Technology-Enhanced Assessment for Skill and Knowledge Acquisition in Online Education

K. H. Enosha Lasanthi Warunika Hettiarachchi
khettiarachchi@uoc.edu

Thesis Committee Members:
Dr. Maria Antonia Huertas Sánchez, Dr. Enric Mor Pera (Directors)
Dr. Jordi Saludes (Commitee Member)

Doctoral Programme in the Information and Knowledge Society
(PhD in Network and Information Technologies Area)
The Internet Interdisciplinary Institute (IN3), Universitat Oberta de Catalunya (UOC)
Carrer Roc Boronat, 117. 08018 Barcelona, Spain

12th July 2013

Abstract

Technology-Enhanced Assessment which is also known as e-assessment is the continuous electronic assessment process where Information and Communication Technology (ICT) is used for the presentation of assessment activity, and the recording of responses. This includes the end-to-end assessment process from the perspective of learners, tutors, learning institutions; awarding bodies as regulators, and the general public. Improving the quality of the student learning experience is a key issue in online education, and it has been widely recognised that e-assessment can contribute to this. Technology-enhanced assessment offers both teachers and students new possibilities for interacting in an immersive and responsive educational environment, moving beyond the static environment of the traditional pen and paper approach.

E-Assessment has become increasingly attractive in Higher Education where providing useful feedback to large number of students can be difficult. However, the nature of such assessments has often been limited to objective questions such as multiple choice questions (MCQ), multiple responses, matching, hot spots and fill in the blank questions, which are usually knowledge-based. Cognitive skills which evaluate students' practical abilities and skills by doing a particular task cannot be assessed via multiple-choice tests and equivalent forms of basic assessment items. This raised the need to go beyond simple type of questions such as MCQ and introduce a dynamic and an interactive user-friendly dimension into formative e-assessment which is capable of assessing knowledge and skill acquirement of students.

The fundamental aim of this research is to propose a general technology-enhanced assessment system to provide a new learning experience for students in both skill and knowledge assessment in an online educational environment. This was achieved through design and development of a general technology-enhanced assessment system which can be easily adapted to any context. As practice is an important aspect of e-assessment which allows students the opportunity to act on the feedback, a formative e-assessment model which include both practice and assessment facilities was proposed and used within the technology-enhanced assessment system.

As the research methodology, design and creation research strategy was used in an iterative process which involved five steps such as awareness, suggestion, development,

evaluation and conclusion. These steps were followed according to User Centered Design (UCD) approach in an iterative cycle.

The evaluation of the system was performed with respect to testing and validation of the system.

Testing of the system was carried-out throughout the development process in an iterative manner. This was done according to a testing methodology and plan comprised of unit, integration, validation and system testing. User acceptance testing was addressed under the validation of the system.

Validation was used to determine the quality and the performance of the system in the real-world context. Both the system and the introduced formative e-assessment model were evaluated in the real online environment through pilot studies. For this, as the case study, Logic course of the Universitat Oberta de Catalunya (UOC), a fully online university was used. Logic course was selected because it is a subject which requires a high level of skill and knowledge in order to obtain the required qualification.

As the conclusions of this research, it can be stated that a fully automated technology-enhanced assessment system was designed and developed for the acquisition of skill and knowledge acquirement. The skill and knowledge assessment through the system was provided through a proposed formative e-assessment model which consisted of both practice and assessment facilities. This system was developed in a general way according to the e-learning and e-assessment standards which maintains security and interoperability. Therefore, it can be easily adapted to any other subject or organization. After application of the system into the real context, it was observed that the use of technology-enhanced assessment had a positive impact on student learning and performance through the implementation of formative e-assessment model. The learning process based on both skills and knowledge using the system through added functionalities such as practice and immediate feedback had improved students' performance. Students learned through more practice and engagement with the system and as a result their performance in the final examination had improved. The system also provided added benefits to teachers through automated marking and tracking of students' progress throughout the whole course. Finally, with the ever increasing interests and adaptation of e-assessment, this research has produced a new perspective, not only theoretical but which can be applied into practice and offer new lessons learned into the e-assessment field, thus significant for further investigation.

To my mother Mrs. B.L.G.P. Buddadasa and my late father Mr. K.H.B. Hettiarachchi

Acknowledgements

It is with great honor and gratitude that I pen these few words to thank all those who helped me in making this research project a great success. First of all I thank my supervisors, Dr. Maria Antonia Huertas Sánchez and Dr. Enric Mor Pera for the immense support, guidance, valuable advice, encouragement and suggestions given to me throughout the entire time period to complete this research work. Also to Dr. Jordi Saludes for being a part of my thesis committee and for the guidance and advice provided to me during this period. I would also like to thank Dr. Ana-Elena Guerrero-Roldán and Dr. Elena Rodríguez who helped me in numerous ways to reshape this research according to a pedagogical perspective. This research project would not have been possible without the guidance of all of you.

I would also like to thank the Internet interdisciplinary Institute (IN3) of the Universitat Oberta de Catalunya (UOC) for offering me a grant for my PhD studies in Network and Information Technologies Area.

I take this opportunity to express my sincere thanks and gratitude to my dear mother, who always stood by me and encouraged me to follow this PhD program. Even though I am far away from home, talking with her always made me feel that I wanted to achieve the best I can. I would also like to thank her for understanding, encouraging and guiding me to achieve my dream. I would also like to thank my sister for giving me the fullest support in all my efforts and also being with my mother and taking care of her when I am not there, which helped a lot for me to concentrate on my research. I also take this opportunity to pay respect to my dear father who passed away 15 years ago, who had always helped and guided me in my studies and whose blessings are always with me. I am sure that he is proud of me right now and I dedicate this thesis to him and to my mother.

I also thank Francesc Santanach and Antoni Bertran Bellido, of the UOC for giving the limelight needed for selecting appropriate standards which persuades me to follow in the direction of using IMS LTI as the standard for the system and supporting me whenever I needed help. I would also like to express my sincere gratitude to Laura López Oros for helping me in numerous ways with the LELA tool including giving the code and helping me to clarify the doubts I had with the tool. Also I would like to thank Dr. César Córcoles for giving access to the Cimanet server for the installation of the system to carry-out the pilot studies. At the same time, I am grateful for the help you have given me to clarify my doubts with Linux and the help given for the installation and maintenance of the system in perfect condition. Not forgetting the valuable help given by Marc Ortega Gil for willing to carry-out pilot studies in his classroom for two semesters and being really patient with the features, new introductions and modifications made to the system from time to time. Without your help, making this research would not have been possible.

I take this opportunity to express my sincere gratitude to Professor Denise Whitelock of The Open University of UK, for the guidance, suggestions and support given as well as for helping me to clarify my doubts.

I also thank all the lecturers who taught me courses during my first six months of the PhD program. I also take this opportunity to give my sincere thanks and gratitude to the IN3 and UOC for conducting a valuable PhD degree program for students to gain and improve their research skills and to perform their best to achieve a doctoral qualification, covering a comprehensive research study within three years of time.

It is my obligation to be thankful to all persons, even whom I have not directly mentioned here but who are in my heart for giving me their fullest support and encouragement to successfully complete this research work.

Thank you!!!

Enosha Hettiarachchi

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List of Acronyms

ADL Advanced Distributed Learning

AFA Abstract Framework for Assessment

AICC Aviation Industry CBT Committee

AIM Alice Interactive Mathematics

ANSI American National Standards Institute

API Application Programming Interfaces

AT Assessment Test

Basic TEA Basic Technology-Enhanced Assessment

Basic LTI Basic Learning Tools Interoperability

CA Continuous Assessment

CAT Continuous Assessment Tests

CLE Collaboration and Learning Environment

EASy The E-Assessment System

ECTS European Credit Transfer System

EMQ Extended Matching Questions

FAQ Frequently Asked Questions

FIB Fill in the Blanks

FML FAQ Markup Language

FREMA Framework Reference Model for Assessment

HE Higher Education

ICT Information and Communication Technology

IEEE Institute of Electrical and Electronics Engineers

IMS Instructional Management System

LIST OF ACRONYMS

IMS GLC Instructional Management System Global Learning Consortium

ISO International Organization for Standardization

IT Information Technology

ITS Intelligent Tutoring Systems

JISC Joint Information Systems Committee

LELA Logic E-Learning Assistant

LIP Learner Information Package

LMS Learning Management Systems

LOM Learning Object Metadata

LTI Learning Tools Interoperability

LTSC Learning Technology Standardization Committee

MCQ Multiple Choice Questions

MRQ Multiple Response Questions

O.K.I Open Knowledge Initiative

OSS Open Source Software

PANDORA Proof Assistant for Natural Deduction using Organised Rectangular Areas

PAPI Public and Private Information

PT Practice Test

QAML Question and Answer Markup Language

QTI Question and Test Interoperability

SCORM Sharable Content Object Reference Model

TC Tool Consumer

TEA Technology-Enhanced Assessment

TELE Technology-Enhanced Learning Environments

TP Tool Provider

UCD User-Centered Design

UOC Universitat Oberta de Catalunya

UPC Universitat Politecnica de Catalunya

URL Uniform Resource Locator

VLE Virtual Learning Environments

XML Extensible Markup Language

1

Introduction

Technology-Enhanced Assessment (TEA) can be noted as the end-to-end electronic assessment process where Information and Communication Technology (ICT) is used for the presentation of assessment activity, and the recording of responses. This includes the end-to-end assessment process from the perspective of learners, tutors, educational institutions, awarding bodies and regulators, and the general public (Australian Universities Teaching Committee, 2002; Cook & Jenkins, 2010; Daly et al., 2010; JISC, 2007). In other words, technology-enhanced assessment involves the use of any web-based method that allows systematic inferences and judgments to be made about the students skills, knowledge and capabilities (G. Crisp, 2007). Technology-enhanced assessment, which is most commonly known as e-assessment or online assessment has become a very integral part of e-learning based study programmes, offered by educational institutes. The main reason is that mostly academics are seeking to expand assessment tasks, while at the same time broaden the range of skills assessed and provide students with more timely and informative feedback on their progress.

When it comes to technology-enhanced assessment, it is also important to consider about the advantages and disadvantages associated with it. Some of the advantages can be noted as; perceived increases in student retention, enhanced quality of feedback, flexibility for distance learning, strategies to cope with large student/candidate numbers, objectivity in marking and more effective use of virtual learning environments (Dermo, 2009; Whitelock, 2007, 2009; Whitelock & Watt, 2008). The downsides can be noted as; plagiarism detection and invigilation issues, academic staff time and training, extra stress imposed on students due to lack of Information Technology (IT) skills needed to complete the tasks, technical problems with question interoperability and lack of venues suitable for on-computer assessment (Whitelock & Watt, 2008).

Considering a technology-enhanced assessment system, main characteristics can be noted as; monitoring student progress through frequent assessments, shortening the time gap between submission and receiving feedback, automatic marking, weighted-average grade calculation, applying a variety of interactive question types, promoting flexible learning and adaptive learning, personalization of quizzes, monitoring question quality using statistical analysis, reducing the potential for cheating by randomizing questions along with timers, and sharing questions via question banks (J. Bull & Mckenna, 2004; Sitthiworachart et al., 2008; Tselonis & Sargeant, 2007).

As V. Crisp & Ward (2008) pointed out, formative computer assisted assessments has become increasingly attractive in Higher Education (HE) where providing useful feedback to large number of students can be difficult. However, the nature of such assessments has often been limited to objective questions such as multiple choice questions (MCQ), multiple responses, matching, hot spots and fill in the blank questions, which are usually knowledge-based (Bruyn et al., 2011). Skill-based questions are more aligned towards modeling of information flows; constructing processes and problem solving, where students have to apply their analytic, creative, and constructive skills to obtain an answer (Majchrzak & Usener, 2011, 2012).

This research explores the application of technology-enhanced assessment for skill and knowledge acquisition in the domain of online education. This work, involved research and requirements analysis, design, development and evaluation of a technology-enhanced assessment system that facilitates skill and knowledge acquisition in the described domain of online education.

This chapter presents the introduction of the thesis and it highlights the motivation as the justification of research interest. Also, the research objectives, questions and the methodology of this research are presented. Finally, the synopsis outlines the structure of this thesis and the way it corresponds to later chapters.

1.1 Justification of Research Interest

E-Assessments have traditionally been used for tasks that focus on testing the acquisition of declarative knowledge (or knowing "what"). Such tasks have required students to select a predetermined response based on factual recall like, for example, the simple multiple-choice and short answer question types (Bruyn et al., 2011; J. Bull & Mckenna, 2004; Northcote, 2003). Such questions have been popular because they are quick to write and are easily constructed in common Learning Management Systems (LMS) used in higher education institutions (G. Crisp, 2010).

However, cognitive skills where students have to apply their analytic, creative, and constructive skills cannot be assessed via multiple-choice tests and equivalent forms of basic assessment items (Gruttmann et al., 2008; Majchrzak & Usener, 2011).

According to Rust et al. (2005), in the constructivist approach to learning, students are expected to make decisions and reflect on the consequences of those decisions. A constructivist learning environment provides students with access to information and authentic learning tools. These same tools and information sources should be available for students to use when they undertake assessment tasks in order for students to demonstrate the development of higher order capabilities.

Currently, most of the e-assessment is provided through simple types of questions such as MCQ, short answer, true/false and fill in the blanks. These simple types of questions rarely give any insight into the thought processes students used to determine their response (Buzzetto-More & Alade, 2006; G. Crisp, 2010).

As G. Crisp (2009a, 2010) stated, in order to test higher order capabilities it is needed to design sophisticated assessment tasks, but the workload in designing such tasks is considerable.

Considering the above, one of the motivations of this research is to go beyond tools which offer simple types of questions such as MCQ and short answer questions and introduce an interactive dynamic environment for both skill and knowledge assessment in an online educational environment.

Assessment types can be categorized as diagnostic, formative and summative based on at which stage of the learning the assessment is carried-out (Cook & Jenkins, 2010; G. Crisp, 2007, 2009a). Diagnostic is used to identify the current knowledge level of students. Formative 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. Summative is the final assessment which is used after the learning has been completed. This type of assessment task is designed to grade and judge a student's level of understanding and skill development for progression or certification.

Practice is an important aspect of assessment as it allows students the opportunity to act on the feedback (Merry & Orsmond, 2008; Sadler, 1989). Also, more emphasis should be given on feedback, as timely and constructive feedback motivates students to learn more efficiently (J. Bull & Mckenna, 2004; Sadler, 2013). By considering both practice and immediate feedback to improve students performance, as the second motivation it was needed to examine a formative e-assessment model that can be used to offer both practice and assessment facilities through the technology-enhanced assessment system.

Advances in computer hardware and software facilities, and more importantly, advances in e-learning and e-assessment standards and specifications make it possible to address the aim of this research - investigating how to introduce both skill and knowledge assessment into the online educational environment through a design and development of a general technology-enhanced assessment system which can be easily adapted to any context.

1.2 Research Objectives and Questions

The main objective of the present research is to propose a general technology-enhanced assessment system for skill and knowledge assessment in online education.

This was achieved through a design and development of a technology-enhanced assessment system which is compatible with the current standards of such technology. Assessment is provided through a designed formative e-assessment model which is comprised of both practice and assessment facilities.

For reaching the above objective, research activities and questions can be stated as;

1. **Design and develop a technology-enhanced assessment system for assessing both skills and knowledge in online education**

   (a) **Which e-learning and e-assessment standards and specifications should be followed in order to develop an e-assessment system which is interoperable and secure?**

   Standards and specifications play an important role in this research as the technology-enhanced assessment system is designed and developed in a general way which can be easily adapted to any subject or organization. In this case, the main concern is given for security and interoperability as it allows any tool to be easily connected with the technology-enhanced assessment system and exchange data between them in a secure manner. In this regard, a literature review can be used to understand the most common standards and specifications available, their functionalities and the way they can be used for connecting and communicating data among tools in a secure manner.

   (b) **Which tools can be used for assessment of skills and knowledge subjects?**

   In this research, a detailed literature review is carried-out to find a general tool which can be used to offer both skill and knowledge assessment. Under this characteristics associated with both skills and knowledge is also studied along with the questions and tools which can be used.

   (c) **Can a technology-enhanced assessment system be developed as a series of modules to support both skill and knowledge assessments while maintaining interoperability and security?**

   The key elements of the technology-enhanced assessment system should be the skill and knowledge assessment modules. Other than that, the system should be incorporated with features for the students' progress, competencies, grades and outcomes. Considering this, instead of designing and developing the system as a whole, it is studied whether it is possible to develop the system as a series of modules while maintaining security and interoperability.

2. **Validate the proposed technology-enhanced assessment system in a real online environment by conducting pilot studies**

   (a) **Can the technology-enhanced assessment system support student learning process?**

   For supporting the student learning process, a proposal of a formative e-assessment model which offers both practice and assessment facilities is introduced through the technology-enhanced assessment system. After applying the system and the model into the real online environment, this is tested through students performance in the formative continuous assessments and the final face-to-face examination.

   (b) **Does practice with the formative e-assessment model, enhance the student learning experience?**

   To validate this question, it would be necessary to analyse students' engagement with the system. Also students' participation in the practice activities provided through the formative e-assessment model is analysed to see how much students have practiced and whether their performance has improved as a result of it. Students performance in the assessments after the completion of the practice activities is also analysed to see whether practice has helped students with the assessment process.

   (c) **Is it possible for teachers to track student learning process throughout the whole course?**

   For this purpose, data obtained from features of the system such as students' progress, competencies, grades, outcomes and statistics are analysed to check whether it provides valuable information for teachers to track the learning process of students.

1.3 Research Methodology

This research is based on the Design and Creation research strategy which is a problem solving approach. Design and creation research strategy focuses on developing a new IT product, also called artefact (Oates, 2006). Types of IT artefacts include: constructs where the concepts or vocabulary is used in a particular IT-related domain (for example: the notation of entities, objects or data flows), models where combinations of constructs that represent a situation are used to aid problem understanding and solution development (for example: interaction flow diagrams, use case scenarios or storyboards), methods where guidance on the models to be produced and process stages to be followed to solve problems using IT (for example: formal mathematical algorithms, commercialized and published methodologies, etc) and instantiations where a working system that demonstrates that constructs, models, methods, ideas, genres or theories can be implemented in a computer-based system. The new technology-enhanced assessment system, is a combination of artefacts such as constructs, models, methods and instantiations. When designing and developing the technology-enhanced assessment system, scenarios, interaction, use case and sequence diagrams are used to explain the situations as well as to aid in the solution development.

Useful data about the formative e-assessment model is obtained after using the system in a real context. The design and creation strategy is used in an iterative process involving five steps such as awareness, suggestion, development, evaluation and conclusion (Oates, 2006).

Awareness is the recognition and articulation of a problem, which can come from studying the literature where authors identify areas for further research, or reading about new findings in another discipline, or from practitioners or clients expressing the need for something, or from filed research or from new development in technology.

Suggestion involves a creative leap from curiosity about the problem to offering a very tentative idea of how the problem might be addressed.

Development is where the tentative design idea is implemented. The way it is done depends on the kind of IT artefact being proposed.

Evaluation examines the developed artefact and looks for an assessment of its worth and deviations from expectations.

Conclusion is where the results of the design process are consolidated and written up, and the knowledge gained is identified, together with any loose ends - unexpected or anomalous results that cannot yet be explained and could be the subject of further research.

These steps are followed according to User Centered Design (UCD) approach (Bevan, 2003; Bevan & Curson, 1999; Goodwin, 2009) in an iterative cycle. User centered design refers to a multidisciplinary design approach based on the active involvement of users for a clear understanding of user and task requirements, and the iteration of design and evaluation. It is considered as the key to product for usefulness and usability (Bevan, 2003; Mao et al., 2001).

As the main case, the Logic course of the Universitat Oberta de Catalunya (UOC), a fully online university is used. This is a subject offered in the first year undergraduate Computer Science (CS) degree programme. Logic was chosen because, it is a subject which requires a high level of skill and knowledge in order to obtain the required qualification in the subject.

According to design and creation research strategy, for *Awareness* step, it is needed to study the existing modules or tools that are currently being used for formative e-assessment. Also literature is studied to understand the problems related to the past research that has been carried-out in this field. Under *Suggestion* step, the need to design and develop a technology-enhanced assessment system for both skill and knowledge assessment of students is studied. The required tools and standards are also identified. Based on that, the design and development of the system is carried-out under the *Development* step with interaction diagrams, scenarios and prototypes. Then the developed system is evaluated in the real online environment under the *Evaluation* step by conducting validation studies through pilots in the Logic course of the Universitat Oberta de Catalunya (UOC). The data obtained through these validation studies are analyzed using mixed method evaluation techniques (Frechtling & Sharp, 1997; Fuente-Valentín et al., 2013). In the *Conclusion* step, these techniques are used to deduce conclusions based on the technology-enhanced assessment system, the overall assessment process and the steps to be taken in the future.

According to UCD approach, these steps of the cycle are carried out in an iterative manner, with the cycle being repeated until the research projects' usability objectives have been attained.

1.4 Synopsis of the Thesis

The following chapters will basically illustrate the "State of the Art" of the research, "Design and Development of the TEA System", "Evaluation" and "Conclusion, Finding and Future research" followed by "References" and "Appendix". These chapters are constructed according to the five steps (Awareness, Suggestion, Development, Evaluation and Conclusion) of the design and creation research strategy. Awareness is taken as the "State of the Art" chapter which consists of a comprehensive literature review. Suggestion and development are combined together as "Design and Development of the TEA System" chapter.

