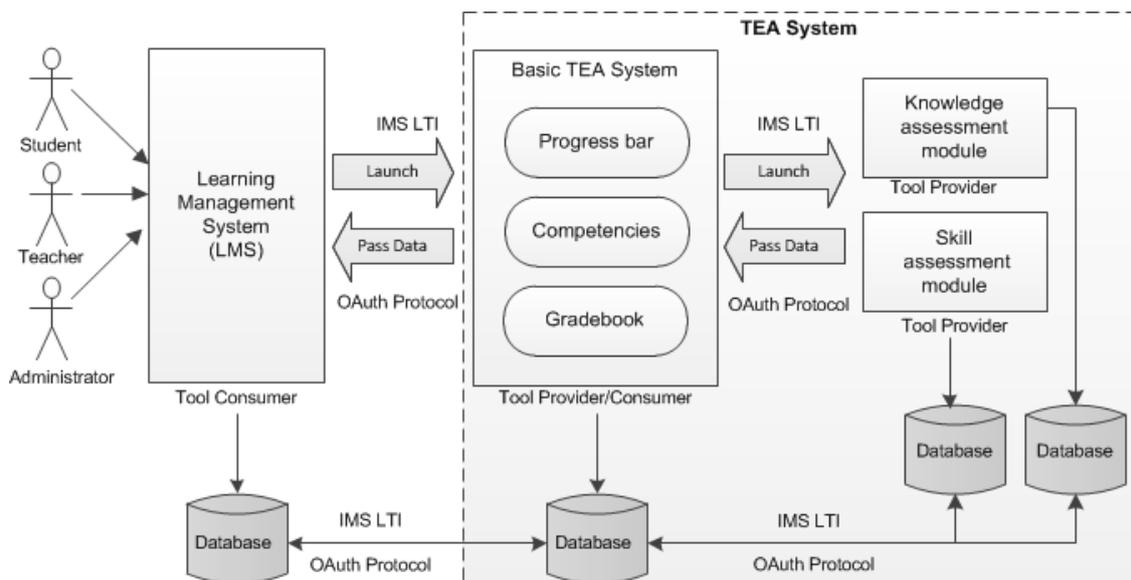


Figure 1: Architecture of the system with main components of the TEA system.

For the evaluation, a formative assessment model was introduced into the Logic course for both skill and knowledge assessment. For the formative assessment, students were provided with both practice and assessment activities through the system. To motivate students to practice with the interactive questions and feedback, a restriction was imposed as students needed to obtain a minimum pass mark in the practice activities to move to assessment activities. Questions within the assessment activities were selected randomly from a large question bank to minimize cheating. Also, soon after completion of a particular test, students were offered with immediate detailed feedback. Also, students were given a face-to-face 2 hour final examination. The final grade of the course comprised of 35% of marks in the formative assessment and 65% of marks in the summative assessment.

#### 4.1 Analysis and Results

Data were collected mainly from two sources. On the one hand, data related to student engagement with the TEA system were obtained through the system log. On the other hand, a questionnaire was given to the students to obtain their feedback regarding the learning experience with the TEA system. This questionnaire was also used to obtain students' perceptions about the system, the improvements needed to be carried-out in the future, and also to draw conclusions regarding the student experience with the system. The questionnaire

consisted of 28 questions consisting of open-ended, yes/no and five-point Likert scale questions. These questions were divided into four sections such as learner information, student satisfaction, formative assessment and assessment model.

To analyse students' engagement, data were obtained from the system logs about student participation using the TEA system. The results of the analysis are shown in Figure 2. According to that, each student accessed the system minimum 5 times during a particular day. The TEA system consisted of session time-out duration and therefore, students might have had to login to the system more than once during the day. This could be shown as the highest peaks in the diagram. The majority of these peaks had occurred when it was closed the deadlines of the assessment activities (AA corresponds to Assessment Activities).

High peaks at the beginning shows that, students have used the TEA system more to get familiar with its features. Overall, students have continuously used the TEA system throughout the whole duration of the course. This could be due to the fact that students had appreciated the facilities, such as interactivity, immediate feedback and marks, provided by the TEA system for practice purposes.

To explore students learning experience, a set of questions was introduced into the questionnaire.

Regarding the student satisfaction, four questions were given to the students. About the instructions presented for answering the questions, 89% of students agreed by answering they were presented in