A brief summary of each chapter can be stated as below:

- **State of the Art :** This chapter explains the present status of the technology-enhanced assessment for skill and knowledge acquisition through a detailed literature review. The chapter starts with an introduction to assessment and then describes the two types of assessments as skill and knowledge. The main topic, the technology-enhanced assessment is explained. Also elements of formative e-assessment are also presented. Further, related to the research the e-assessment tools, standards and specifications and e-assessment models are discussed in detail. The general trends and positions associated with the technology-enhanced assessments are also explained. Some of the knowledge and skill assessment tools that are currently in use are also presented. Finally, the summary of the chapter is explained with respect to the reasons for selecting the approach.

- **Design and Development of the TEA System :** This chapter presents the requirements, design and development of the technology-enhanced assessment system. The detailed requirements for the system are identified to support both skill and knowledge assessment. After identifying the necessary requirements, analysis of requirements is carried-out. The definitions of the technology-enhanced assessment system and the formative e-assessment model are also explained in this chapter. The design of the system with respect to the process of defining the scenarios, interaction flow diagrams, use case and sequence diagrams, architecture, components, and interfaces is presented. Finally, the development of the system is explained with respect to these designs.

- **Evaluation :** This chapter explains the evaluation of the system with respect to testing and validation. Testing of the system is carried-out after developing the IT artefact. Under this, different types of testing carried-out are explained along with the test methodology and plan. The validation of the system and the formative e-assessment model through pilot studies are also discussed based on the validation methodology and the plan.
- **Conclusions and Future Research :** This chapter discusses how this research has met its objectives as specified in "Chapter 1 - Introduction" and the conclusions drawn based on that. Then, it presents the original contributions of this research in-detail and finally, the chapter concludes with future research work and closing remarks.

2

State of the Art

This chapter describes the background for the present research along the dimensions of skill and knowledge assessment, technology-enhanced assessment, elements, systems, tools, and approaches, to knowledge and skill assessment. These dimensions provide theory and technology which are useful for designing and developing a technology-enhanced assessment system for skill and knowledge acquisition. More specifically:

- Advantages and disadvantages associated with technology-enhanced assessment
- Supporting students' learning process through formative e-assessment
- Standards, specifications and models that should be followed to design and develop an e-assessment system which is interoperable and secure
- General trends and positions associated with technology-enhanced assessment
- Previous research based on skill and knowledge assessments

The chapter starts with an introduction to assessment including skill and knowledge assessment. Also, a brief introduction to technology-enhanced assessment is given. The elements of formative e-assessment are described along with its effects on students' learning process. Furthermore, this chapter explains the e-learning systems, standards & specifications, e-assessment tools that are currently in use, and the currently defined e-assessment models. Finally, the approaches to knowledge assessment are explained along with general trends and positions associated with the technology-enhanced assessment followed by a skill and knowledge assessment tools that are currently in use.

2.1 Assessment

Before moving into technology-enhanced assessments, first it is needed to consider about assessment in general. 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, 2007). In other words, assessment can also be denoted as an appraisal (or judgment, or evaluation) of a student's work or performance (Sadler, 2013). As G. Crisp (2007) has mentioned, assessment activities are expensive and produce stress for people involved in the process such as for both teachers and students. 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, etc. At the same time, assessments encourage learning and provide feedback on learning to both students and teachers. Therefore, it is interesting to have a look at the relationship between assessment and learning.

2.1.1 Relationship between Assessment and Learning

As Biggs (2003) 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. He also mentioned that *"assessment drives student learning and that teachers should take a strategic and integrated approach to curriculum design so that assessment of learning is clearly distinguished from assessment for learning"*. Accordingly, "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 et al., 2012). This research mainly focuses on"assessment for learning" as students are provided with the facilities to assess their own learning process through the formative e-assessment and feedback given.

2.1.2 Skill and Knowledge Assessment

Assessment tasks can be divided broadly into two types such as convergent assessment and divergent assessment (G. Crisp, 2009a). Convergent assessment also known as knowledge assessment, mostly uses simple forms of questions such as multiple choice questions, multiple responses, short answers, fill in the blanks, matching and crossword puzzles. 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.

Divergent assessment also known as skill assessment is more authentic and makes it easier to assess higher cognitive skills. However, they can be time consuming to set and mark. They also require greater marking proficiency than convergent assessments; which can involve training markers or detailing criteria (McAlpine, 2002).

According to Bloom (1956), 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. 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 represents the lowest level of learning outcomes in the cognitive domain and therefore, exercises that require knowledge to be memorized only account for a fraction of the overall examinations (Majchrzak & Usener, 2011, 2012). Knowledge assessment is based on items in such a cognitive domain. Where knowledge is the principle issue, convergent assessments can be very useful. As McAlpine (2002) pointed out, because of the convergent assessments ability of wide curricular coverage, it can be very important in assessment to quickly and effectively highlight areas of weakness and gaps in the students' knowledge. When the core of knowledge is a fundamental base for the study of the subject, convergent assessment can be used.

Divergent assessment is often associated with a constructivist view of learning (G. Crisp, 2007) and it is best suited when there may be a difference of opinion based on interpretation. Subject areas which require a high level of skills can be stated as skill assessment of a particular software package, online music theory assessment to teach music, assessing the skill of language learning and constructing a mathematical solution or a logic proof. Following Gibbs & Simpson (2004), a 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. These exercises rely on students being able to think in a structured way and to acquire skills in modeling (e.g. of information flows, business processes, mathematical proofs and medical diagnosis).

In summary, convergent and divergent assessments are used for knowledge and skill assessment respectively.

2.2 Technology-Enhanced Assessment

Technology-enhanced assessment which is also known as e-assessment is the continuous electronic assessment process where Information and Communication Technology (ICT) is used for the presentation of assessment activity, and the recording of responses. This includes the end-to-end assessment process from the perspective of learners, tutors, learning institutions; awarding bodies as regulators, and the general public (Australian Universities Teaching Committee, 2002; Cook & Jenkins, 2010; Daly et al., 2010; JISC, 2007). Improving the quality of the student learning experience is a key issue in higher education, and it has been widely recognised that e-assessment can contribute to this (Dermo, 2009). Technology-enhanced assessment offers both teachers and students new possibilities for interacting in an immersive and responsive educational environment, moving beyond the static environment of the traditional pen and paper approach (G. Crisp, 2009b). Alternative modes of presenting assessment tasks are now possible, ones that are more adapted to the diversity in learning styles displayed by students. Technology-enhanced assessment has the potential to offer new forms of assessment with immediate feedback to students and is therefore, one of the major challenges for both schools and higher educational institutions today. It is, therefore, becoming increasingly important to construct a pedagogically driven model for e-assessment that can incorporate assessment and feedback into a holistic dialogic learning framework, which recognises the importance of students reflecting upon and taking control of their own learning (Whitelock, 2009).

For an assessment to take place online, three components are normally involved such as creation, storage and delivery of an assessment to students; the capturing, marking, storage and analysis of student responses; and the collation, return and analysis of the results (SQA, 2003) .

Technology-enhanced assessment can be categorized as diagnostic, formative and summative based on at which stage of the learning the assessment is carried-out (G. Crisp, 2007). Diagnostic assessment task is carried-out before the beginning of the learning process and is used to identify the current knowledge level of students so that learning activities can match student requirements. Formative assessments are 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. Summative assessment is the final assessment which is used after the learning has been completed. This type of assessment tasks is designed to grade and judge a student's level of understanding and skill development of progression or certification (G. Crisp, 2007; Hettiarachchi & Huertas, 2012). A growing body of evidence, indicates that well-designed and well-deployed diagnostic and formative assessments can foster more effective learning for a wider diversity of learners (Nicol, 2006; Sharpe et al., 2006). A diagram to depict the relationship between diagnostic, formative, summative assessment tasks linked to learning activities can be shown as in Figure 2.1.

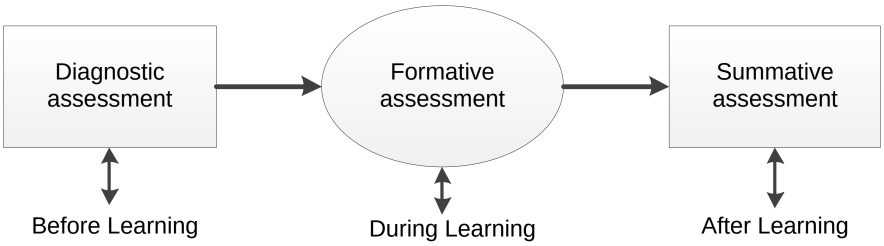


Figure 2.1: Relationship between diagnostic, formative, summative assessment and learning

The formative e-assessment process explained in JISC (2007) with respect to e-assessment and effective learning, is described below. To provide an effective progress for the learner, learning and e-assessment has to be integrated together. Learning modules are provided either as e-learning or blended learning through a learning management system. After completion of the learning module students are provided with assessments either as formative or summative depending on the course. After completion of the assessment, if they have successfully completed it, they will be provided with feedback or the final qualification. If they are not successful in the assessment, they will also be given a constructive feedback and a revision module which they can practice and take the assessment at a later stage. The relationship between e-assessment and effective learning is illustrated as in Figure 2.2.

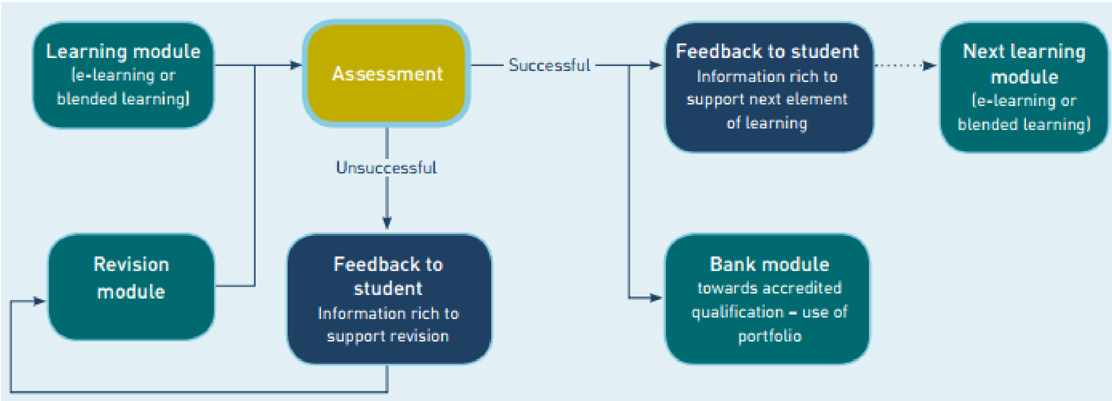


Figure 2.2: The relationship between e-assessment and effective learning (JISC, 2007)

However, according to this model students are provided with practice only if they are not successful in the assessment. As can be seen from the diagram, before moving to assessments, students are not provided with practice activities. As Sadler (1989, 2013) has mentioned practice plays an important role in assessment as it provides students with the opportunity to act on the feedback given and improve their learning process. Therefore, this is an important aspect which has to be considered when introducing the formative e-assessment model for the technology-enhanced assessment system.

Technology-enhanced assessment is an emerging concept nowadays (Spector, 2013), therefore, it is needed to understand the advantages and disadvantages associated with using e-assessment for different online higher educational contexts.

2.2.1 Advantages of using Technology-Enhanced Assessment

As several authors (Dermo, 2009; Hettiarachchi & Huertas, 2011, 2012; Whitelock, 2007, 2009; Whitelock & Watt, 2008) have suggested, main drivers for using technology-enhanced assessment for online higher education can be noted as: perceived increases in student retention, enhanced quality of feedback, flexibility for distance learning, strategies to cope with large student/candidate numbers, objectivity in marking and more effective use of virtual learning environments. Teachers have also reported that one of the main benefits of e-assessment has been to enhance the engagement of students in the subject and to broaden their experience of the domain. Whitelock et al. (2011)

have also stated that using high quality feedback can achieve more benefits than just simple short-term recall on the part of the students. As Nicol & Macfarlane-Dick (2006) have stated timely and constructive feedback which generates a pause for reflection starts to close the gap between the current and expected performance. These drivers are the many of competing forces which are shaping todays higher education, which ensures that e-assessment will play an increasingly important part in higher educational practice (Whitelock & Watt, 2008) .

2.2.2 Disadvantages Associated with Technology-Enhanced Assessment

As with advantages, there are some limitations and risks that need to be considered when introducing the technology-enhanced assessment in the online educational context. There are many barriers that needed to be overcome in order to achieve the successful introduction of e-assessment into an educational institution. They can be highlighted as; practitioners' concerns about plagiarism detection and invigilation issues; accessibility issues together with reliability and validity of high stakes assessments and user identity issues (Whitelock & Brasher, 2006). However, they have mentioned that the principal barrier for the development of institution-wide e-assessment is the academic staff time and training.

Also, there are some barriers associated with the software used for e-assessments. According to J. Bull & Mckenna (2004), these 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, security and accessibility. The reliability and accessibility of e-assessments can be improved through software features that reduce the chances of loss of the student's responses by accidental quitting during assessment and saving of partially-completed student responses or the ability to commence partially completed assessments (G. Crisp, 2007). As the result of the research of Clariana & Wallace (2002), teachers can minimize opportunities for copying and cheating by allowing the assessment software to randomly select items from an item bank and also by shuffling the order of items and the order in which the options are presented to the students.

Another common problem associated with e-assessment systems is that, they are based on tools which offer simple types of questions such as Multiple Choice Questions (MCQ), true/false, short answer and fill in the blanks (Marriott, 2009; Pachler et al., 2010). These types of tools and questions are used to test knowledge at the lower levels of blooms taxonomy (Bloom, 1956). Therefore, they address knowledge, comprehension and application. However, in order to obtain a higher level of analysis, synthesis and evaluation, it is needed to introduce tools and questions which can be used to measure the skill level of students (Gruttmann et al., 2008).

2.3 Elements of Formative E-Assessment

The literature offers a diverse set of perspectives on the nature and value of formative e-assessment (Pachler et al., 2010).

Formative e-assessment is predominantly about improving student learning. Formative e-assessment tasks with timely and appropriate feedback should be used throughout a course; these tasks are primarily intended to have an impact on the current learning of students and most often use feedback to connect the formative task to potential improvements in student performance in subsequent summative tasks (G. Crisp, 2011). As Whitelock (2007) mentioned, formative e-assessment is a means of promoting self-reflection and students taking control of their own learning.

Black & Wiliam (2009) proposed five key strategies for formative e-assessment such as :

1. Engineering effective classroom discussion, questions, and learning tasks that elicit evidence of learning
2. Providing feedback that moves learners forward
3. Clarifying and sharing learning intentions and criteria for success
4. Activating students as owners of their own learning
5. Activating students as instructional resources for one another

Through the above five strategies, it shows the importance of student engagement with the system for improving their learning process through practice and self-assessment. In this case, practice, immediate feedback and monitoring of progress can be identified as the main elements of formative assessment.

2.3.1 Effects of Formative E-Assessment Process on Student Learning

There is a firm body of evidence that formative assessment is an essential component of classroom work and that its development can raise standards of achievement (Black, 2002; Moss & Brookhart, 2009).

Generally, as the effects of the formative assessment process students learn more, learn smarter, and grow into self-aware learners who can tell what they did to get to exactly where they are. In other words, students become self-regulated learners and data-driven decision makers. They learn to gather evidence about their own learning and to use that information to choose from a growing collection of strategies for success. And students not only learn how to take ownership of their learning but also increasingly view themselves as autonomous, confident, and capable (Moss & Brookhart, 2009).

Although formative e-assessment has a significant effect on learning for all students, it *"helps low achievers more than other students and so reduces the range of achievement while raising achievement overall"* (Black, 2002). Therefore, practice is an important aspect of formative e-assessment as it gives students the opportunities to act on the feedback (Sadler, 2013). In this case, immediate feedback is particularly useful for formative e-assessment as it helps students to monitor their own progress (Bruyn et al., 2011).

According to J. Bull & Mckenna (2004), timely and constructive feedback motivates students to learn more effectively. Therefore, it is interesting to study about the relationship between student motivation with respect to feedback and e-assessment. 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, 2009). Assessment can be used as a means of channeling students' energies, and the feedback that it generates 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 (Oliver, 1988). Because the more students practice a subject and receive feedback on it, the more they tend to learn and the more engaged they become (Kuh, 2003; Sadler, 1989). The importance of feedback in the assessment process is 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 (Gibbs & Simpson, 2004; Nicol, 2004, 2007).

2.4 E-Assessment Systems and Tools

In this section, the e-learning systems that are currently in use are discussed. Under that, the most important learning management systems are presented. Since standards and specifications play an important role in both e-learning and e-assessment, they are explained with respect to sharing of learning resources and communicating with similar systems. The different assessment formats that can be used are also discussed. Then the frameworks or design architectures for e-assessment systems are explained under e-assessment models. Finally, the e-assessment tools are explained in general with special focus on e-assessment tools used for teaching and learning logic.

2.4.1 E-Learning Systems

In recent years there has been a rapid increase in demand for e-learning systems (Krishnamurthy & O'Connor, 2013). Through the use of e-learning systems, the knowledge and skills are transfered electronically through different communication medium and devices. Further, in e-learning systems, the learner is not always at a fixed, predetermined location. The principal benefit is the ability to provide users the flexibility of learning and efficiently communicating anytime and from anywhere (Krishnamurthy & O'Connor, 2013).

E-Learning systems are also known as Learning Management Systems (LMS), Virtual Learning Environments (VLE) or Technology-Enhanced Learning Environments (TELE) (Carneiro & Steffens, 2013). There are many e-learning systems that are developed successfully either as Open Source Software (OSS) or Proprietary software. Most of the commercial proprietary software have been developed based on either a traditional software process or some form of tailored traditional process, in order to accommodate local needs. On the other hand, OSS systems are developed by a community of like-minded developers, who are geographically distributed, yet work together closely on a specific software product (Krishnamurthy & O'Connor, 2013; Scacchi et al., 2006). Some of the most important e-learning systems which are both open source and proprietary are presented below. ATutor, Claroline, Moodle and Sakai fall into the category of open source software whereas Blackboard and Desire2Learn are categories of proprietary software.

ATutor is an open source web-based LMS used to develop and deliver online courses. Administrators can install or update ATutor, develop custom themes to give ATutor a new look, and easily extend its functionality with feature modules. Educators can quickly assemble, package, and redistribute web-based instructional content, easily import prepackaged content, and conduct their courses online. Students learn in an accessible, adaptive, social learning environment. At the same time, ATutor adheres to e-learning standards as well (ATutor, 2013)

Blackboard is a commercial learning management system which includes features such as course management, customizable open architecture, and scalable design that allows integration with student information systems and authentication protocols (Blackboard Inc., 2013). However, Blackboard lacks ability to adapt to different teaching styles as a result of its rigid structure (García, 2013).

Claroline is an open source software to easily deploy a platform for learning and collaboration online. It is based on a flexible educational model that information becomes knowledge through the activities and productions of the learner in a system driven by the motivation and interaction. This system does not provide assessment facilities (Claroline, 2013).

Desire2Learn is a commercial user-friendly learning environment which includes features such as course design, assessment, reporting, collaboration facilities and integrated mobile capabilities (Desire2Learn, 2013). Since this is a commercial proprietary software, it was not possible to analyse the type of assessment offered.

Moodle is currently the most popular open source LMS in terms of usage. A large part of its success is due to its modular structure, which allows any developer to create additional modules and features easily (Moodle, 2013c). Moodle courses basically consist of resources and activities. Additionally, Moodle provides other functionalities, such as gradebook, course backup, course settings and reports. A detailed explanation of the Moodle is given in the "Appendix" under the "Section A - Moodle".

Sakai is a community of academic institutions, commercial organizations and individuals who work together to develop a common Collaboration and Learning Environment (CLE). The Sakai CLE is an open source software used for teaching, research and collaboration. Unlike most of the open-source LMS, which are developed in PHP, Sakai is written in Java. The Sakai includes many of the features common to course management systems, including document distribution, a gradebook, discussion, live chat, assignment uploads, and online testing. The Sakai is also intended as a collaborative tool for research and group projects (Sakai Foundation, 2013).

2.4.2 Standards and Specifications

Both in e-learning and e-assessment, sharing of learning resources as well as communicating with similar systems has become a major challenge. Different standards and specifications have been defined to represent the e-learning systems and components. In order to have a high quality technology-enhanced assessment system, a set of features and requirements have been identified. One of the main requirements is standard conformation while designing and implementing the systems. Standards help to ensure five abilities to the e-learning and e-assessment system such as interoperability, reusability, manageability, accessibility and durability (AL-Smadi et al., 2009).

Interoperability is to share information and services in a common file format between different systems. Reusability is the use of learning content and tools by different tools and platforms. Manageability is how much the system is able to keep track on the learning experience and activities, rather than the ability of tracking how learning objects are created, stored, assembled and delivered to users. Accessibility is the ability to customize, access and deliver learning content and tools from anywhere and anytime to anyone. For durability, learning content and tools does not need any redesign or redevelopment even with new versions of the system (AL-Smadi et al., 2009; J. Bull & Mckenna, 2004).

Before moving into relevant standards associated with e-learning and e-assessment systems, it is interesting to look at the features associated with a standardized and a flexible e-assessment system (AL-Smadi & Gütl, 2008). These features include; (a) *Flexible design* to be used as a stand-alone service or to be easily integrated into existing systems, (b) *User-friendly interfaces* for both students and educators where a user interaction and online submission of solution and evaluation can be done, (c) Assessment environment for *various learning and assessment settings* which supports guided as well as self-directed learning. (d) *Management and (semi-) automatic support* over the entire assessment life-cycle (exercises creation, storage and compilation for assessments, as well as assessment performance, grading and feedback provision), (e) *Rubrics design and implementation interfaces* to allow the educators to design their own rubrics based on learning objectives to assess learners performance against a set of criteria, (f) *Support of various educational objectives and subjects* by using various tool sets which for example enables automatic exercise generation or selection, automatic grading and feedback provision, (g) *Results analysis and feedback provision* (immediately or timely) of the current state of usernames/passwords, (h) *Standard-conform information and services* to be easily sharable, reusable and exchangeable. This includes the test questions, answers and student results, rather than any other required services, and (i) *Security and privacy* where a secure logon of users based on pre-defined levels of access, and also user authentication based on the machine (domain users) or by usernames/passwords.

E-Learning and e-assessment standards and specifications are defined by organizations such as Aviation Industry CBT Committee (AICC) (AICC, 2013), Institute of Electrical and Electronics Engineers (IEEE) (IEEE, 2013), Advanced Distributed Learning (ADL) (Advanced Distributed Learning, 2013a), the Instructional Management System Global Learning Consortium (IMS GLC) (IMS GLC, 2013f), IEEE Learning Technology Standardization Committee (IEEE LTSC) (IEEE LTSC, 2013a) and Open Knowledge Initiative (O.K.I) (MIT, 2003). At the end standards are approved by official standards organizations as the International Organization for Standardization (ISO) (ISO, 2013a) and the American National Standards Institute (ANSI) (ANSI, 2013) to be official standards. Standards vary according to their approval and use. With respect to this research, some of the standards were selected as described below. When selecting these standards main consideration was given for standards which were capable of maintaining the security and interoperability, key features of this research, between learning content and tools.

LOM (Learning Object Metadata) is a standard by IEEE where LOM (IEEE LTSC, 2013b) is a data model, usually encoded in Extensible Markup Language (XML), used to describe a learning object and similar digital resources used to support learning. The purpose of learning object metadata is to support the reusability of learning objects, to aid discoverability, and to facilitate their interoperability, usually in the context of online learning management systems.

SCORM (Sharable Content Object Reference Model) is a collection of standards and specifications introduced by ADL for web-based e-learning. This defines communications between client side content and a host system called the run-time environment, which is commonly supported by a learning management system. SCORM also defines how content may be packaged into a transferable ZIP file called "Package Interchange Format" (Advanced Distributed Learning, 2013b).

IMS QTI (Question and Test Interoperability), also developed by IMS GLC is another specification widely accepted inside the developers community. The latest version available of this standard (IMS QTI 2.0) enables to implement a wide range of item types: multiple choice, ordering, association (1:1), union (1:N), fill in the blanks, essays, hotspots, object positioning and painting. In addition, QTI uses the XML for coding the items and tests. This fact allows the visualization of items or tests on different devices like desktops, laptops, mobile devices. That could be very interesting for expanding the functionality of an e-learning system (IMS GLC, 2013c).

IEEE PAPI (Public and Private Information) was introduced by IEEE as a specification devoted to support the exchange of learner data between different systems. It specifies both the syntax and semantics of a 'Learner Model', which characterize a learner and his or her knowledge or abilities (CEN WS-LT LTSO, 2013).

IMS LIP (Learner Information Package) is a specification defined by IMS GLC. "Learner Information" is a collection of information about a learner (individual or group learners) or a producer of learning content (creators, providers or vendors). The IMS Learner Information Package (IMS LIP) specification addresses the interoperability of internet-based learner information systems with other systems that support the virtual learning environment (IMS GLC, 2013e).

IMS Basic LTI (Learning Tools Interoperability) is a specification defined by the IMS GLC. IMS Basic LTI is a simple version of LTI (IMS GLC, 2013a,b).

The IMS LTI specification provides significant benefits for all parties involved in developing, deploying and utilising learning applications. 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 learning management systems, portals, or other educational environments.

IMS Basic LTI provides a simple but standard method to establish a secure link to a tool from another tool. The launch of this link allows a seamless learning experience for students who gain access to rich applications that appear to take place inside the learning environment (IMS GLC, 2013d).

The basic use behind the development of the Basic LTI specification is to allow the seamless connection of web-based, externally hosted applications and content, or tools to platforms that present them to users. In other words, examples such as an interactive assessment tool or a virtual lab, can be securely connected to an educational platform in a standard way without having to develop and maintain custom integrations for each platform.

O.K.I (Open Knowledge Initiative) has defined an architecture that specifies how the components of a learning technology environment communicate with each other and with other campus systems. This architecture has considered the interoperability which allows the components of a learning environment to be developed and updated independently of each other (MIT, 2003). The core of O.K.I. is a set of Application Programming Interfaces (API) that realize the O.K.I. architecture. O.K.I. is providing Java versions of these API. These Java API are provided for use in Java-based systems and also as models for other object-oriented and service-based implementations. This architecture has been defined as a modular architecture, therefore, the structure of this architecture and modules and the way the communication among modules were carried-out is taken into account while designing and developing the technology-enhanced assessment system.

Communication between different systems is not easy if they are not developed according to shared standards. Therefore, it is needed to use some appropriate standards to maintain the security and interoperability while carrying out a seamless communication. Out of the standards mentioned above, IMS Basic LTI, IMS LIP, IEEE PAPI and O.K.I specifications can be used to communicate data between different systems such as LMS and e-assessment systems.

Additionally, there are some assessment formats whose main objective is the authoring and sharing of assessment resources. This is an important factor which has to be considered when communicating and exchanging information between different systems, especially to maintain the interoperability among systems.

2.4.2.1 Assessment Formats

The main objective of assessment formats is the authoring and presentation of assessment resources. Therefore, these formats are important elements of any e-assessment system and, because of that, it was needed to review the main formats available. The selection of the formats to be analysed are based on features they provide, and relevance on existing e-learning and e-assessment systems. Accordingly, formats such as IMS QTI (IMS GLC, 2013c), Moodle XML (Moodle, 2013e), Blackboard (Blackboard Inc., 2013), Hot Potatoes (Hot Potatoes, 2013), and OpenMark (The Open University, 2013) were analysed (Gutierrez et al., 2010).

IMS QTI has also been included in the analysis due to their widespread deployment and experience. A description of IMS QTI was presented in the previous section.

Moodle XML is a Moodle-specific format for importing and exporting questions to be used with the quiz module of Moodle. The format has been developed within the Moodle Community but other software may support it to a greater or lesser degree.

Blackboard offers several options for creating assessment resources, including typing into the question-by-question format provided by Blackboard, copying and pasting questions into the Blackboard format (which allows one to work offline and take advantage of the word processor's spell check), and uploading questions in a pre-established format.

HotPotatoes is a tool which enables to create interactive multiple-choice, short-answer, jumbled-sentence, crossword, matching or ordering and fill in the blank exercises. This is freeware, which can be used for any purpose or project.

OpenMark interactive questions typically consist of four elements such as questions which states the problem, predicted responses which are matched with student responses, feedback and full explanation which is seen by all students either after providing a correct response or after making too many incorrect attempts.

Additionally, some general purpose formats such as DocBook (DocBook, 2013), FML (The Apache Software Foundation, 2013b) and QAML (QAML, 2013) which can be applied to learning and assessment were also studied.

DocBook is a large and robust schema, and its main structures correspond to the general notion of a "book". It is used to write books and technical articles. DocBook has been adopted by a large and growing community of authors writing books of all kinds. DocBook is supported by a number of commercial tools and also by free and open source software environments. These features have combined to make DocBook a generally easy to understand, widely useful, and very popular schema.

FML, also known as FAQ (Frequently Asked Questions) Markup Language, is an XML document conforming to a small and simple set of tags which is used for describing frequently asked questions.

QAML, also known as the Question and Answer Markup Language, is a specification for creating FAQ.

An assessment format should include a set of features such as (Gutierrez et al., 2010):

- Response and outcomes processing *(Proc)*: the possibility of processing the response given by the student in order to determine if it is correct or not; the processing of several question responses in order to get a global result of the assessment.
- Metadata capabilities *(Meta)*: the possibility of storing the metadata of assessment items, sections and tests.
- Hybrid question management *(Hybrid)*: the possibility of defining a hybrid question as a combination of a set of simple ones.
- Correct response indication *(C.R.)*: the possibility of indicating the correct response given a concrete question.
- Multiple responses related to one question *(M.R.)*: the possibility of defining more than one response to a given question (one correct and the others incorrect).

Based on the above features, a comparison of some of the assessment formats is illustrated in Table 2.1.

Table 2.1: Key features in assessment formats (Gutierrez et al., 2010)

Formats	***Meta***	***Proc***	***M.R.***	***C.R.***	***Hybrid***
IMS QTI	*	*	*	*	*
MoodleXML	*	*	*	*	*
Blackboard	*	*	*	*	*
Hot Potatoes	*	*	*	*	*
OpenMark	*	*	*	*	*
DocBook	*		*		
FML	*				
QAML	*		*		

Table 2.1 summarizes the comparison of the analysed formats regarding the features presented above. All the formats use metadata, but it is limited to a series of predefined

fields like author or date in some formats. Most of the formats also support multiple responses to one question except FML. The remaining features such as correct response, response processing or using a hybrid question are only supported by the assessment formats such as IMS QTI, Hot Potatoes, Moodle XML, OpenMark and Blackboard.

In order to support the comparison between assessment formats, a series of question types were selected as follows (Gutierrez et al., 2010):

- Short answers (Short): a textual answer consisting of a few words.
- Essay: a textual answer with unlimited or limited number of words that is not corrected automatically.
- Multiple choice question (MCQ): choose one option out of a list of possible answers.
- Multiple response question (MRQ): choose one, more or no option out of a list of possible answers.
- Fill in the blanks (FIB): complete missing words in a sentence or paragraph.
- Match: given two lists of terms, match each term on one list with one term on the other.
- Crossword (Cross): fill out a crossword using definitions of words in horizontal and vertical positions.

The question types supported by these assessment formats are illustrated in Table 2.2.

According to Table 2.2, short answer and essays are supported by all formats. Only assessment formats such as IMS QTI, Hot Potatoes, Moodle XML, OpenMark and Blackboard allow multiple choice, multiple response, fill in the blanks or match questions. Crossword is a complex question type that is supported by Hot Potatoes that can also be implemented in IMS QTI.

By comparing both Table 2.1 and 2.2 for key features and question types, assessment formats such as IMS QTI, Hot Potatoes, MoodleXML, OpenMark and Blackboard can be taken. However, Blackboard is closed commercial software and both Hot Potatoes and OpenMark are application specific (Whitelock & Brasher, 2006). Therefore, it

Table 2.2: Question types of assessment formats (Gutierrez et al., 2010)

Formats	Short	Essay	MCQ	MRQ	FIB	Match	Cross
IMS QTI	*	*	*	*	*	*	*
MoodleXML	*	*	*	*	*	*	
Blackboard	*	*	*	*	*	*	
Hot Potatoes	*	*	*	*	*	*	*
OpenMark	*	*	*	*	*	*	
DocBook	*	*					
FML	*	*					
QAML	*	*					

is preferred to go for open source systems that follow standards, which can be easily integrated with other tools. As a result, MoodleXML, (Gutierrez et al., 2010; Moodle, 2013c) and IMS QTI (IMS GLC, 2013f) can be considered.

Moodle is an open source e-learning system that includes e-assessment facility (Moodle, 2013c). As Blanco & Ginovart (2012) stated, Moodle help educators create quality online courses and administer learner outcomes. In particular, the Moodle quiz module allows the creation of quizzes with different question types, adapted to specific objectives to be achieved at any step in the teaching-learning process, supplying prompt and automatic feedback. Moodle's quiz module also supplies statistical methods to measure the reliability of the tests and is used mostly in formative e-assessments with feedback (Blanco & Ginovart, 2012).

On the other hand, IMS QTI cannot be directly integrated with LMS such as Moodle. The reason is that, the LMS does not have a QTI question engine integrated in them. Therefore, in order to communicate, it is needed to have a separate plug-in. In addition to that, QTI lacks some basic features such as list handling and string handling. To adopt portability, QTI does not specify a QTI compliant player. This means that player features such as the use of tools, journaling and reply are not covered. QTI also lacks flexibility and adaptive test modes (Beevers, et al, 2010).

As a summary, based on the above two formats, simple type of questions of Moodle XML can be used for knowledge assessment but not for skill assessment.

2.4.3 E-Assessment Models

It is important to find out whether all forms of assessment have a common framework or design architecture. Therefore, it is needed to find the common underlying features of all assessment types, relationship between individual assessment components, scoring and feedback mechanisms (G. Crisp, 2009a).

The four-process architecture model proposed by (Almond et al., 2002), uses a generic description that should apply to any assessment, and includes activity selection, presentation, response processing and summary scoring. This model can be shown as in figure 2.3. In this model, both response processing and summary scoring process are important for improving students learning process as it provides feedback for each task at the end of the assessment process. This is one of the aspects which has to be considered when designing and developing the formative e-assessment model for the technology-enhanced assessment system.

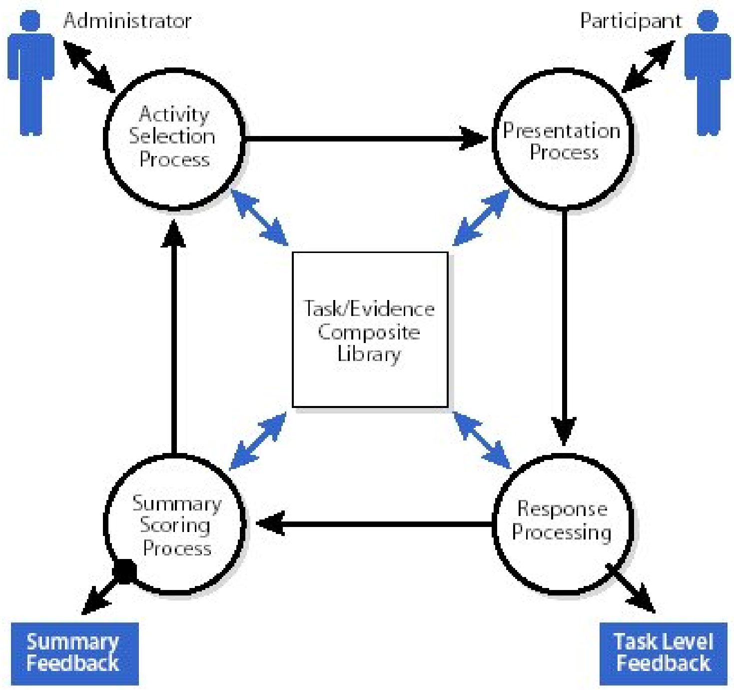


Figure 2.3: A Four-process architecture for assessment (Almond et al., 2002)

By viewing an assessment as a modular process, complex tasks can be undertaken with a clear view of the relationships between design framework and operational processes.

For categorizing and organizing the entities and activities associated with assessment in e-learning, a visual framework has been proposed in the form of FREMA (Framework Reference Model for Assessment) (University of Southampton, 2006).

FREMA represents an intensive guide for the assessment domain resources standards, projects, people, organizations, software, services, and use cases. FREMA structure is based on concept maps describing the ontology that has been used to model the assessment domain (Wills et al., 2007).

Abstract Framework for Assessment (AFA) is another model for the design and implementation of the e-assessment systems (AL-Smadi et al., 2009). AFA is a service-oriented approach which has the ability to support standards and specifications. As a result the system is interoperable and flexible. Service-oriented architectures allow the development of modular and flexible systems, where the components of the system are flexible to be added, replaced or removed. These architectures also allow new systems to be composed from a collection of suitable services (Davies & Davis, 2005).

A service-oriented framework may provide e-assessment systems to easily share and exchange test among each others. Services for tests, items, results, users' information, can be easily implemented in the system and they are flexible to be used by other authorized services or systems. For example, students that have registered for a specific test can only attend the e-learning course/assessments in another system and vice-versa Davies & Davis (2005).

The AFA consist of four main layers, the "Application Layer", the "Application Layer Services", the "Common services" and the "Infrastructure Layer" as shown in 2.4 (AL-Smadi et al., 2009). The assessment services in AFA have been identified based on FREMA processes concept map (AL-Smadi et al., 2009; Millard et al., 2005).

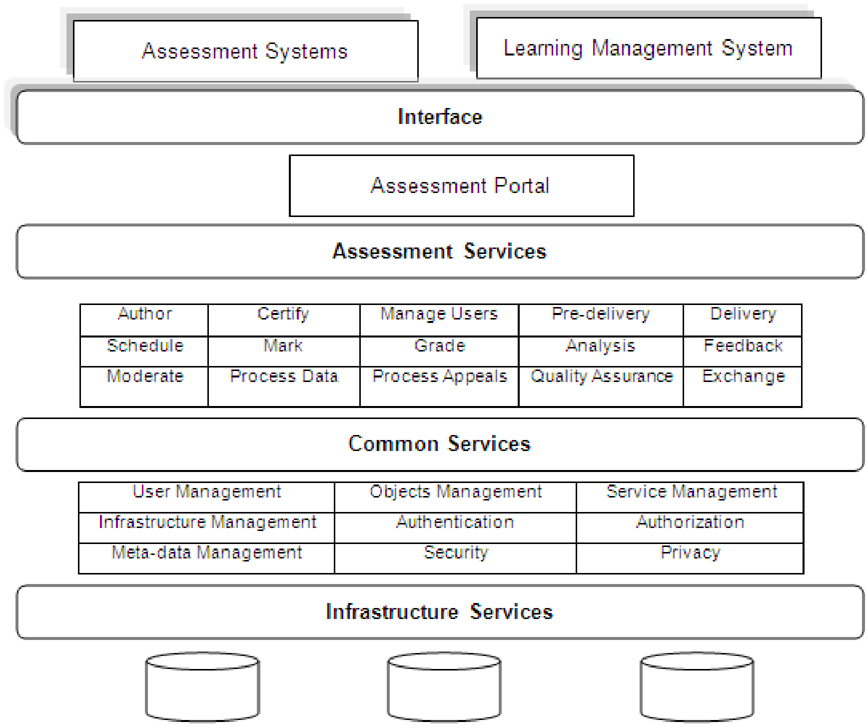


Figure 2.4: Abstract Framework for Assessment (AL-Smadi et al., 2009)

The services available under "Assessment Services" work together in order to support the assessment process. The group of "Common Services" is a set of services that may be found in any assessment system or any other system such as e-learning systems. The services should be standard-conform in order to gain the benefits of standards such as flexible, interoperable, reusable, manageable, accessible and durable. For example, services such as the "Author" service and the "Delivery", can be designed based on standards or specifications like IMS QTI where the service of the "Manage User" can be based on IMS LIP or PAPI.

However, one of the drawbacks of this model is that the "Assessment System" and the "Learning Management System" are separated.

2.4.4 E-Assessment Tools

The main characteristics of an e-assessment system are: monitoring student progress through frequent assessments, immediate feedback, automatic marking, weighted-average grade calculation, applying a variety of interactive question types, promoting flexible learning and adaptive learning, personalization of quizzes, monitoring question quality using statistical analysis, reducing the potential for cheating by randomizing questions along with timers, and sharing questions via question banks (J. Bull & Mckenna, 2004; Sitthiworachart et al., 2008; Tselonis & Sargeant, 2007).

There are some interesting tools available for e-assessment in online education (G. Crisp, 2010). They can be noted as; ExamOnline (Intelligent Assessment Technologies Limited, 2011), TOIA (TOIA, 2007), Moodle Quizzes (Moodle, 2013c), Moodle Assignments (Moodle, 2013c), Turnitin (IParadigms, LLC., 2013), Hot Potatoes (Hot Potatoes, 2013) and Maple T.A.(Maplesoft, 2013).

However, most of them are based on knowledge assessment rather than skill assessment. One of the reasons is that most of the tools support simple type of the questions such as MCQ, short answer, fill-in the blanks and true/false. Another can be noted as the lack of awareness or misunderstanding about skills and its technological complexity.

Some universities and educational institutes offer formative e-assessments; but they are mostly based on MCQs (Marriott, 2009; Pachler et al., 2010). However, cognitive skills where students have to apply their analytic, creative, and constructive skills cannot be assessed via multiple-choice tests and equivalent forms of basic assessment items (Gruttmann et al., 2008; Majchrzak & Usener, 2011). Therefore, it raised the need to look into above aspects as well as to go beyond this type of knowledge assessment tasks and incorporate a dynamic and an interactive dimension into formative e-assessments for skills.

At the same time, tools that are based on skill assessment depends only on a specific subject context. Based on the above, it can be stated that there is no general tool which can be used for e-assessment of skills.

Since Logic subject was selected as the case for this research, the main focus is on the e-assessments tools used for logic as shown in the following section.

2.4.4.1 E-Assessment Tools for Logic

Currently, there is a large sample of tools used for learning introductory mathematics and logic courses. While many of them can be categorized as Intelligent Tutoring Systems (ITS) for learning mathematics and logic (also called computer-based tutors or assistants), only a few can be categorized as e-assessment systems. Therefore, it is important to discuss about the main characteristics of both ITS and e-assessment systems.

The main characteristic of an ITS for learning is providing customized assistance and feedback to students while simulating the presence of an e-tutor or learning-assistant (Huertas, 2011). ITS facilitates learning through interactivity by monitoring each step carried-out by students in an exercise and providing some guidance such as error messages and feedback.

There is an extensive discussion on e-assessment tools in G. Crisp (2007) and on ITSs for teaching logic in Huertas (2011). By way of illustration of one and the other, it can be noted that some of the existing tools fall into the category of e-assessment tools for mathematics, for example: EASy (Kuchen et al., 2009), AiM (Strickland, 2002) and OpenMark (The Open University, 2013); whereas other falls into the category of ITS tools for Logic, for example: Pandora (Imperial College London, 2013), Organon (Dostalova & Lang, 2007), and AELL (Huertas, 2011).

A detailed analysis of the above tools can be explained as given below.