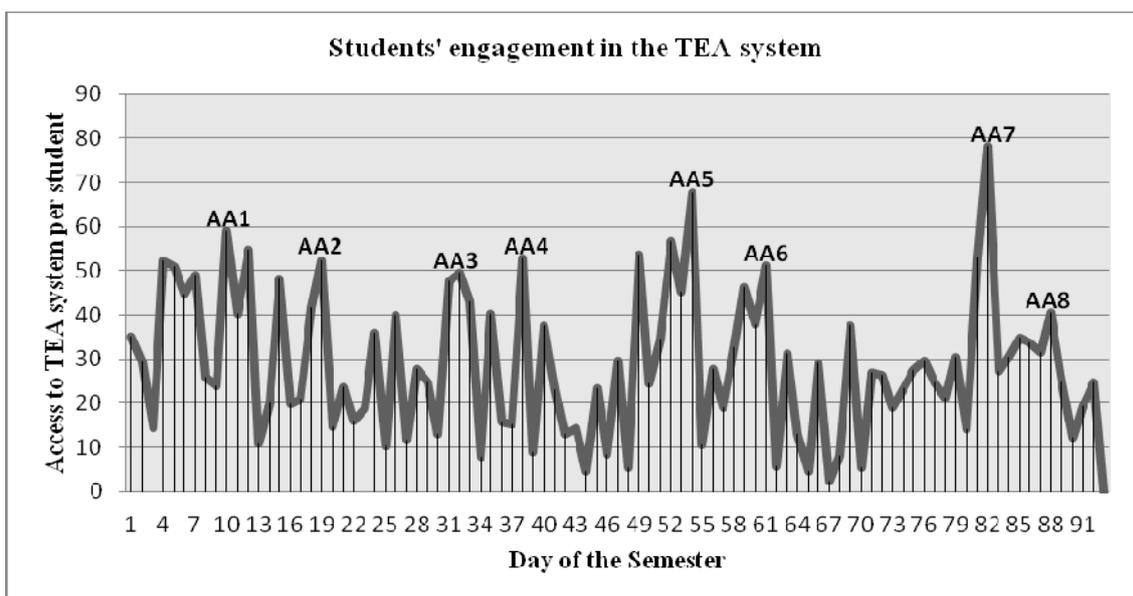


Figure 2: Students' engagement in the TEA system.

a clear and concise manner. Also, 68% of the students agreed that the automatic grades offered through the system were very good. At the same time, 89% of students were satisfied with the questions provided for both practice and assessment. Overall, students were satisfied with the TEA system. For formative assessment, students' opinions about practice, assessment, feedback and their relationship to improving learning process were evaluated. First, it was needed to understand whether it was helpful to practice before attempting the assessments and 74% of students agreed and they further mentioned that practicing using the system helped them to evaluate the skills and knowledge acquired as well as they were able to practice and get a comprehensive review of the questions offered in the assessments. When it comes to the automatic feedback, 89% of students agreed that feedback provided by the TEA system was satisfactory. This can be taken as a reason due to detailed immediate feedback, hints and suggestions introduced in the system. Based on the marks offered by the TEA system, 89% students agreed that the marks fit their knowledge and skills developed. Therefore, it can be stated that the TEA system was capable of offering correct marks or grades to fit the skills and knowledge acquired by students. Also, 79% of students considered that practice and assessment tests provided were helpful for learning skills related to the course. Furthermore, students also agreed that both tests helped them to understand the topics covered in the materials. Therefore, to find the difficulty of the assessments, when asked about the average number of attempts students had to complete in-order to achieve the minimum score, 74% mentioned 2 attempts and another 11% mentioned 3 attempts. As a conclusion an average of 2 attempts were needed to obtain the minimum score. At the same time, it can be taken as an indicator that the assessments were of medium difficulty level and they are suitable for assessment of knowledge and skills. Also, 79% of students strongly agreed that assessment tests have helped them to evaluate their strengths and weaknesses in the Logic course. To get students' opinions about the use of assessment tests in the subject, whether they would have learned the same if they did not have assessment tests and 89% of students answered by saying no. Therefore, it shows that students have valued the importance of assessments in the learning process. When it comes to evaluating the progress of doing tests using the progress bar, only 74% agreed, whereas some students have mentioned, it was useful but not essential. About the usefulness of the

competency module, 79% of students agreed by saying it was useful, whereas the rest of the 21% did not agree. When asked about the reasons most of them have mentioned that they have not seen the module since they have not been informed about it. However, when asked about grades and outcomes, interesting 100% agreed that both grades and outcomes were useful information. Finally, an open-ended question was given to obtain students comment and suggestions about the system. Overall, students liked the system, unless some students have mentioned that the time given, 2 hours, for the assessment test was not enough.

## 5 CONCLUSIONS

The TEA system was introduced to support the student learning process based on both skill and knowledge acquisition. The system was designed to offer interactivity in e-assessments with an architecture that favours its application to different domains and its connection with different existing LMS in a secure and interoperable way.

This system provided both practice and assessment facilities for students to improve their learning process. Therefore, students were constantly engaged in the system and as a result, their performance in the formative assessment and summative assessment had improved. Also, the information provided through the progress bar and competencies module helped students to evaluate their own progress. However, most of the students have not fully utilized these features, as they were not informed about them. Therefore, in the future, students have to be informed at the beginning of the course about the facilities offered through the progress bar and the competencies module.

Student participation data in the TEA system showed that students were constantly engaged in the system for both practice and assessment purposes. It also showed that students were more engaged in the system when it was close to a completion date of an assessment test. Also, students had used the system even after the completion dates of the assessments. This showed that students had used the system to prepare for the final examination. Overall, as a conclusion, it can be stated that students had constantly engaged in the TEA system throughout the course duration. Overall, students were satisfied with the TEA system, formative assessment, assessment model, course scheduling, marks and feedback provided. Students were also satisfied with the detailed and immediate feedback and they

believe that doing practice activities had helped them to perform better in the assessments, and to evaluate the skill and knowledge acquired. Also, according to students, both practice and assessment tests helped them to evaluate their strength and weakness in the Logic subject, and learn skills related to the subject. However, some students mentioned that it was a bit stressful and the allocated time was not enough to complete some of the questions related to skills. Therefore, as improvements it is needed to consider about the time given for the assessments, mostly in the sections where students have to construct the answer using the skill assessment module. At the same time, a complete schedule with assessments has to be displayed in the main course page.

Although this research was carried out in a fully online environment, the developed TEA system with the formative assessment approach based on skills and knowledge can be extended to blended courses. In the future, for testing the interoperability of the TEA system, it will need to be introduced into other courses based on skills and knowledge as well as by connecting with other LMS.

As a general summary, the technology-enhanced assessment system was capable of supporting students learning process and as a result students' performances in the online classroom had improved.

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