EASy (The E-Assessment System) is a system which has been designed for automated skill assessment at the University of Münster for evaluating new e-assessment tasks and activities in computer science lectures (Kuchen et al., 2009; Majchrzak & Usener, 2011). It focuses on assessing higher-order cognitive skills where students have to apply their analytic, creative, and constructive skills. Such skills cannot be assessed by simple e-assessment techniques such as fill in the blanks or multiple choice exercises (Majchrzak & Usener, 2012). The system is designed as a modular web application and currently provides four different assessment modules: a module for assessing software verification proofs, a mathematical proof module, a module for programming exercises written in the Java programming language, and a multiple choice module. As (Majchrzak & Usener, 2011, 2012) mentioned, their project has some limitations. They were not able to check whether the system can be replicated at other universities and whether they apply to other courses as well. At the same time, the EASy is not open source, developed specifically for their context and does not support e-tutoring with feedback facility.

AIM (Alice Interactive Mathematics) is a system for computer-aided assessment in mathematics and related disciplines, with emphasis on formative assessment (Strickland, 2002). The original version was developed at the University of Ghent in Belgium. AIM is mostly written in the Maple programming language and requires a commercial license for Maple in order to use it. This is a tool used for knowledge assessment with only simple form of questions such as MCQ, drag & drop and short answer.

OpenMark is an e-assessment system developed by the Open University of UK which provides questions for knowledge assessments (The Open University, 2013). The OpenMark is an online interactive assessment system, which provides instantaneous, targeted and detailed feedback to students. The system is constructed in an editor such as Eclipse using a combination of OpenMark XML components and Java. This provides a range of question components that can be used flexibly to construct a wide variety of interactions. This supports most multimedia elements and allows easy incorporation of text, equations, tables, graphics and sound. The system provides full support for questions that are designed to allow multiple tries with stepped feedback. Also the system allows random generation of questions using variables and hence the answers required can be made to vary from student to student. Questions were randomly chosen from a group of questions and limited reports are directly provided to teachers about users. Since OpenMark is linked with Moodle, it has a link to the Moodle Gradebook which provides reports to students, lecturers and student services. However, OpenMark does not provide question authoring facilities and authoring forms for use by module users; question implementation is undertaken at the Open University by Learning and Teaching development staff as part of the production process; the authors provide paper specifications (using a template) to Learning and Teaching staff. Also OpenMark does not provide assessment building tools for use by module users. According to this project, they provide multiple attempts at each question with a “hint” option. The maximum score obtained out of the attempts were stored. The “Open Mark” system has done pilot studies on the use of interactive internet assessment with the Open University level 1 mathematics students, to make feedback more immediate and useful within student learning. Initial trials suggested that users found the quizzes fun as well as useful for their learning. According to the Open University, authoring of the quizzes was more time-consuming initially than the traditional methods, but lead to less work subsequently. Students generally liked the shorter quizzes with detailed tailored feedback. In fact the questions provided within the system were also of usual type such as MCQ, short answers, drag and drop, fill in the blanks, matching type questions. At the same time, this system provides more advanced features compared to other system such as random generation of questions, different groups of questions and reports. Through the analysis of this system, it was possible to understand some of the missing features. This system is not suitable for skill assessment, because of the usual type of questions offered. Also the question authoring facility is not provided to all users and the fact that they are developed particularly for this system, sharing of question banks with other tools are not possible.

PANDORA (Proof Assistant for Natural Deduction using Organised Rectangular Areas) is an ITS for logic by Department of Computing, Imperial College, London, South Kensington Campus (Imperial College London, 2013). PANDORA provides students with exercises that can be downloaded from the web-based continuous assessment system and the first time students save a proof, their identity is coded. From this, the tool can produce a report for each student and a summary of results for the tutors with minimal human intervention. PANDORA also provides learning support to guide students in the construction of a natural deduction proof of a conclusion or goal from given premises. It allows the user to reason "forwards" (example: from one or more given formula to deduce another formula using one of the rules) and to reason "backwards" (example: to reduce one of the current goals to one or more sub goals from which the current goal can be deduced using one of the rules). It can be noted that PANDORA is more of an ITS than an e-assessment system which is focused on skills rather than knowledge.

Organon is another ITS which aims to support basic logic courses at the University of West Bohemia in Pilsen (Czech Republic) (Dostalova & Lang, 2007). The application was designed to fulfill two requirements. Firstly, to help students during their study to practice exercises on their own (providing permanent control during students' practicing exercises as well as answering students' questions immediately as they arise). Secondly, to reduce teachers' burden (diminishing the amount of consultations as well as administrating students' homework including correcting and grading). The tool consists of procedural questions for assessing mathematical proofs and logic. Therefore, the system is mostly used for automated skill assessment and at the same time the tool can act as an e-tutor which monitors student activities and issues feedback on each step. Organon does not provide knowledge assessment facility and it is not an open source tool.

AELL is another intelligent tutoring system developed by the Universitat Oberta de Catalunya (Huertas et al., 2011). This tool was developed for assisting the learning of logic in the context of a fully online Computer Science degree using a web-based learning environment. This tool provides guidance through interactive feedback, and continuous assessment for logic course students, covering major topics in an introductory course (natural deduction, resolution and truth tables in propositional and predicate logic). Therefore, this tool can be used to perform automated skill assessment but when it comes to knowledge assessment, it is needed to opt for another tool or build improvements to the current system.

The table 2.3, outlines a comparison of the above tools with respect to the expected characteristics of an e-assessment system for logic.

Table 2.3: Characteristics found in some of the tools for logic

Characteristics	**E-assessment tools**			**ITS tools**		
	EASy	**AiM**	**OpenMark**	**Pandora**	**Organon**	**AELL**
Monitoring progress	*	*	*			
Immediate feedback		*	*	*	*	*
Automatic marking	*	*	*	*	*	*
Weighted-average grade	*	*	*			
Knowledge questions		*	*			
Interactive Skill questions	*			*	*	*
Randomizing questions		*	*			
Personalization of quizzes		*	*			
Sharing questions banks		*	*			
Statistical analysis	*	*	*	*	*	*

Thus, by comparing the representative tools that can be used for learning and assessing logic or most related math subjects, as in table 2.3, it was not possible to find a general tool which can be used to conduct both skill and knowledge assessment. In particular, when considering most of the available e-assessment tools, they offer only 'usual type' of questions such as MCQ, short answer, yes/no and fill in the blanks that can be used for only knowledge assessment. What happen in the case of Logic is that only ITS type of tools can offer the intelligent type of questions for skill acquirement, unfortunately these tools do not support most of the e-assessment characteristics as shown in table 2.3. In addition to that, some of these tools are developed only for a specific context and not according to e-learning and e-assessment standards. Therefore, integrating these tools with other existing tools in an online environment becomes a major problem because the tools have to be modified basically from scratch.

2.5 Approaches to Knowledge and Skill Assessment

Under this section general trend and positions associated with technology-enhanced assessment is discussed. At the same time, previous research carried-out in the area of formative e-assessment of skill and knowledge acquisition is also presented.

2.5.1 General Trends and Positions

Even though with the evolution of online education, the technology-enhanced assessments or e-assessments emerged, they were merely a transformation of paper based assessments. As mentioned in the previous sections, most of the tools support only predetermined questions such as MCQ, true/false, short-answer and fill in the blanks questions (Marriott, 2009; Pachler et al., 2010). However, these types of questions are good for assessing knowledge levels of students but when it comes to assessing skill levels, it is needed to go beyond these types of questions to provide rich feedback (Millard et al., 2005).

MCQ and their variants are not always appropriate especially in science and engineering subjects where mathematical expressions provide a more acceptable form of answers. MCQ are good to measure knowledge (Beevers, et al, 2010). At the same time, cognitive skills and application of methods cannot be assessed via multiple-choice tests and equivalent forms of basic assessment items (Gruttmann et al., 2008).

If designed appropriately, technology-enhanced assessment offers a number of benefits that can enhance learning and reduce the workload of administrators and practitioners: e-assessments can be accessed at a greater range of locations than is possible with paper-based examinations, enabling learners to measure their understanding at times of their own choosing; immediate expert feedback delivered online in response to answers selected by learners can rapidly correct misconceptions; and the time saved in marking can be used in more productive ways, for example in supporting learners who are experiencing difficulties. Outcomes of assessments can also be more easily collated and evaluated for quality assurance and curriculum review processes (JISC, 2010).

Feedback also plays an important role in e-assessment and practice through adequate feedback which helps students to improve their learning process (Sadler, 2013). Technology can add value to this aspect. There is a considerable potential for multimedia technologies to make feedback richer and more personal. In addition, online tools can support peer and self-assessment in any location and at times to suite learners. Help provided by peer and self-assessment in developing learners' ability to regulate their own learning is increasingly recognised (JISC, 2010).

As a summary, it can be stated that MCQ, short answer, yes/no and fill in the blanks questions can be used for knowledge assessment, but for skill assessment it is needed to go beyond these types of questions. It is needed to introduce a more dynamic, interactive and intelligent type of questions to assess the higher cognitive skills. Technology-enhanced assessment and feedback refers to practices that provide some, or all, of the benefits such as; greater variety and authenticity in the design of assessments, improved learner engagement (for example through interactive formative assessments with adaptive feedback), choice in the timing and location of assessments, capture of wider skills and attributes not easily assessed by other means (for example through simulations and interactive games), efficient submission, marking, moderation and data storage processes, consistent, accurate results with opportunities to combine human and computer marking, immediate feedback, increased opportunities for learners to act on feedback (for example by reflection in e-portfolios), innovative approaches based around use of creative media and online peer and self-assessment, and accurate, timely and accessible evidence on the effectiveness of curriculum design and delivery (JISC, 2010; Pachler et al., 2009).

In brief it can be stated that, technology offers the potential for enhancing assessment and feedback and as a result improves the overall assessment experience for both teachers and students.

2.5.2 Skill and Knowledge Assessment Tools

Introduction to research work about formative e-assessment for knowledge acquisition and support provided for skill assessment is explained as below.

The effectiveness of computer-assisted formative assessment in a large, first-year undergraduate geography course conducted at the University of Toronto, Canada is one such research (Wilson et al., 2011). In particular, they have evaluated the impact of computer-assisted multiple-choice practice tests on student performance in the course as well as student opinions on this type of formative assessment in two academic years (2008 and 2009). The multiple-choice questions included in the formative assessment varied in their level of difficulty and range from those that focus on knowledge and comprehension to those that focus on application and analysis. While the use of the computer-assisted practice tests is completely voluntary over 50 percent of students used them. Feedback questionnaires from both academic years had revealed that students were overwhelmingly positive where over 95 percent have indicated that the computer-assisted practice tests assist them in identifying their strengths and weaknesses and helped them to prepare for in-class midterms and final exams. Statistical analysis of in-class performance on midterms has shown that students who used the computer-assisted practice quizzes had earn significantly higher grades than those students who do not. The results of the research had demonstrated that computer-assisted formative practice assessment had a positive impact on student performance. As it can be seen from this research they had only used knowledge assessments and not skill assessment for the formative assessment.

Formative assessments carried out at the University of Bradford to measure the impact of topic-based feedback can be taken as another similar project. Here as the cases they have selected two subjects such as clinical sciences and engineering. For both subjects they had given questions of type MCQ, yes/no, short answers and fill in the blanks (Dermo & Carpenter, 2011). Under this project, the main question was

"Can MCQs/EMQs deliver quality feedback to enhance learning?". The impact of formative assessment was investigated by: measuring the total number of attempts per students, quantitative analysis with student progress in summative assessment, comparing with data from previous studies, analysis of student access patterns, evaluating student attitudes and obtaining data on student use of the formative over the course of the semester through questionnaires and by comparing with tutor-delivered feedback. This can be taken as another example where they have used 'usual type' of questions such as MCQ, yes/no, short answers and fill in the blanks for knowledge assessment. From the questionnaires, they had understood that, students mainly used formative assessments as part of the learning process, as mock examinations and as for evaluating revisions. As results they found that, students valued feedback-rich formative e-assessments. Students had also indicated that their learning was benefited through engagement with online feedback and it was important not to carry-out over-assessment (Dermo & Carpenter, 2011).

Another example where students had used Moodle quizzes for formative e-assessment is a project subsidised by the Institute of Education Sciences at the Universitat Politecnica de Catalunya (UPC) (Blanco & Ginovart, 2012). The main aim of this project was to design and implement a number of Moodle quizzes for the formative e-assessment of students enrolled in mathematics courses for engineering bachelors degrees. Subsequently, the reliability of the quizzes as assessment tools was analyzed to ensure the quality of the e-assessment system proposed. First of all, their fundamental idea was to evaluate whether the consistency of the e-assessment system used aligned with that of the traditional assessment tools used. The correlation between scores in the quizzes and the final mark of each subject for two years had shown that Moodle quizzes could be regarded as a suitable tool to inform students of their performance throughout the learning process. In addition, the particular use of the quizzes as low-stakes assessment activities for checking a particular chapter had contributed to the promotion of student self-regulation and regular work throughout the year. Therefore, through this research it was possible to obtain evidence that Moodle quizzes represented a consistent alternative to open-ended tests in terms of continuous and formative assessment. In order to meet the requirements of formative assessment, the e-assessment system had to supply tools for the lecturers to adapt an activity to the learners' needs, thus improving its reliability from the feedback obtained. The item analysis provided by Moodle's quiz module had turned out to be an interesting psychometric tool to estimate, refine and improve the reliability of quiz questions. The fact that the students' ratings of the Moodle quizzes were very positive reinforced the idea that activities of this kind were suitable for mathematics teaching and learning and that this Moodle system could be extrapolated naturally to other courses as well. According to this research, it can be stated that Moodle quizzes are a consistent and reliable tool for formative knowledge e-assessment.

Cognitive skills and application of methods cannot be assessed via multiple-choice tests and equivalent forms of basic assessment items. Therefore, the majority of existing e-assessment systems is inappropriate for use in mathematics and similar subjects (Gruttmann et al., 2008).

When it comes to formative assessment for skill acquisition, there were not many research projects based in this area. Even though some projects or tools mentioned skill assessment, they have used 'usual type' of questions such as MCQ, yes/no, short answers and fill in the blanks.

EASy (The E-Assessment System) is an interesting tool developed by University of Münster for assessing higher-order cognitive skills in an online environment for general mathematical proofs (Gruttmann et al., 2008; Majchrzak & Usener, 2011, 2012). This system is based on German Language. At the time of analysing this tool for the proposed research, it was identified, that it is not easy to share question banks as the questions were developed specifically for this tool. Also this tool was developed specifically for skill assessments rather than knowledge assessment and it does not support e-tutoring with feedback facility. The code of the EASy tool was not available and therefore, it was not possible to customize and easily adapt to any context. Also the developers of the tool were not able to check whether the tool could be replicated at other universities and whether it could be applied to other courses as well. This research project gave the idea of designing and developing the technology-enhanced assessment system as a modular web application. Additionally it helped to understand about students perceptions on formative e-assessments.

As mentioned under "Section 2.4.4.1 e-assessment tools for Logic", some e-assessment tools and intelligent tutoring systems such as AiM, OpenMark, Pandora, Organon, AELL were studied. From the analysis, it was understood that when it comes to the case of logic, only intelligent tutoring systems can offer the intelligent type of questions for skill assessment. But these tools do not support e-assessment characteristics.

To sum up, literature does not provide a general system which was able to support skill and knowledge e-assessment of logic in a convincing way. Accordingly, there are not any documented evaluations of the use of e-assessment for Logic. This was taken into consideration when designing and developing the technology-enhanced assessment system for skill and knowledge acquisition.

2.6 Summary

This chapter presented background for the present research. Under this, skill and knowledge assessment, technology-enhanced assessment, elements, tools, standards, specifications, models, and approaches, to knowledge and skill assessment were discussed. These provided theory and technology which are useful for designing and developing a technology-enhanced assessment system for skill and knowledge acquisition.

According to literature discussed previously, most of the organizations use knowledge assessment rather than skill assessments. Even if they use skill assessment, the questions are based on simple types such as multiple choice questions, multiple responses, short answers, fill in the blanks, matching and crossword puzzles. Also, cognitive skills and application of methods cannot be assessed via multiple choice tests and equivalent forms of basic assessment items. Therefore, to decide on a tool which can be used to access both skill and knowledge acquirement, existing tools developed for skill and knowledge assessment were studied. Some tools fall into the category of intelligent tutoring systems whereas others are categorized as e-assessment tools. Most e-assessment tools support knowledge assessment whereas intelligent tutoring systems support skill assessment. There was no general solution which supports both skill and knowledge assessment. At the same time, these tools depend on a particular subject, therefore, it is not easily to apply or adapt it into another context. In the case of logic subject, there were no e-assessment tools which can be used for acquisition of skills.

3

Design and Development of the Technology-Enhanced Assessment (TEA) System

This chapter presents the requirements, design and development of the Technology-Enhanced Assessment system (in short, TEA system). This is related to the *suggestion* and *development* steps of the "design and creation" research strategy. The detailed requirements for the technology-enhanced assessment system are identified and analysed to support both skill and knowledge assessment. The definitions of the technology-enhanced assessment system and the formative e-assessment model are also explained in this chapter. The design of the system with respect to the process of defining the scenarios, interaction flow diagrams, use case and sequence diagrams, architecture, components, and interfaces is presented. The user interface designs of the main components of the system are also illustrated as wireframe designs. Finally, the development of a general technology-enhanced assessment system which is capable of providing both skill and knowledge assessment is explained.

3.1 Requirements of the TEA System

The goal of this research is to propose a general technology-enhanced assessment system for skill and knowledge assessment in online education. To achieve this, it was decided to design and develop a technology-enhanced assessment system. Therefore, design and development played a strong part in this research. One subject was selected as the domain for development and evaluation. To do this, relevant information had to be obtained. Interviews with teachers were carried-out and also, the context of skill and knowledge assessment was analysed. As a result, the Logic course of the UOC which requires a high level of skill and knowledge to obtain the required qualification was selected.

Also, it was needed to identify the detailed requirements for the technology-enhanced assessment system to support both skill and knowledge assessment. For this purpose, user research techniques were used throughout the project life cycle to better understand users and to test their behavior (Lazar et al., 2010). Also these techniques were used to identify user groups that should be of highest priority during the project and their needs. Basic steps of user research include defining primary user groups, planning for user involvement, conducting research through data collection methods such as user interviews and observations, validating user group definitions and as a result generating user requirements (Unger & Chandler, 2009). Since the aim of this research is not just to design and develop a new general technology-enhanced assessment system but also to provide a new learning experience for students in both skill and knowledge assessment in an online educational environment, the requirements associated with both educational and technological considerations were studied. In addition to user research techniques, a review of the previous literature in the assessment domain facilitated the identification of the expected requirements.

3.1.1 Data Collection Methods and Sources

This research is for a technology-enhanced assessment system which will be used in an online environment. Students, teachers, institutions and administrators were identified as the primary users of this type of system. To identify the features and functionalities expected by each user group, some of the data collection methods were carried-out as explained below.

There are numerous ways to collect data about prospective users in the form of surveys, focus groups and interviews (Goodwin, 2009; Lazar et al., 2010). For this research, interviews, observations and previous literature studies have been employed to identify requirements associated with users, educational context and technological needs.

User interviews can be understood as conversations with current or potential users of the system. These interviews help to understand users preferences and attitudes, but cannot be used to make formal statements about actual performance. As mentioned by Unger & Chandler (2009), to look for specific information on how people interact with the environment, it is better to observe them in the actual context. Additionally, combining observations with interviews allows the researcher to gather rich, useful information very quickly while minimizing self-reporting error. Furthermore, spending time with individual users in their own environments help to understand how they perform their typical activities as well as to clarify doubts about interpreting what was observed (Goodwin, 2009).

Once the domain was defined as the Logic course, an interview with five users was carried-out. Out of them, three were teachers who were involved in monitoring student activities and answering questions in the online classroom, and two were course coordinators who were in charge of the course design and scheduling. This interview mainly helped to identify the problems associated with the domain in assessing skills and the measures that should be taken to rectify the problems. Teachers wanted an assessment solution which can offer both practice and evaluation facilities in both skill and knowledge acquirement.

To obtain student data, observations were carried-out in the Logic classroom to observe students behavior. Also, students' feedback about the Logic course was obtained through general satisfaction questionnaires of the UOC and from the teachers. Students' usage information in the classroom was also obtained. Additionally, two questionnaires were used to gather information about the assessment in the Logic course. The questionnaires are given under the "Appendix G - Questionnaires".

In addition, observations were conducted in the online Logic course to understand the existing structure of the course, type of exercises and assessment model. After getting an in-depth knowledge about the online Logic course, three more interviews were carried-out with the teachers to understand the requirements that they expect from the technology-enhanced assessment system.

Literature studies were conducted to understand the existing systems and tools developed for e-assessment and the features, modifications and pitfalls associated with them and the way e-assessment has been used. One of the given institutional requirements was that the system should be developed in a standardized way while maintaining security and interoperability. Therefore, three informal interviews/discussions were conducted with the system administrators and technological experts to discuss about the tools, standards, protocols and architecture about the system. After identifying the standards and protocols, three discussions were carried-out to clarify issues regarding the implementation. The standards, protocols and architecture will be explained in the "Section 3.3 - Design of the TEA System" and "Section 3.4 - Development of the TEA System".

As the sources for the collection of data, information from the UOC databases, previous literature in system design and development, interviews, observations and questionnaires were used. The information from the UOC databases was used to identify the user profiles, socio-demographic information, access patterns to the LMS and enrollment history.

Previous literature was used to understand the e-learning and e-assessment system design and development process. Also, pitfalls of the existing systems and how they can be addressed by the new technology-enhanced assessment system were studied. At the same time, literature helped to understand the frameworks, architectures, standards and specifications that can be used. Interviews helped to identify the actual context where the system is applied as well as the requirements expected from the system. In addition to that, questionnaires were used to obtain the necessary requirements expected by the users. Observations were used to study the actions and performance of users in the online Logic course.

The following section includes an in-depth analysis into the educational and technological context of this research.

3.1.2 Educational and Technological Context

Context is a core part in the design and creation research strategy as it focuses on understanding the problems associated with real-world practice. In most cases, the context can change the way the problem is addressed. Also, the context as the place in which the research is situated can provide relevant information to the research project (Barab & Squire, 2004). In this section, the context is addressed with respect to both educational and technological considerations.

In general, the educational context of the system is a subject which requires a high-level of skill acquisition at a fully online higher educational environment. Fully online education refers to the use of various kinds of electronic media and ICT in education. Online learning integrates independence (asynchronous online communication) with interaction (connectivity) that overcomes time and space constraints in a way that emulates the values of higher education (Garrison, 2011).

Online educational environments can include both learning as well as assessment features. The technological context of a Learning Management System (LMS) is used as the delivery method. LMS is a software used for delivering, tracking and managing training or education. Sometimes an LMS can also support e-assessment facilities as well.

As the case study for this research, a first year Logic course of a Computer Science degree in a fully online higher educational university, Universitat Oberta de Catalunya (UOC) ("Appendix B - The Universitat Oberta de Catalunya (UOC)") was used.

Logic is a course which requires a high level of skill acquisition in order to successfully understand the salient concepts. The Logic course based on Propositional Logic and Predicate Logic is related to other courses of a mathematical nature and provides student with logical-mathematical foundations that facilitates further study of courses from different areas of knowledge. It is a fundamental course in the whole area of programming languages because of its importance to provide algorithms of a good logical structure, and its relevance in formal verification and the derivation of algorithms. Within the area, it will be useful for subjects such as automata theory and formal languages. It is also essential for the study of databases following the relational data model, because the standard language is based on predicate logic.

Logic skills are also useful when learners are interpreting and analyzing problems. One goal of the course is to learn to formalize using the logic language. The skills and abilities required to formalize and to validate or refute arguments are essentially the same as detecting the problems of an incorrect specification. The contents of the Logic course are divided into 8 learning modules and there is a significant interaction between them.

With the aim of providing tools to facilitate the learning process, teachers of the Logic course had developed an Intelligent Tutoring System (ITS) that facilitates and supports the learning of three major themes of the course: natural deduction, resolution and truth tables (Huertas et al., 2011). The ITS tool solves different exercises, guiding and informing the student of the correctness of their solutions. Exercises can be either proposed by the teachers or selected by the students themselves. The ITS tool was introduced into the online classroom to provide learners with more practice through automatically graded exercises and to improve their skills in these themes. It is a tool that impacts not only upon learning but also on continuous self-assessment. Using this tool, students are given the opportunity to construct the correct answer with error messages given at each step of any learning activity. However, for some topics of the subject, such as formalization, not supported by the ITS, the only way of practicing is by utilizing the traditional pen and paper method.

At the time of this research, based on the 8 learning modules, the assessment model of the course provided 4 Continuous Assessment Tests (CAT) which had to be completed using the ITS tool. The questions offered through the CAT were the same for all the students. As a result of it, the students had the possibility to copy the answers from other students. In addition to that, at the end of the course, students had to do a 2 hour face-to-face examination. Both CAT and face-to-face examination were used as summative assessment. In this case, students were not provided with facilities for formative assessment. When calculating the final marks, 35% was given for the 4 CAT and 65% was given for the final face-to-face examination. The structure of the Logic course with respect to the relationship between learning modules and assessment activities can be illustrated as in Figure 3.1.

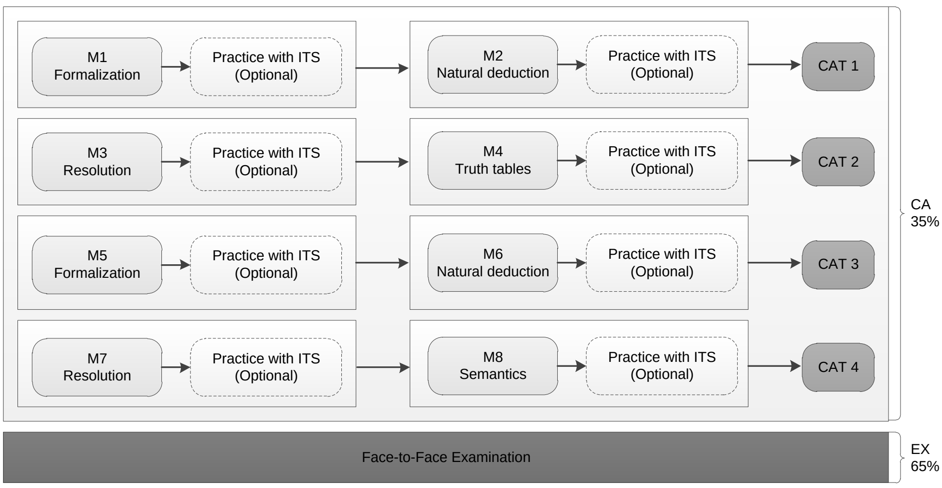


Figure 3.1: Relationship between learning modules and assessment activities

According to the teachers at the UOC, one reason for using CAT within the ITS was to promote its use. When the use of the ITS was voluntary, students have used it very little or not at all because they saw the tests as creating more work for them. This is a recognized effect of learning support tools that are not directly involved in the assessment. The other reason teachers wanted the students to use the ITS was to obtain the advantage of the automatic grading of most exercises for each test.

After studying the specific context of Logic, it was observed that the practice in the subject is optional and only if students prefer, they have the possibility to practice using the ITS tool. This tool provided only the skill type of questions and therefore, for knowledge specific content, students had to use paper-based methods. When it comes to assessment, students were provided with 4 CAT and a final face-to-face examination. In this case, using the ITS is mandatory for the completion of the CAT. However, all students were provided with the same CAT and therefore, students had the possibility to copy answers from others. Also the usage of the ITS tool for practice was low. As with the informal interviews with the teachers, they would prefer to offer formative e-assessment with both practice and evaluation in addition to final face-to-face examination. As a solution to this and to properly utilize the ITS tool, formative e-assessment model together with practice and evaluation can be introduced into the first year Logic course.

Considering the technological context while adhering to institutional needs, a system which is able to provide practice and evaluation for both skill and knowledge acquirement according to a formative e-assessment model can be designed and developed. However, in both cases, the system and the assessment process should be designed and developed in a general way which can be easily adapted to any other subject. This is further explained together with the requirements discovered from the data collection methods under the types of requirements.

3.1.3 Types of Requirements

According to the user-centered design approach, the main requirements were based upon user and educational context. Since technology plays an important role in this research in addition to the user and their educational context, the technological requirements were also studied. With respect to the educational context, the environment where the assessment takes place was also determined. Under technological requirements, existing tools were studied to understand whether they can be adapted to the required environment. Therefore, with respect to the e-assessment system three main types of requirements were identified as user, educational and technological.

3.1.3.1 User Requirements

The purpose of the user requirements analysis was to identify all users who may influence or be impacted by the system as well as to identify the needs of all those users. Understanding user requirements is an integral part of information systems design and is critical to the success of interactive systems. As specified in the ISO 13407 standard (ISO, 2013b) (revised as ISO 9241-210 standard (ISO, 2013c)), user-centered design begins with a thorough understanding of the needs and requirements of the users. The benefits can include increased productivity, enhanced quality of work, reductions in support and training costs, and improved user satisfaction (Maguire & Bevan, 2002).

Understanding users in-depth is necessary as this information helps in designing and developing the technology-enhanced assessment system effectively to match user needs, wants and limitations.

Also usability heuristics is an important aspect which has to be considered while analyzing the user requirements, as it puts the users and their real needs in the center (Zaharias, 2004).

For designing user interfaces, Shneiderman (1997) proposed “Eight Golden Rules of Interface Design” that are derived heuristically from experience and applicable in most interactive systems after being properly refined, extended, and interpreted. These can be outlined as strive for consistency, enable frequent users to use shortcuts, offer informative feedback, design dialogs to yield closure, offer error prevention and simple error handling, permit easy reversal of actions, support internal locus of control and reduce short-term memory load.

When it comes to web applications, Nielsen (1995) defined ten usability heuristics as visibility of system status, match between system and the real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, help users recognize, diagnose, and recover from errors and help and documentation.

However, for e-learning applications it is important to note that unlike users of a traditional software product, who return time and again and gradually learn the interface, an instructional interface of an e-learning or e-assessment application must make sense quickly since the user is unlikely to use the environment for an extended period of time (Lohr, 2000; Zaharias, 2004). University of Georgia (Benson et al., 2002), modified Nielsen's heuristic rules Nielsen (1995) and refined heuristics for evaluating e-learning programs. In addition to the 10 rules, they have included, interactivity, message design, learning design, assessment, media integration, resources, performance support tools, learning management, feedback and content in to the list (Benson et al., 2002).

Usability heuristics were also considered in addition to understanding the users for obtaining user requirements through analysis. Usability heuristics can also taken as design guidelines. As mentioned earlier, for understanding user requirements, techniques such as interviews, observations and previous literature studies were used. User requirements deal with potential participants involved in the process. Accordingly, there are three types of users who directly interact with the system such as students, teachers and administrators.

E-Assessment with its instantaneous feedback can be seen as providing 'a tutor at the student's elbow' Ross et al. (2006). In a distance-learning environment feedback plays an important role (Jordan & Butcher, 2010). Therefore, for formative e-assessments, students need activities which they can use to practice and learn a particular topic (Sadler, 2013). According to the good assessment and feedback practices demonstrated by (Nicol, 2007), some of the interesting factors of an e-assessment system can be noted as, help clarify the good performance, goals, criteria, and standards, encourage time and effort on challenging learning tasks, deliver high quality feedback information that helps learners self-correct, encourage positive motivational benefits and self-esteem, facilitate the development of self-assessment and reflection in learning, and help teachers adapt teaching to student needs.

Considering the above practices, from the students perspective, students can benefit from an e-assessment system which can be used for both practice and evaluations of skill and knowledge acquisition. The system should offer immediate grading soon after the completion of a particular activity. At the same time, the system should provide different types of feedback at various stages of the assessment process with guidance to students. Students can use this feedback to understand where they have gone wrong and improve their learning process as a result of it.

Generally, for students, the interface of the e-assessment tool should be flexible, efficient, user-friendly and designed in a way that students do not spend too much time learning the system. Since the system is used to provide e-assessment facility, the students should be able to focus on the content rather than spending time on getting familiar with the system. Therefore, learnability of the tool is an important requirement as students should be able to easily understand the content and the components as students use the system only to accomplish the specific tasks such as learning and assessment. For teachers and administrators this is also important as they are intensive users of the system. They access the system on regular basis therefore, they get familiar with the system rapidly compared to students, although their focus is more on adding content.

According to good assessment and feedback principles (Nicol, 2007), the system should clarify good performance to students through goals, criteria and standards. This is one of the characteristics that teachers expected from the e-assessment system. Therefore, teachers preferred the system to provide student grades and outcomes as a report where they have the facility to select outcomes based on the grades. Furthermore they wanted to evaluate the overall marks of students, progress and competencies through the system which allows them the flexibility to observe students' online while they perform their task and also to understand where more attention has to be given regarding specific student difficulties.

Additionally for helping teachers to adapt teaching to student needs, from the teachers' perspective the system should provide both skill and knowledge assessment and offer immediate feedback during this process. Teachers would like to use the system to provide tests where students can use to practice and then carry-out assessments. According to them, the system should provide facilities to minimize the level of cheating by students (Clariana & Wallace, 2002). Teachers also acknowledged the benefit of simplifying their workload through the immediate marking facility and statistics found in the e-assessment environments.

From the institutions and system administrators' perspective, they mainly wanted to consider the standardization facility where the system can be easily adapted to any subject area without many modifications. Even the questions provided within the system should follow some standardized format so that in future it can be easily maintained and also shared among different systems. They also wanted the system to provide detailed statistical information such as logs of participants, error logs, activity reports and records of each student.

In addition to studying the requirements of the users, it is interesting to have a look at the educational and technological requirements related to the technology-enhanced assessment system.

3.1.3.2 Educational Requirements

The purpose of studying the educational requirements is to understand the need for e-assessment and how it can be adapted to the actual context, in this case a first year Logic course of an undergraduate Computer Science degree at the UOC, a fully online university.

In general, e-assessment can be explained as the continuous electronic assessment process where ICT is used for the presentation of assessment activity, and the recording of responses. E-Assessment contributes to the higher education through improving the quality of student learning experience (Dermo, 2009). It is widely recognized that rapidly received feedback on assessment tasks has an important part to play in underpinning student learning, encouraging engagement and promoting retention (Jordan, 2009b; Rust et al., 2005; Yorke, 2001). Also, practice is an important aspect of e-assessment as it allows the opportunity for students to act on the feedback (Sadler, 1989, 2013).

As explained under the "Chapter 2 - State of the Art", e-assessment can be used to evaluate both knowledge and skill acquisition of students. Knowledge can be specified as the recall or recognition of specific items (Bloom, 1956). It can be more elaborate as remembering of previously learned material. Knowledge represents the lowest level of learning outcomes in the cognitive domain and therefore, exercises that require knowledge to be memorized only account for a fraction of the overall examinations (Majchrzak & Usener, 2012). A skill can be defined as a practiced ability, expertness, technique, craft, art, etc (Sangwin, 2003). Higher-order cognitive skills are typically required for solving exercises encountered in the natural sciences including computer science and mathematics. Courses in these areas rely on students being able to think in a structured way and to acquire skills in constructing a mathematical solution or a logic proof. Considering the above, for knowledge assessment, knowledge type of questions such as MCQ, true/false, short answer, fill in the blanks, types of questions can be used and for skill assessment, interactive and intelligent types of questions which allow students to construct the appropriate answer with the help of feedback can be used.

As mentioned in the "Section 2.4.4 - E-Assessment Systems and Tools", several e-assessment tools and projects were analyzed to understand the characteristics of these tools as well as to find how they have been used for e-assessment. As a result, it was identified that there are some tools for e-assessments whereas others are for Intelligent Tutoring Systems (ITS). When considering the skill and knowledge aspect, it was understood that most of the intelligent tutoring system support skill type of questions and e-assessment systems support knowledge type of questions. Even some of these tools are not fully automated. However, ITS does not support the e-assessment characteristics. As a result, the literature does not include a general tool which can be used for both skill and knowledge assessment. Based on the results of the interviews performed with the teachers, they preferred the system to offer facilities to evaluate student performance, learning process and the quality of the course. Thus, in addition to assessment, facilities such as progress, competencies, grade report with outcomes and statistics can be introduced to enrich the e-assessment and learning experience.

Also, a general e-assessment system should consist of features such as ("Chapter 2 - State of the Art"): monitoring of progress, immediate feedback, automatic marking, weighted average grade, questions for knowledge assessment, questions for skill assessment, randomization of questions, personalization of quizzes, sharing of question banks, and statistical analysis which can be used for formative e-assessment. Therefore, these features have to be incorporated into the proposed solution.

3.1.3.3 Technological Requirements

The purpose of analysing the technological requirements is to understand the technical issues associated with the technology-enhanced assessment system and how they can be solved (Goodwin, 2009). The most appropriate technologies, tools, standards, web services and protocols that can be used to design and develop an appropriate e-assessment system are also analysed. Requirements such as security, interoperability, reliability, user-friendliness and consistency of the technology-enhanced assessment system have to be considered. More consideration was given for security and interoperability. To obtain technological requirements, unstructured interviews with the system experts and administrators helped to identify the appropriate standards and protocols that can be used. At the same time, study of the relevant literature was also carried-out.

In this research, when it comes to development, the main concern was to design and develop a generic system which can be easily adapted to any subject and organization. Literature did not indicate a general tool which can be used for both skill and knowledge assessment. Since this research mainly focuses on proposing a general technology-enhanced assessment system to provide a new learning experience and not on a final end product, the advantages and disadvantages associated with developing a system from scratch was studied. As the advantages, the system can be developed exactly to suite the requirements of the real educational context and reduce the burden of understanding the code of another tool. On the other hand this can also be taken as a disadvantage, because extra effort and time is dedicated on a new tool or a component which has already been developed and freely available. If the selected components or tools are developed and tested according to standards then the development time can be saved and used to enrich features of these tools or components. Another disadvantage can be that the standardized aspect of the system might not have been addressed. Therefore, unnoticed security issues such as open to a SQL injection attack (OWASP, 2013; Websec, 2013), or unnoticed performance or scaling issues might occur. Also from personal experience of system development and through the studies of existing systems, developing a system from scratch tends to make it more align towards the requirements of the actual context rather than considering the general requirements.

Considering all these, it was seen the need to develop the system using existing components to make it more general. In this case, any interested party can use the system for their own requirements by making minor modifications, by plugging in a new component or removing an existing one. Through this, the interoperability can also be maintained which allows diverse systems and organizations to work together. This can be done through a set of standardized plug-ins which saves time and effort. Therefore, standards can be used for the seamless communication of data between the components and the TEA system. With respect to the standards and specifications, special consideration was given to the standards mentioned under the"Section 2.4.2 - Standards and Specifications".

As in all computer based systems, technology-enhanced assessment systems should also support main characteristics such as interoperability, reusability, manageability, accessibility and durability (AL-Smadi & Gütl, 2008). When it comes to the technological requirements associated with the TEA system, characteristics such as reliability, consistency, user-friendliness, interoperability and security were addressed. For reliability, the TEA system should provide a sufficient degree of reliability in relation to its accessibility by being able to handle large amounts of data and error conditions should be minimized to make the system robust. Also, the system should provide consistency in relation to the manageability and the behaviour of the individual modules. The system should be interoperable where it can be easily connected with another institutional system or subject and exchange information and data while maintaining security of the whole system. The user interfaces should be developed in a user-friendly manner considering both user and technological requirements. As for user requirements, usability is an important aspect as users should be able to easily find the functionalities within a short period of time with little or no training. For technological requirements, the system should be efficient and easy to install. At the same time, the system should be easy to troubleshoot and be able handle errors effectively. Also adhering to standards is an important technical requirement when it comes to user-friendliness of a software system.

3.1.4 Summary of Requirements Analysis

As a summary, based on the analysis performed under different type of requirements such as user, educational and technological, the technology-enhanced assessment system should consist of the following requirements:

- Offer both skill and knowledge assessment in a fully online environment.
- Include different types of questions for both practice and evaluations of skill and knowledge acquisition.
- Offer immediate grading facility soon after the completion of a particular activity.

- Provide different types of immediate feedback at various stages of the assessment process with guidance to students.
- Introduce facilities to minimize the level of cheating by students through a large database of questions, randomization of questions and shuffling of answers within a question.
- Provide teachers with the facilities to evaluate the overall marks of students, outcomes, progress and competencies.
- Display students with their own progress and the total competencies achieved.
- Present statistical reports on student performance to teachers and administrators.
- Maintain interoperability, security, reliability, consistency and user-friendliness.
- Adhere to the most appropriate e-learning standards, specifications and should be easily adaptable to any institute or system.
- Maintain a seamless communication between modules and components to transfer data back and forth without any problems in a secure manner.

The study of the user, educational and technological requirements, and the analysis of the context, showed the need to design and develop an e-assessment solution which provides skill and knowledge assessment. As understood from the requirements, the system should be structured to meet interoperability, security, reliability, consistency, and user-friendliness using independent components for knowledge assessment, skill assessment, progress, competencies, grades and outcomes.

3.1.5 Summary

This section addressed the detailed requirements of the technology-enhanced assessment system with respect to user, educational and technological considerations. The context of the Logic course was also studied through user-centered design research techniques in order to understand the expected requirements and features that are needed to be included in the technology-enhanced assessment system. As a result, a summary of the requirements was gathered and the components required to cater to those requirements were also identified.

3.2 Definition of the TEA System

The proposed technology-enhanced assessment solution should provide both practice and evaluation facilities in both skill and knowledge assessment. This is related to the *suggestion* step of the “design and creation” research strategy, which involves a creative leap from curiosity about the problem to offering a tentative idea of how the problem might be addressed.

The technology-enhanced assessment system should be designed and developed in a way to provide both learning and assessment facilities. For learning, students can be provided with facilities such as learning materials and practice tests. At the same time, the system should be able to provide assessment (evaluation) tests. Assessment of knowledge is related to the first two levels (knowledge and comprehension) of Blooms taxonomy (Bloom, 1956; G. Crisp, 2007) and the next four levels (application, analysis, synthesis, and evaluation) are used for skill assessment (Bloom, 1956; G. Crisp, 2007) which relates to practical abilities for which practical based examinations or simulation software can be used.

Both practice and assessment tests should include feedback and based on the feedback students should be able to attempt the tests till they obtain the required marks needed to master the knowledge and skills required. In order for assessment to be effective, feedback must not only be provided, but also understood by students and acted on in a timely fashion (Jordan, 2009a). Therefore, the feedback should be immediate and detailed with guidance. Based on that, students should be able to learn their errors or mistakes and obtain a higher mark in the subsequent attempt. For assessment test, some restrictions can be imposed with time and attempts to motivate students as well as to offer the assessment atmosphere. Both practice tests and assessment tests can be provided for each topic of the subject.

As explained above, knowledge and skill assessments are a key requirement of the system and as a result, these are taken as the two main components of the TEA system. This main TEA system consist of another system known as the “Basic TEA System” based on the general features of an e-assessment system. The Basic TEA system itself consists of inbuilt components such as progress bar, competencies, grades and outcomes. Progress bar and competencies components are used for monitoring and evaluating the progress. Grades and outcomes components are used to store marks of automatic marking and calculations of weighted average grades and outcomes. These components help teachers to track students learning progress throughout the whole course period. At the same time, the data obtained through these components can be used to improve the course.

The overall TEA system consists of main components for knowledge assessment, skill assessment, progress, competencies, grades and outcomes. Since both the knowledge assessment and skill assessment components are not inbuilt within the Basic TEA system, these components should be linked with the Basic TEA system. For this purpose, appropriate e-learning and e-assessment standards can be used to communicate and send data back and forth between the Basic TEA system and the components. Also, appropriate standards should be used to communicate data among the learning management system and the whole TEA system as well. This proposed technology-enhanced assessment system along with the components and communication links is illustrated as in Figure 3.2.

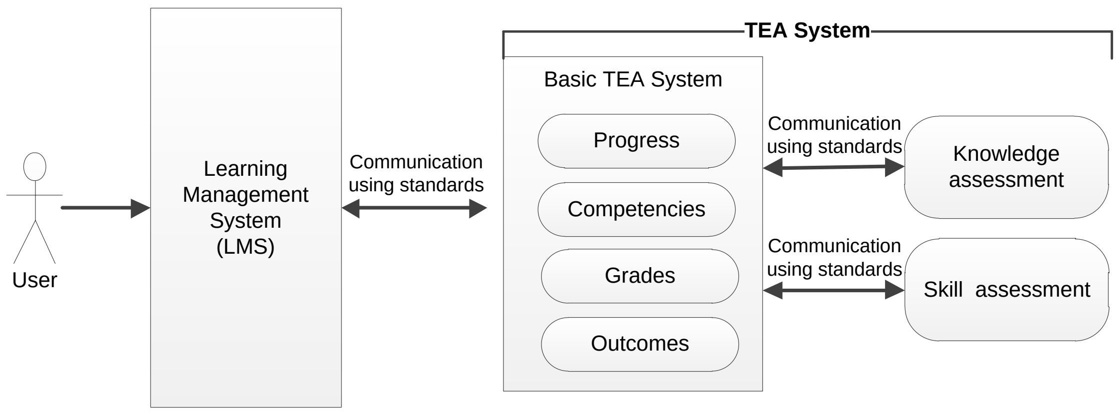


Figure 3.2: Proposed technology-enhanced assessment system

3.2.1 Definition of the Formative E-Assessment Model

After identifying the expected requirements and components of the TEA system, it is needed to study about how the formative assessment should be carried-out through both skill and knowledge assessment modules. As mentioned in the “Chapter 2 - State of the Art", JISC (2007) has depicted the relationship between assessment and effective learning as shown in Figure 3.3.

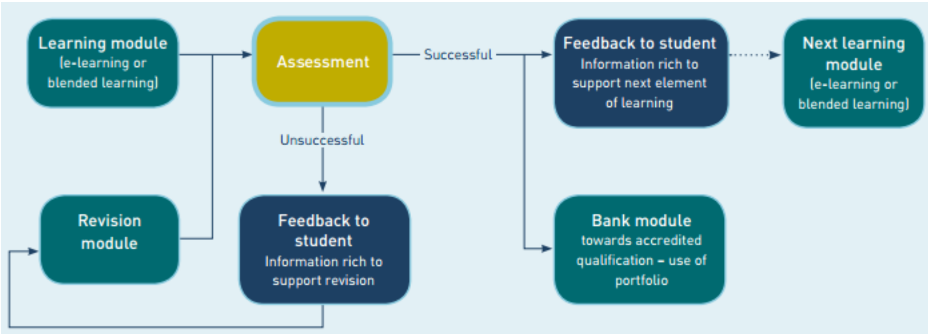


Figure 3.3: The relationship between assessment and effective learning JISC (2007)

After studying this model it was understood that practice, one of the key areas of online education and assessment (Sadler, 1989), had to be given more emphasis. As Rountree (1987) has mentioned, "*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 (Whitelock, 2010; Whitelock et al., 2011). Also, students must have the opportunity to act on the feedback (Sadler, 1989). This underlines the importance of allowing students the opportunity to practice before moving into the assessment. Considering this factor, the model outlined by JISC (2007) was enhanced into the proposed formative e-assessment model as explained below.

The main purpose of introducing this model was to provide more benefits for students to improve their learning process through practice. When introducing practice, feedback plays a vital important role. Whitelock (2010) has coined a term, "advice for action" as "helping students find out what they do not know and how to remedy the situation can avoid the trauma of assessment". Accordingly, feedback should be provided in a way that encourages the students to actively change their ideas and ways of organizing their answers and discourse within a given subject domain (Whitelock, 2010). This was taken into consideration while designing the formative e-assessment model to make it general to be used for any subject domain.

In the formative e-assessment model, students access a particular learning module and then use the practice test provided in that module. For practice tests, students are provided with feedback both in the cases of being successful and unsuccessful. If they are unsuccessful, based on the feedback they are directed to the revision module and at the same time they are provided with an unlimited number of attempts to practice the test. The reason for allowing multiple attempts is to allow students to interactively engage in the assessment system while acting upon the feedback given “then and there” to solve the problem (Butcher et al., 2009). In the case of students who have obtained the required pass mark, they are directed to the assessment (evaluation) test. This was done with the intention to allow students with the benefit of practice before moving to assessment tests (Sadler, 1989). Even in this case, students are provided with constructive feedback. However, students have to obtain the required pass mark within a given time (eg: 2 hours) and a limited number of attempts (eg: 3 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 those attempts. As (Sadler, 1989) and (Gibbs & Simpson, 2004) have stated, in most cases students are allowed multiple attempts (usually three) at each question, with increasingly detailed and tailored prompt allowing them to act on the feedback whilst it is still fresh in their minds and to learn from it. 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, 2008). This encourages an all-important “focus on form” for students (Fowler, 2008; Long, 1991). To discourage guessing in some cases, minus marks are given. The questions offered within a particular attempt are selected randomly from a bank of questions. The answers within the particular question are also shuffled within each attempt. These are done to minimize the facilities of cheating and copying the answers as expected with the introduction of the e-assessment solution (Clariana & Wallace, 2002). 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 particular assessment, students can move to the next learning module. The proposed formative e-assessment model is shown in the following Figure 3.4.

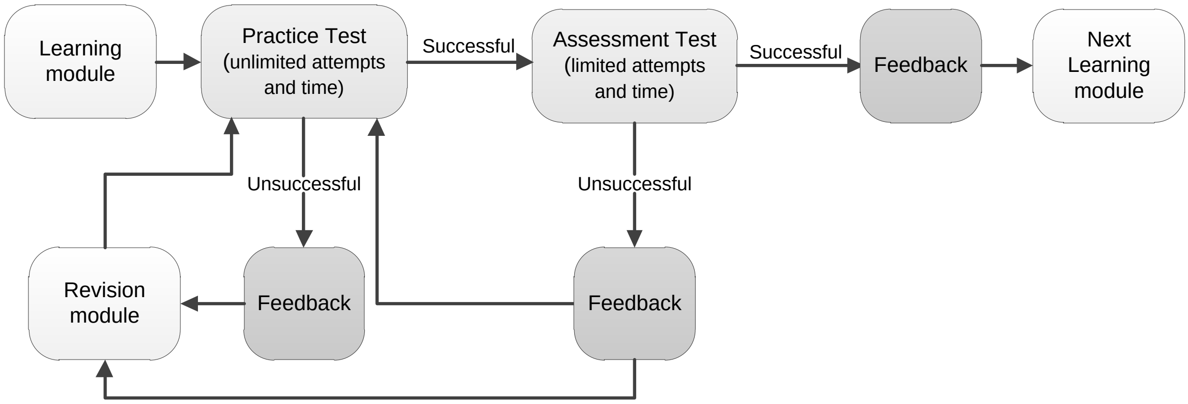


Figure 3.4: Proposed model for formative e-assessment process

3.2.2 Summary

This section included a detailed description about the proposed technology-enhanced system along with the formative e-assessment model. The next phases are the design and development of the TEA system which will be explained in the subsequent sections.

3.3 Design of the TEA System

This section presents the design of such a system with respect to the process of defining the architecture, components, interfaces, and data for a system to satisfy the requirements specified in the previous section. Since the system is intended to provide the infrastructure that is needed to carry out the research, the system is also designed to be flexible and standardized to make it suitable for any educational context. Also, the conceptual design of the system is finalized with the assistance of user profiles and scenarios. The structure of the TEA system is designed to understand the elements of the system. The interaction flow diagrams are also designed to graphically represent how objects will flow through the various rules and system states. Also, the logical design of the system is outlined to explain the interaction among users, system and its components. The architecture of the system is designed while giving special attention to standards, web services and protocols to be used in the development. Finally, the user interface designs of the main components are illustrated as wireframe designs. These wireframes were used as prototypes when developing the system.

3.3.1 Conceptual Design:Profiles and Scenarios

Conceptual design is defined as a description of the proposed system in terms of a set of integrated ideas and concepts about what it should do, behave, and look like, that will be understandable by the users in the manner intended (Rogers et al., 2011). Under conceptual model, user profiles and scenarios were defined.

User Profiles and Scenarios

The TEA system consists of three groups of users such as students, teachers and administrators, as mentioned in the requirements section.

To understand the data associated with a specific user, user profiles were created. User profiles describe the characteristics of typical target users and it helps to provide a clear representation of the person who is using the system, and potentially how they are using it (Unger & Chandler, 2009). Furthermore, creating user profiles helps to focus on representative users by providing insight into "real" behaviours of "real" users. This helps to resolve conflicts that arise when taking design and development decisions (Goodwin, 2009; Unger & Chandler, 2009; Williams, 2009). Data about user profiles were obtained from the interviews, UOC databases and questionnaires.

A scenario is a plausible description of the future based on a coherent set of assumptions. Scenarios are among the most powerful tools in product and service design, with uses ranging from developing requirements to ensuring that a design accounts for the full range of possible interactions (Goodwin, 2009). User scenarios associated with each user profile are defined to understand how they interact with the system. A goal-directed scenario is a textual description of a user's interaction with the system. Each scenario begins with a specific situation, and then describes the interaction between user and system from the beginning of a task or session through its completion (Goodwin, 2009).

Both user profiles and scenarios were used as tools to aid the design process of the TEA system.

The user profiles and scenarios for the three user groups can be described as follows.

Student

Student Profile

Student profile was built mainly based on the data obtained from the UOC databases such as socio-demographic information, access patterns to LMS and enrollment history. The users of the system are students of the Logic course of the UOC. This course is part of the Computer Science degree. 50% of the students of the Logic course are first year students. That means that for most of them, this is their first experience with the online education. At the same time, 23% of students enrolled to the course had a previous university degree. Average age of students is 32 years and out of them 85% of students are male and 15% of students are female. 91% of the students are working while studying for the computer science degree, whereas the rest is full time students. Out of the students who are working, 19% of students are working in the information and communication technology area. Students mainly connect to the LMS from home but, sometimes, they access the system from work during lunch hours and also from mobile devices. Students mostly check the forums, notices and messages posted in the LMS during daytime but, they complete the activities mainly in the evening and at night. Students mainly use the LMS during weekdays and on weekends they only access the system if they have activities to deliver. On average, students spent 7 minutes in the LMS for a single login session, if they do not need to do learning activities, else, the time spent on the LMS vary related to the type of activity and if the activity is assessed. Regarding the learning materials, goals, and activities, most students download the learning materials and read offline. They prefer to have clearly defined learning goals and work on activities that require looking for contents rather than just reading learning contents.

Student Scenarios

Scenario 1

Situation : Beginning of the Logic course

Description: When the student get an announcement from the UOC LMS that the Logic course is activated, they login to the classroom and then from there move to the TEA system to check the content and learning materials available. They note down the calendar with starting dates and ending dates for the assessment tests and download the learning materials and log out of the system.

Scenario 2

Situation : After the announcement of an assessment test

Description: When students get an announcement for the starting date of the assessment test, they again login to the TEA system, access the tests given for practice with the help of feedback till they are familiar with the subject content as well as till they achieve the required marks needed to move to the actual assessment test. Then, they attempt the assessment test, within the given time. If they are not successful in passing the assessment test, they try again within the given attempts. After that, they check the qualifications obtained from the grades section.

Scenario 3

Situation : Midterm of the course

Description: As students move along with the assessment tests, they can see that the progress bar is getting filled and an indicator showing their progress as a percentage. Students look at this to understand the activities they have to complete with the allocated deadlines and to understand where the rest of the classroom is at that particular time. At the same time, they carry-on with both practice and assessment tests.

Scenario 4

Situation : At the end, after completion of the assessment tests and before the final examination

Description: After completion of the entire tests, before the final examination they also look into the competencies module to understand the competencies they have achieved. Also as a way to get ready for the final examination, they use the system to practice the questions.

Conclusions

Based on the above student scenarios, the general steps and tasks that a student has to follow can be outlined as follows:

1. Access the Logic classroom and then the TEA system.
2. Read the learning materials and competencies expected for a particular test.
3. Practice for the test using the TEA system and move to the assessment test.
4. Attempt the assessment test within the allocated time period and number of attempts allowed.
5. Obtain a feedback and a mark for the test.
6. Check the qualification from the grades section.
7. View the progress bar to understand the activities completed as well as the activities which has to completed.
8. View the competencies achieved for the test.

Teacher

Teacher Profile

Teachers of the Logic course, have more than 5 years of teaching experience in the subject. They also have more than 5 years experience in online teaching and learning environments. They mostly access the course during the day and sometimes at night to activate the tests. Teachers also check the course while the tests are going on to see whether there are any problems and if any, to correct them and notify students. Therefore, overall they spend more than 12 hours per week in the course. Teachers post messages and questions into the forums, to keep students motivated and engaged in the subject. Teachers also check the forums to look at the conversations carried-out between students, to see whether they can help with any doubts as well as to answer the questions directly asked from them. After the deadline of a test is over they access the course to check the grades obtained by students, assign outcomes and to check statistics.

Teacher Scenarios

Scenario 1

Situation : Before the beginning of the Logic course

Description: Before the beginning of the semester, teachers login to the UOC Logic classroom and the TEA system several times to check the calendar, check questions, upload new questions, upload learning materials, set progress and set competencies.

Scenario 2

Situation : Throughout the duration of an assessment test

Description: When it is near the starting date of each assessment test, teachers set the assessment test, check the test as a student and set the assessment test to be automatically activated at a particular date and time. While the test is going on, they login several times especially at the beginning of the course to check whether things are progressing well and if not to take necessary steps to prevent problems. After the deadline of a particular assessment is over, they check the student grades and statistics, and assign competencies and outcomes based on students' marks.

Scenario 3

Situation : At the end of the course

Description: At the end of the course, teachers collect reports from the system as course statistics about tests, participation logs, activity reports, grade reports, progress data, competencies data and outcome reports to analyze and arrive at a conclusion about each test. They also prepare a report of formative e-assessment marks to be included in the final examination.

Conclusions

Based on the above teacher scenarios, the general steps that a teacher has to follow can be outlined as follows:

1. Access the logic classroom and then the technology-enhanced assessment system.
2. Prepare schedule for the assessment test.
3. Check the questions in the question bank, modify feedback and add more questions.
4. Set test for practice and assessments and test them through a student login.
5. Make the assessment test to be auto activated at a particular time and date.
6. Set progress bar and competencies.
7. Check student marks and set competencies and outcomes based on the marks.
8. Check and analyze statistical reports regarding tests and student performance.
9. Obtain reports on student participation, activity reports, progress, competencies and outcomes through the system.
10. Make a report of formative e-assessment marks to be included in the final examination.

Administrator

Administrator Profile

Administrators are involved in the system development and administration related work. They access the system before the beginning of the course to make appropriate connections between learning tools, LMS and the TEA system. Then, they check whether they work correctly as expected as well as the security, stability and performance of each tool along with the complete system. Also before the beginning of the course, administrators are involved in assigning the students to the appropriate virtual classroom. Then, while the course is going on, they solve issues that arise from the teachers or correct errors and problems that occur within the system. They also take care of the security, performance and backup of the LMS.

The scenarios for the administrators are not included here as the main focus of this research is to facilitate students and teachers in the skills and knowledge assessment process through the introduction of the TEA system and the formative e-assessment model.

3.3.2 Structure and Interaction Design

The structure and the navigation of the system was designed based on the tasks identified through the scenarios. The TEA system is implemented as an online environment and therefore, it is interesting to represent the structure as an information architecture. This is a visual way to display how content has been organized in the web application according to a hierarchical structure in order to aid the development process (Unger & Chandler, 2009).

The TEA system consists of six main elements such as progress bar, practice test, assessment test, gradebook & outcomes, competencies block and reports. In addition to that, the system is equipped with reports which records activity reports, logs and course participation of all users.

Both practice test and assessment test include of results of students, which is capable of storing and showing sub categories of results such as grades obtained by students for all attempts, responses given for all attempts and statistics with respect to results and attempts. The structure of the TEA system can be displayed as in Figure 3.5.

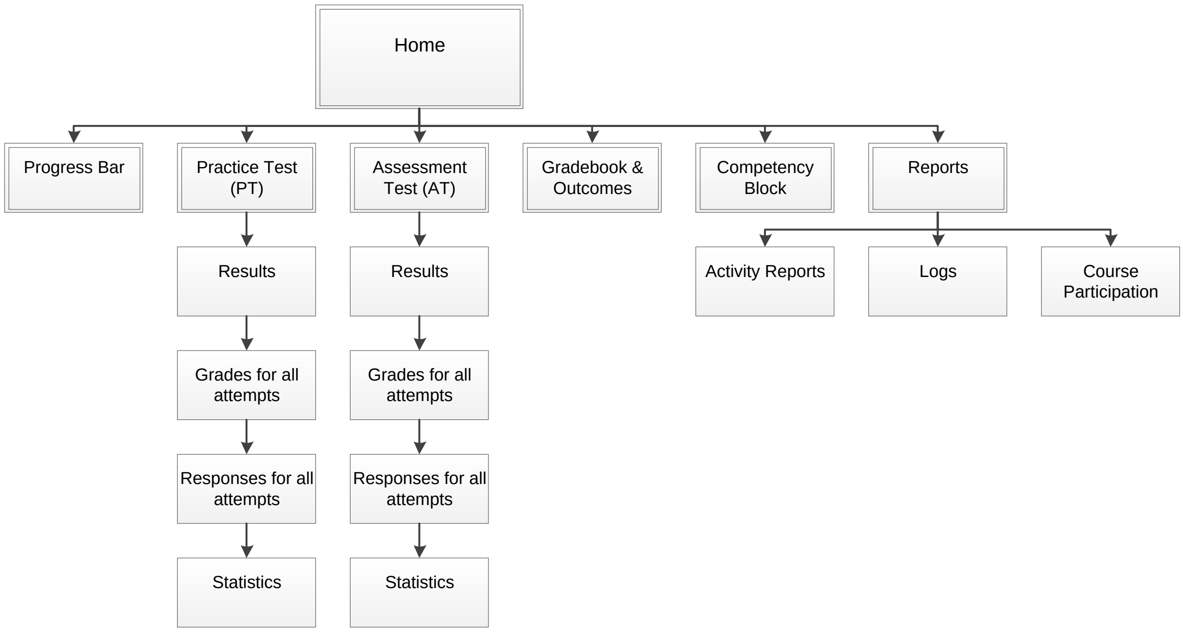


Figure 3.5: Structure of the TEA System

After designing the structure of the system as a visual hierarchy, interaction flow diagrams were constructed which identify the paths or processes that users or systems will take as they progress through the web application (Unger & Chandler, 2009).

Students' first need to login to the UOC LMS. If they are logged in, then they can access the TEA system. Once they are in the TEA system, they can attempt the Practice Tests (PT). However, to move to the Assessment Test (AT), they need to obtain a pass mark (in the example it has been given as 30). Students can keep on attempting the practice test, till they obtain the required pass mark and later they can move to the assessment test. After completing the assessment test they can view their progress, marks and competencies through progress bar, gardebook and competencies respectively. Students' interaction with the TEA system can be represented as an interaction flow diagram in Figure 3.6.

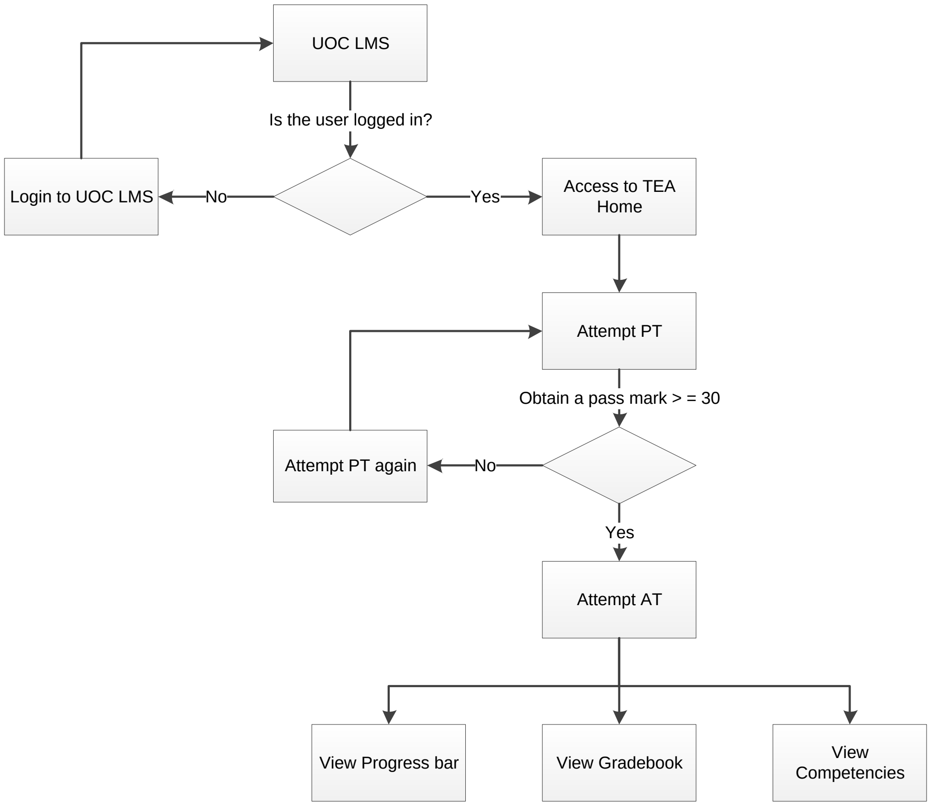


Figure 3.6: Interaction flow diagram - Students' interactions with the TEA system

As with students, teachers also have to first login to the UOC LMS in order to move to the TEA system. To make the system suitable for formative e-assessment, at the beginning of the semester, teachers have to set the progress bar, practice tests, assessment tests and competencies. Once the students are assigned to the course, teachers can view the practice tests, assessment tests and reports to see students' participation, performance and logs to see whether things work correctly as expected. After students have attempted the assessment test, teachers can view their overall results as grades for all attempts, responses for all attempts and statistics. At the same time, based on the grades, teachers have to select appropriate competencies and outcomes which will be viewed by students under gradebook and competencies modules. Figure 3.7 underlines the teachers' interaction with the TEA system as an interaction flow diagram.

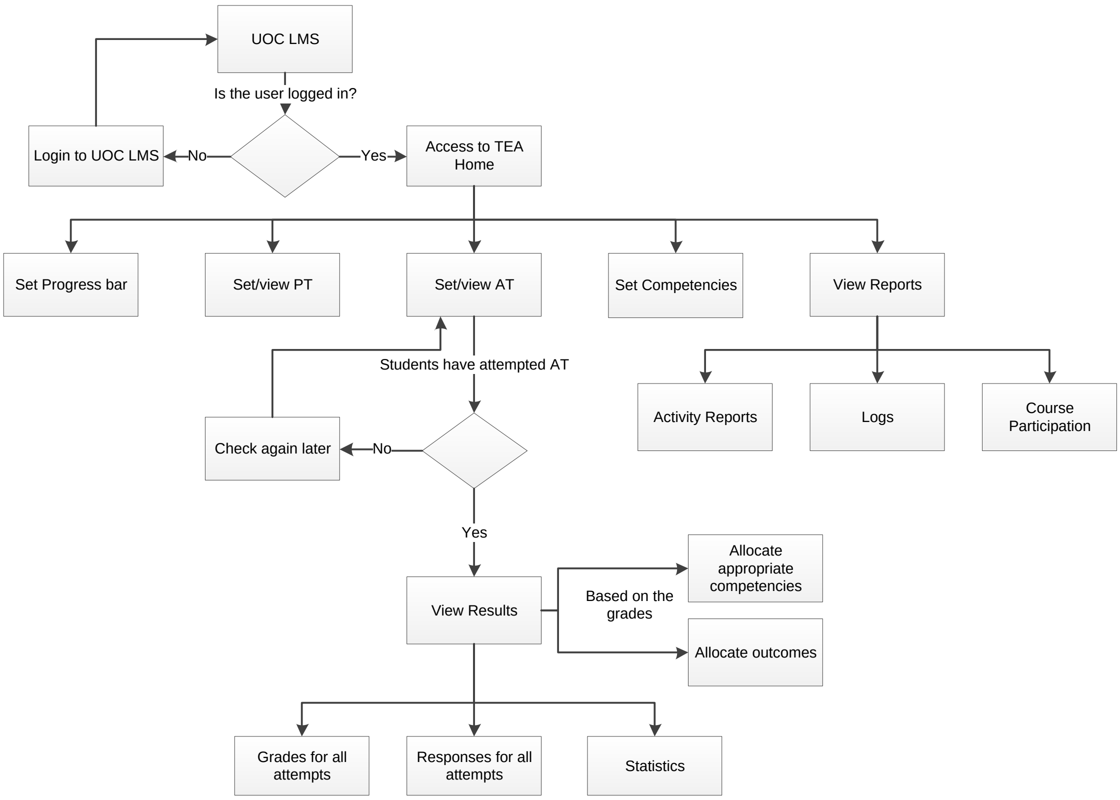


Figure 3.7: Interaction flow diagram - Teachers' interactions with the TEA system

3.3.3 Logical Design

The logical view of the system and user interactions between the users and the system are explained in the form of a UML, using Use Case diagram and Sequence diagram by considering the actual components of the technology-enhanced assessment system. The reason for drawing both interaction flow and the UML diagrams were to aid both the design and development process of the TEA system.

Interaction flow diagrams are often used for documentation purposes and to obtain user feedback about the interaction of the system as it is easier to explain to non-programmers. Interaction flows can be taken as high-level, end-to-end visualizations which also aid in designing logical design diagrams. Both use case and sequence diagrams show how a system interacts with the external entities. These diagrams show what is expected from the system to perform rather than describe how it can be accomplished. One of the major benefits of these diagrams is communication between users and elements. Additionally logical designs are more detailed and represent complex details. Once an interaction flow is drafted, the individual steps in an interaction flow can be used for further elaboration of details with diagrams such as use case and sequence.

3.3.3.1 Use Case Diagram

A use case diagram is a description of a cohesive set of possible dialogs (i.e., series of interactions) that an individual user initiates with a system (Booch et al., 2005). As a user-centered analysis technique, the purpose of a use case is to yield a result of measurable value to a user in response to the initial request of that user.

Use cases help to ensure that the correct system is developed by capturing the requirements from the user's point of view. Because they are written in natural language, use cases are easy to understand and provide an excellent way for communicating with users of the system (Booch et al., 2005).

A use case is a diagram that shows the relationships among actors and use cases within a system. An actor defines a coherent set of roles that users of an entity can play when interacting with the entity. An actor may be considered to play a separate role with regard to each use case with which it communicates. The use case construct is used to define the behavior of a system or other semantic entity without revealing the entity's internal structure. Each use case specifies a sequence of actions, including variants that the entity can perform, interacting with actors of the entity. The complete arrows given in the use case diagrams are a direct association between use cases or between the actors and the use cases. Dotted arrows sometimes depict include or extend relationships. An "include" relationship defines that a use case contains the behavior defined in another use case. An "extend" relationship defines that instances of a use case may be augmented with some additional behavior defined in an extending use case (Booch et al., 2005). Use cases are designed to form the foundation on which to specify end-to-end timing requirements for real-time applications as the TEA system.

The use case diagram explains the series of interactions among the three type of users within the TEA system.

Administrators are responsible for creating the communication links between the UOC LMS and the TEA system. In addition to that, they are responsible for over-

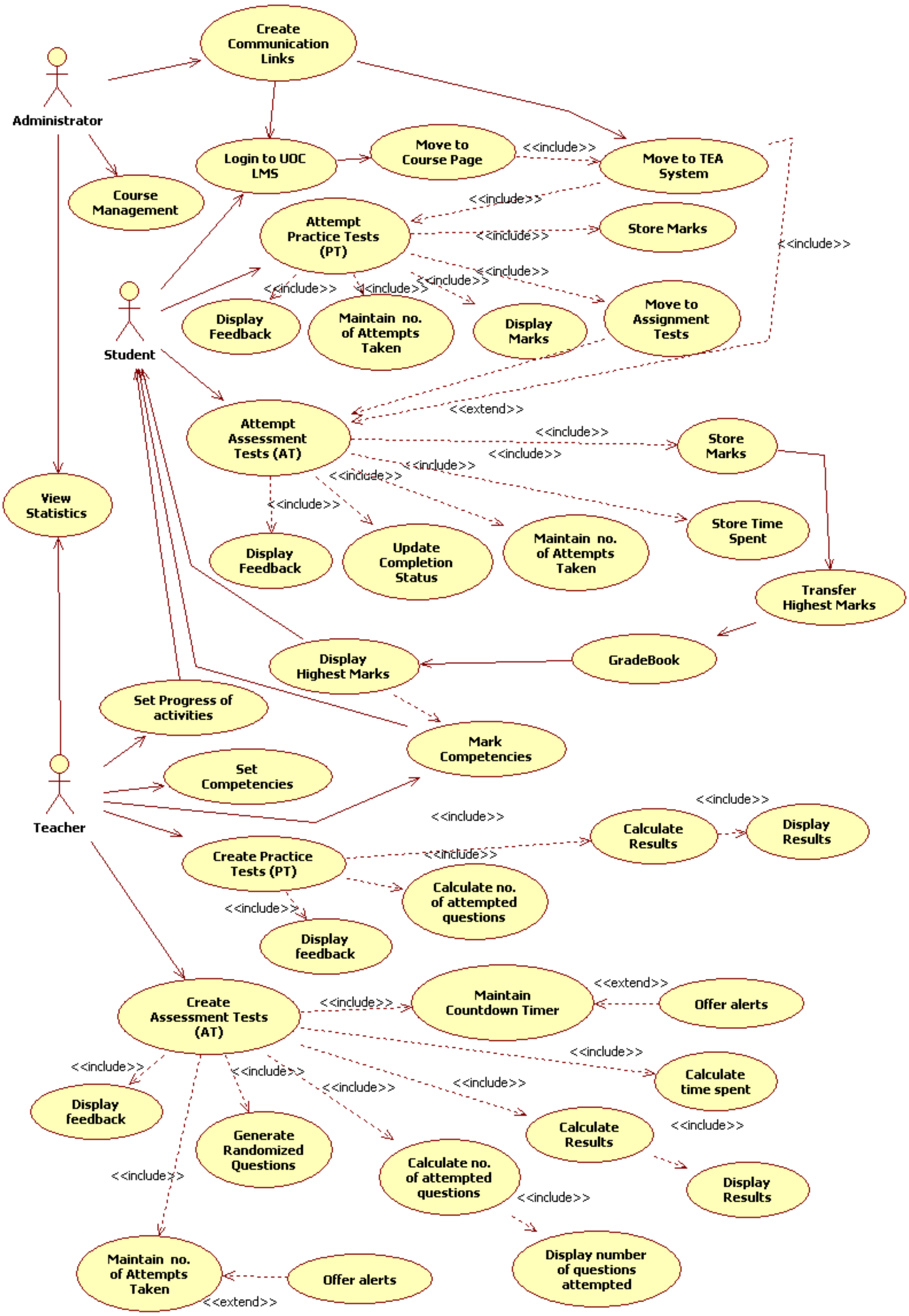


Figure 3.8: Use case diagram for the TEA system

all course management activities such as setting courses and managing modules and components within the system. They also view the statistics of the system to see the performance and the load of the system to check whether there is any overload of data, access permission or upload restrictions.

Teachers are responsible for creating Practice Tests (PT) which include features such as displaying feedback, calculating the number of attempted questions, calculating results and displaying results. Teachers also create Assessment Tests (AT) which include features such as displaying feedback, generating randomized questions, calculating number of attempted questions, maintaining number of attempts, calculating results, maintaining countdown timer and calculating time spent. In the case of maintaining countdown timer, and maintaining number of attempts taken the system should offer alerts of the remaining time and attempts within AT. In addition to that, teachers have to set progress for activities and competencies. Later, based on the marks obtained by students for AT, teachers have to mark the competencies. Teachers also view the statistics to check the performance and participation of students.

Students also login to the UOC LMS and then move to the logic course page and then to the TEA system. Once inside the TEA system, they attempt the PT, which is capable of displaying feedback and marks. At the same time PT, maintain the number of attempts taken along with the marks obtained for each attempt. After students obtained the required pass mark, students are provided with a link to move to the AT through the PT. Then students attempt the AT, which also displays the feedback, completion status, number of attempts taken, time spent and marks obtained within each attempt. The highest mark is transferred to the gradebook, which is also displayed to the students. At the same time, students can view their own progress and the competencies obtained through the respective modules. The use case diagram for the TEA system is shown in Figure 3.8.

3.3.3.2 Sequence Diagram

A sequence diagram is a representation of object interactions arranged in a time sequence. It depicts the users and components involved in the scenario and the sequence of messages exchanged between the objects in order to implement the functionality of the scenario. Sequence diagrams are typically associated with use case realizations in the logical view of the system (Booch et al., 2005).

Sequence diagrams are useful tools to find architectural, interface and logic problems early on in the design process. It helps to validate the architecture, interfaces and logic by allowing to see how the system architecture would handle different basic scenarios and special cases. Sequence diagrams are valuable collaboration tools during design meetings because they allows to discuss the design in concrete terms. This allows to see the interactions between entities, various proposed interactions on paper as when discussing the design (Booch et al., 2005).

Sequence diagram shown in Figure 3.9, depicts the two users, student and teacher, and the components involved in the TEA system and the sequence of messages exchanged between them. Teachers login to the UOC LMS and then move into the TEA system. Then, teachers set the PT and AT. At the same time, they have to do some more activities such as preparing the gradebook, allocate activities to the progress bar and set competencies table. These tasks are completed before the beginning of the course.

Students login to the UOC LMS and then move into the TEA system. First they view objectives and access the learning materials. Then they move to the PT. Soon after the completion of a particular PT, students are offered with feedback. Within the system, attempt counter is updated along with the marks for each attempt. Also the marks obtained for each attempt are displayed to the students. If the marks obtained are higher than or equal to the pass mark (in this case 30), students are directed to the assessment tests. Even in the AT, students are offered with feedback and the completion status is recorded. If the students were not able to obtain a pass mark for AT, they are given the feedback and a link to move back to PT for more practice. At the same time, within the AT, attempt counter is updated along with the marks and time taken for each attempt. Since there is a restriction to complete the AT within an allocated time, based on the time remaining, the AT gives time alerts to the students. Finally when the given attempts are over, the highest mark is transferred to the gradebook and the competency components. The completion status is updated in the progress bar and the progress is displayed to the students.

Based on the highest marks obtained by students for the AT, teachers have to assign the appropriate outcome. Soon after the completion, students are displayed with the outcome they have achieved. At the same time, based on the marks obtained, the teachers mark the competencies achieved by students which is later displayed to the

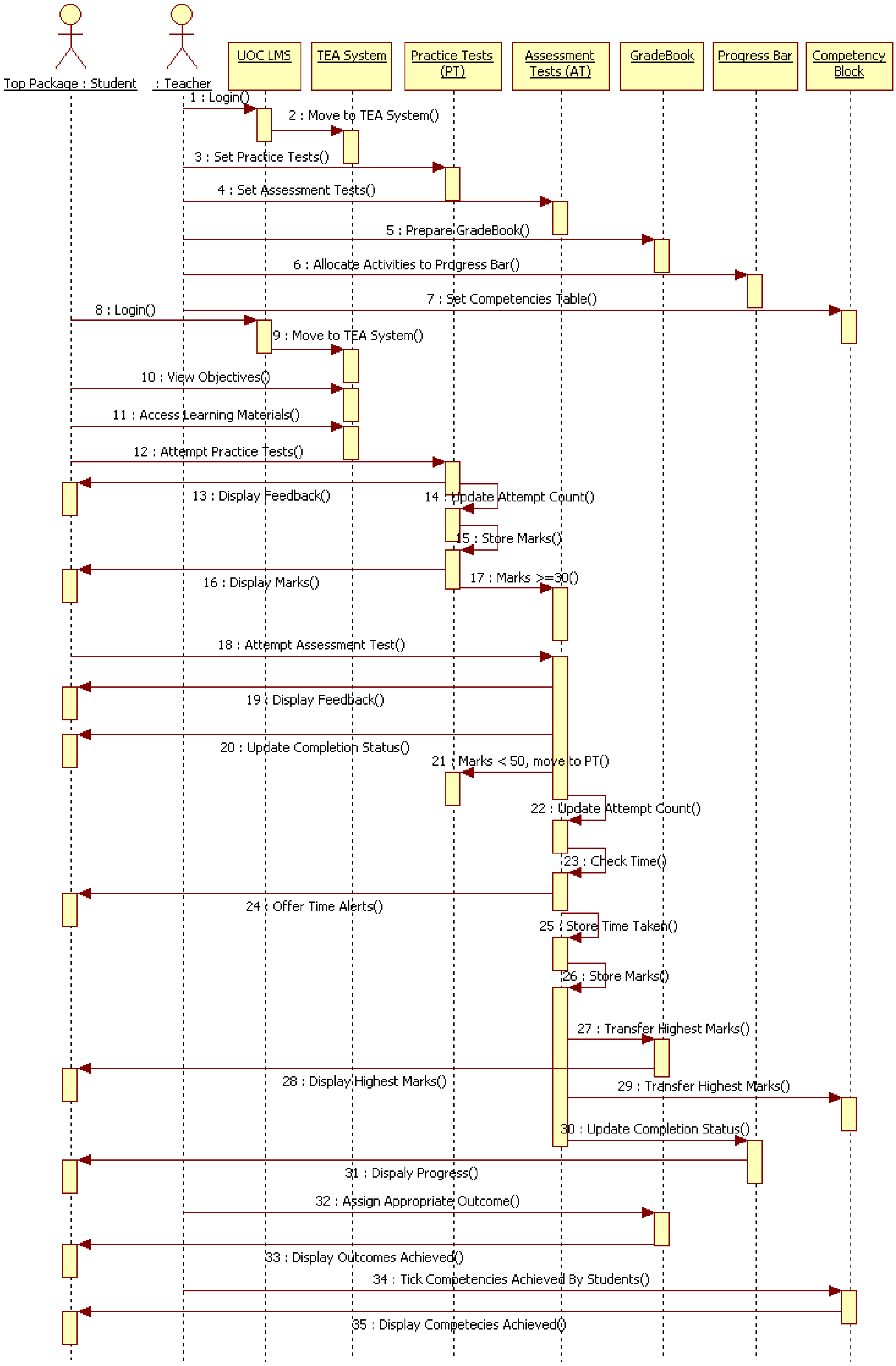


Figure 3.9: Sequence diagram for the TEA system

students. This process with both PT and AT, is repeated for all the given tests. The sequence diagram for the TEA system is shown in Figure 3.9.

3.3.4 Architecture of the System

An interactive information system combines hardware, software, data, procedures and people into a system architecture. The architecture translates the system's logical design into a physical structure that includes hardware, software and processing methods. Furthermore, the architecture of a system can be explained as an abstract description of the entities of a system and their interconnections and interactions (Crawley et al., 2004; Shelly & Rosenblatt, 2011). Under this section, the architecture of the system is explained in terms of tools, modules and standards used.

Students, teachers and administrators need to be connected to the LMS site. From there, they need to automatically connect to the TEA system. For this, after studying the appropriate standards and the discussions with the system experts and administrators, IMS Basic LTI specification was used (IMS GLC, 2013a). This specification can be used to establish, a standard way to integrate rich learning applications with platforms like LMS, portals or other educational environments. Through IMS Basic LTI standard it is possible to provide single sign-on facility which allows users to automatically connect to the technology-enhanced assessment system without the need to login again.

The users connect to the LMS and through the single sign-on facility provided through the IMS Basic LTI standard, they can automatically move to the TEA system. The TEA system is a combination of the Basic TEA system, knowledge assessment module and skill assessment modules. The overall TEA system consists of five main modules; progress bar, competencies module, gradebook, knowledge assessment module, and skill assessment module. Out of these, the first three modules are integrated within the Basic TEA system. Both, the knowledge assessment and skill assessment modules are connected with the Basic TEA system through a link. To make this link, IMS Basic LTI standard is also used. Therefore, users who are logged into the TEA system can automatically move to both knowledge and skill assessment modules. For transferring data such as user data, grades, time spent and attempts, from these modules to the Basic TEA system, OAuth protocol (OAuth, 2013) is used together with IMS Basic LTI. Even though both of these modules are capable of storing its own data by itself, all the data are passed to the Basic TEA database and stored within it, to allow users to easily view data directly from the Basic TEA system. Finally, the data are displayed to the user through the TEA system. In addition to that, using the OAuth protocol together with IMS Basic LTI, data are also passed and displayed in the LMS as well (Hettiarachchi et al., 2012a,b).

The architecture of the technology-enhanced assessment system with the above modules and the connections can be illustrated as in Figure 3.10.

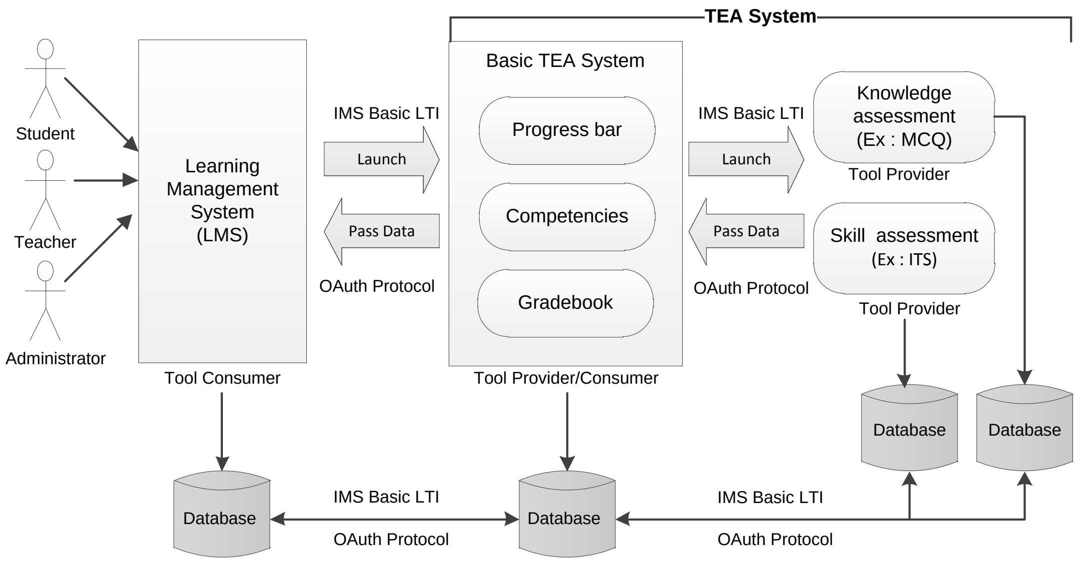


Figure 3.10: Architecture of the system with main components of the TEA system

Decisions about the standard, modules and how it can be connected are described here. The development of the communications and the modules is explained later in the "Section 3.4 - Development of the TEA System" of this chapter.

A brief description of the main modules of the TEA system can be explained as:

Progress bar is a visual guide for helping students to understand their progress with respect to the course. This module is designed to aid students as 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 is used to display grades and outcomes obtained by students for each activity or test. Outcomes are similar to sub-categories of a grade. A grade is an assessment of students performance based on tests, participation, attendance and projects.

Knowledge assessment module provides both practice and assessment tests for students with simple knowledge type of questions such as MCQ, true/false, short answers, and fill in the blanks. Students are provided with marks and feedback for the whole test as well as for each question.

Skill assessment module provides both practice and assessment tests for students with skill type of questions which are dynamic and interactive. In these types of questions, students have to construct the correct answer with the guidance of feedback, errors and hints. The complete test consists of marks and feedback.

3.3.5 User Interface Designs for the Components of the TEA System

The user interfaces were first designed as wireframes for each component of the technology-enhanced assessment system. The wireframes were later used as prototypes for the development of the system. The details and design decisions of the wireframe designs are given under the "Appendix C - User Interface Designs for the Components of the TEA System".

3.3.6 Summary

In this section, the design considerations for the technology-enhanced assessment system were presented. The conceptual design of the system was articulated with the help of user profiles and user scenarios. The conceptual design of the system was comprised of the structure of the system along with the interaction flow diagrams and was illustrated through the use case diagram and the sequence diagram, showing the interaction among users and the components of the system. The architecture of the system was designed and later user interfaces were constructed as wireframe designs for the main components of the system. These were used as prototypes for the development of the system which is explained in the next section ("Section 3.4 - Development of the TEA System").

3.4 Development of the TEA System

The previous sections have explained how the requirements and designs of the technology-enhanced assessment system were established. This section takes the process one step further by presenting the development of the system.

The purpose of this section is to present and discuss the way the system was developed, through firstly deciding upon the development environment. An appraisal of the languages, packages and tools which was used for the development is also presented. The major modules of the system with important code segments are explained together with the final user interface designs. The use of standards, specifications and protocols are discussed. The way the data communication between systems such as LMS and TEA system, and Basic TEA system and Skill Assessment Module is also presented here. The system installation and verification process are also explained to guide anyone who is interested in using the system.

3.4.1 Development Environment

The TEA system consists of 5 main modules such as progress bar, competencies module, gradebook, knowledge assessment module, and skill assessment module as mentioned in the "Section 3.3.4 - Architecture of the system. As two of the main modules, knowledge assessment module and skill assessment module were written in PHP 5 (The PHP Group, 2013), to maintain the consistency among the modules, the complete system was developed based on PHP programming language. The database of the complete system was based on MySQL 5 (Oracle Corporation, 2013). In order to handle the administration of MySQL, phpMyAdmin (phpMyAdmin Development Team, 2013), a free and open source tool was deployed. Apache 2 (The Apache Software Foundation, 2013a) was taken as the web server and for this purpose XAMPP 1.8.1 (Apache Friends, 2013), a free and open source cross-platform web server solution stack package comprising of phpMyAdmin 3.5.2.2, PHP 5.4.7, Apache 2.4.3, and MySQL

5.5.27 was used. The complete TEA system was tested under both Windows and Linux operating systems before deploying the final version. Also the system was tested on web browsers such as Google Chrome, Mozilla Firefox, Safari and Internet Explorer to ensure that it worked without any problems since the students working from home made use of a number of browsers and the system should be open to all the students.

3.4.2 Languages, Tools and Standards Used

In this section, languages, tools and standards used are stated and then the reasons and justifications for choosing them are also explained.

The main focus of this research is to propose a general technology-enhanced assessment system. Therefore, the main objectives while developing the TEA system was to make the system general and to be suitable for use in any subject and organization. Since the system is designed and developed according to the modular architecture as explained in the "Section 3.3.4 - Architecture of the system", it is needed to maintain the security and interoperability while communicating among these modules. Considering these aspects and the key elements of e-learning systems as in the "Section 2.4.1 - E-Learning Systems", it was decided to use Moodle 2.3.2 (Moodle, 2013c) as the core system in terms of services. Moodle provides an added benefit through a layer of services that can be used to securely connect external modules and tools rather than developing a core system from the beginning. Also, Moodle is one of the most popular open source LMS and currently, there are 84,578 registered sites from 236 countries (Moodle, 2013f). A detailed explanation of the Moodle is given in the "Appendix A - Moodle". It is also being developed according to standards and through this, it supports integration of modules. Therefore, it is possible to carry-out seamless communication among these modules without interruptions in a secure and interoperable manner. Also, the educational institutions that do not have their own LMS, can directly use Moodle as their main LMS and then communicate with the other tools in a standardized manner through the proposed methods explained in this research. These considerations and the fact that it already consists of an inbuilt storage repository for questions with a MCQ quiz engine, made Moodle the most favorable candidate.

In this case, the MCQ quiz module of the Moodle was used as the knowledge assessment module. Even though the MCQ quiz module of the Moodle was used in this research, in the general architecture of the TEA system, knowledge assessment is a separate module.

However, the technology-enhanced assessment system goes beyond this basic structure by incorporating rich features such as skill assessment, progress, competencies assessment, grades, and outcomes. Modules for progress, competencies, grades and outcomes were developed separately and integrated into the technology-enhanced assessment system. To maintain the consistency among these modules and the TEA system, they were mainly built using PHP.

As the skill assessment module, Logic course ITS tool of the UOC (Huertas et al., 2011) was used. This tool was also developed using PHP. One of the reasons for using this tool was that students were already familiar with it. In addition to that, the tool itself provided error messages and hints to students based on the selection of rules. These features were useful for the skill assessment but however, it was necessary to adapt the tool from an ITS into an e-assessment tool. Therefore, features such as; creating a large database of questions with detailed feedback, offering questions in a randomized order and having a timer for a particular quiz was included into the ITS tool. This tool was also developed using PHP programming language. MySQL was used as the common database tool for the complete system.

Additionally, IMS Basic LTI specification was used for the communication between the LMS and the TEA system as well as between the Basic TEA system and the ITS tool, as explained in the "Section 3.3.4 - Architecture of the system". In order to transfer data of students such as; grades, time, attempts taken and completed date, OAuth protocol (OAuth, 2013) was used together with the IMS Basic LTI specification. These are explained in detail in the following sections.

3.4.3 Major Modules and Codes

This section summarises the modules used in the technology-enhanced assessment system. According to the system architecture described in the previous "Section 3.3 - Design of the TEA System", the development of the individual modules are explained. Since IMS Basic LTI was selected as the main specification for communicating between the systems, a detailed introduction to this specification is also presented. Then the way the communications were carried-out between the LMS and the TEA system as well as between the Basic TEA system and the ITS tool is described in detail.

Before coming up with the goal to design and develop the technology-enhanced assessment system, several tools and projects were studied as mentioned in the "Section 2.4.4 E-Assessment Tools for Logic". These tools were divided into two categories such as e-assessment tools and intelligent tutoring tools for logic. However, by comparing the representative tools that can be used for learning and assessing logic, the literature did not provide a general tool which can be used to conduct both knowledge and skill assessment.

By considering all of the above and the main aim of this research, to make the TEA system general, as mentioned in the previous section the existing Logic ITS tool of the UOC for skill assessment and the MCQ quiz module of the Moodle system for knowledge assessment was selected. As for the learning management system, the UOC LMS was used.

The final architecture of the TEA system was derived from the architecture presented under the "Section 3.3.4 - Architecture of the System" (Figure 3.10). Only one modification was made to the initial architecture illustrated in Figure 3.10. When developing the TEA system, the knowledge assessment module was integrated within the Basic TEA system. The reason for this is that the TEA system made use of the Moodle which already consisted of a rich MCQ quiz module. Other than this, no other changes were made to the initial architecture. The architecture used for the development of the final TEA system is shown in Figure 3.11.

A detailed description of the modules with respect to the development, standards and specifications used for communications, and the way the communications were carried out between the LMS and the TEA system as well as between the Basic TEA system the ITS are explained in the consecutive sections.

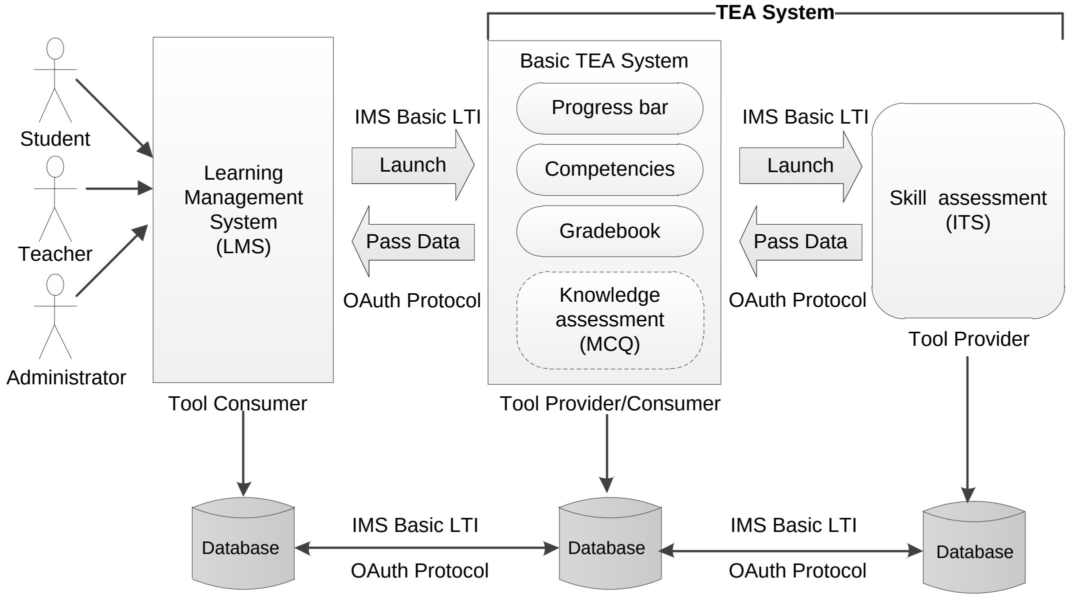


Figure 3.11: Final architecture of the system with main modules of the TEA system

3.4.3.1 IMS Basic Learning Tool Interoperability Specification

The communications between the LMS and the TEA system as well as the Basic TEA system and the ITS were carried-out using the IMS Basic Learning Tool Interoperability (IMS Basic LTI) specification and the OAuth protocol. An overview of this specification and the message signing using the OAuth protocol are explained under this section.

IMS Basic LTI is a subset or profile of the full IMS Learning Tool Interoperability (LTI) v1.0 specification. IMS is developing Learning Tools Interoperability (IMS LTI) to allow remote tools and content to be integrated into an LMS.

In IMS Basic LTI, what is traditionally known as the LMS is referred to as the "Tool Consumer" (TC) as it "consumes" the tool. The external tool or content is called the "Tool Provider" (TP) as it "provides" the tool for use in the Tool Consumer. As an example, Tool Providers might include an externally hosted testing system or a server that contains externally hosted premium content (IMS GLC, 2013d). This specification uses the OAuth protocol (OAuth, 2013) to secure its message interactions between the tool consumer and tool provider. OAuth requires a key and a shared secret to sign messages. The key is transmitted with each message, as well as an OAuth-generated signature based on the key. The tool provider looks up the secret based on the provided key and re-computes the signature and compares the recomputed signature with the transmitted signature to verify the sender's credentials.

According to IMS (IMS GLC, 2013d), as a best practice, the tool provider should isolate data based on the key. The tool provider must decide exactly how the key is used to isolate data. For example, the tool provider might maintain a table which maps multiple keys into single data storage. Otherwise, the tool provider might arrange to use the same key repeatedly in all cases where data belong to the same data storage. The tool consumer can make choices as to how it manages credentials (keys and secrets) within its system. Basic LTI specification consists of three patterns for the credentials. Credentials associated with these three patterns along with the Basic LTI message signing is explained in the "Appendix D - Major Codes of the Development".

3.4.3.2 Communication between the UOC LMS and the TEA system

To make a communication link between the UOC LMS and the TEA system, the URL associated with the particular course of the TEA system was obtained. This URL is known as the "Launch URL" as is it used in the UOC LMS to launch a connection and move to the TEA system. After the establishment of this connection, students who were logged into the LMS could automatically login to the TEA system through the single sign-on facility. The steps followed for this communication along with the screen captures are given in the "Appendix D - Major codes of the development".

3.4.3.3 Communication between the Basic TEA System and the Skill assessment module

It was needed to carry-out the communication between the Basic TEA system and the skill assessment module, the Logic ITS tool. For this purpose, a special standardized plug-in entitled "ITS URL" was developed. This was also developed based on IMS Basic LTI specification together with OAuth Protocol. Through the aid of this plug-in, it was possible to easily connect the ITS tool to the Basic TEA system. As a result of it, the students who were logged into the Basic TEA system could automatically move to the ITS tool through the single sign-on facility without the need to login again. Also, through this plug-in it was possible to transfer student data, such as highest marks of the students, time spent and no of attempts taken, from the ITS to the Basic TEA system after the completion of a particular test. The plug-in was developed in a way that any tool can be connected with the Basic TEA system instead of the ITS tool as shown in Figure 3.12.

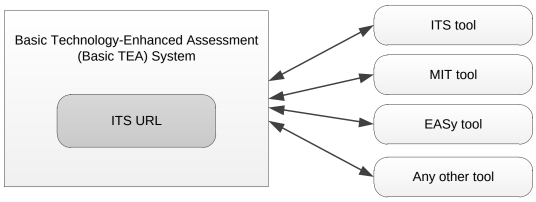


Figure 3.12: Communication between Basic TEA system and any other tool through "ITS URL" plug-in

The steps followed for this communication between the Basic TEA system and the ITS tool along with the screen captures are given in the "Appendix D - Major Codes of the Development".

3.4.3.4 Skill Assessment Module

After carrying-out the communication between the TEA system and the skill assessment module, for the topics which consist of skill assessment tests, students were provided with a link to the skill assessment module. Using this link, students could move to the skill assessment module (ITS of the Logic course) as shown in Figure 3.13.

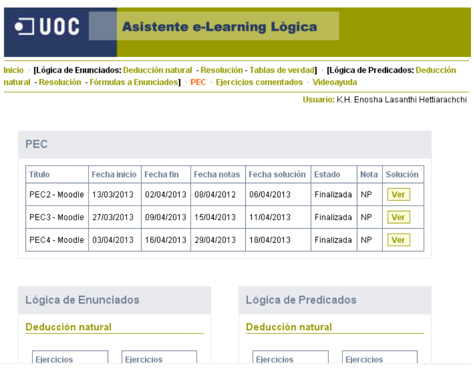


Figure 3.13: Skill assessment module - ITS of the Logic course

Students had the possibility to practice as well as attempt the Assessment Tests (AT). Since there was a time schedule to activate each AT, students were directed only to the corresponding AT. There was a time limit imposed on the students to complete the AT and after the particular time period was over, students could not attempt it again and only possible activity was to view the results and the correct solutions. Soon after completion of the AT, results were transferred back to the technology-enhanced assessment system. In this case, the highest mark obtained was stored in the technology-enhanced assessment system. With this module, students had to complete the assessment within 1 hour and 30 minutes. The questions were provided randomly from the question bank and students were given only 3 attempts to obtain the pass mark. The total marks allocated for the assessment was 80% and the way the AT was displayed to the students is illustrated as in Figure 3.14.

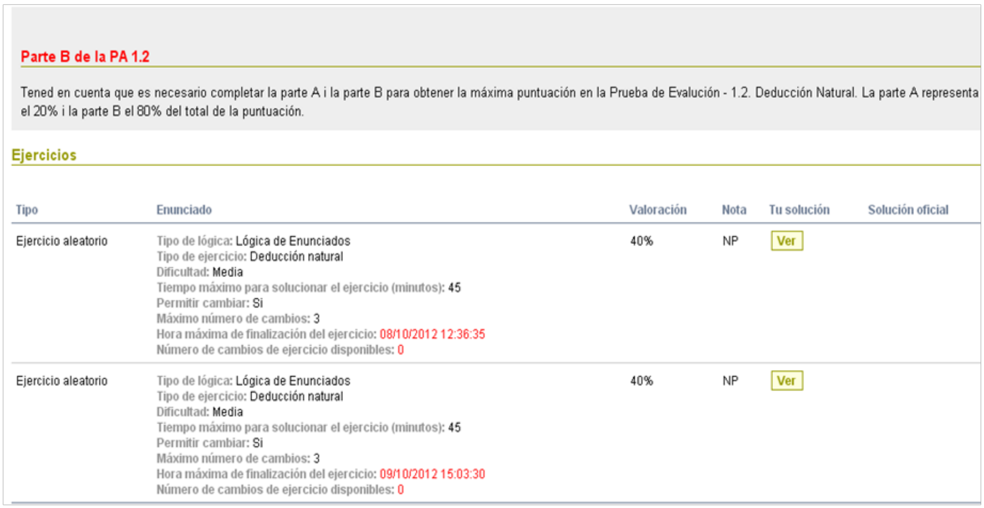


Figure 3.14: View of Assessment Test - Skill questions

For each question students were provided with feedback, error messages and hints in a step by step manner while constructing the answer for a given question. This guidance was provided in the case of students selecting an incorrect formula, rule or scope. This can be displayed as in Figure 3.15.

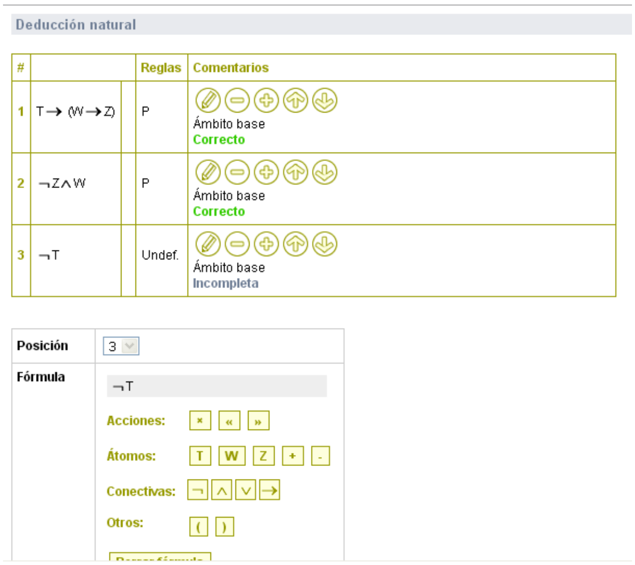
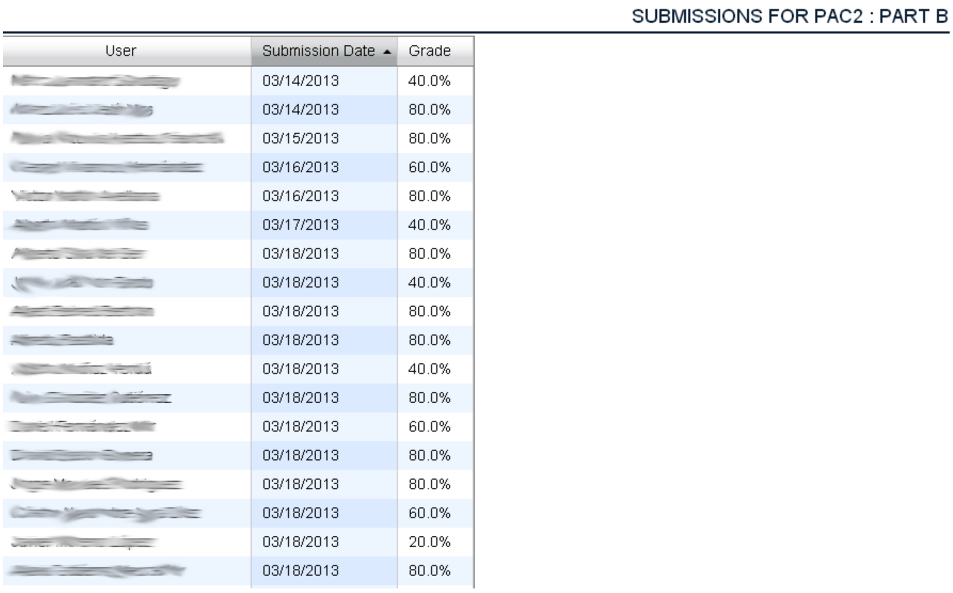


Figure 3.15: Skill questions with hints, feedback and error messages

After completion of the tests, the highest grades were transferred from the skill assessment module to the Basic TEA system and it can be displayed as shown Figure 3.16.



SUBMISSIONS FOR PAC2 : PART B

User	Submission Date	Grade
[illegible]	03/14/2013	40.0%
[illegible]	03/14/2013	80.0%
[illegible]	03/15/2013	80.0%
[illegible]	03/16/2013	60.0%
[illegible]	03/16/2013	80.0%
[illegible]	03/17/2013	40.0%
[illegible]	03/18/2013	80.0%
[illegible]	03/18/2013	40.0%
[illegible]	03/18/2013	80.0%
[illegible]	03/18/2013	80.0%
[illegible]	03/18/2013	40.0%
[illegible]	03/18/2013	80.0%
[illegible]	03/18/2013	60.0%
[illegible]	03/18/2013	80.0%
[illegible]	03/18/2013	80.0%
[illegible]	03/18/2013	60.0%
[illegible]	03/18/2013	20.0%
[illegible]	03/18/2013	80.0%

Figure 3.16: Grades transferred from the skill assessment module to the Basic TEA system

3.4.3.5 Knowledge Assessment Module

This module was used for both practice and assessment tests. However, for assessment tests, in addition to the MCQs, questions from the skill assessment module were also offered. To move from Practice Test (PT) to Assessment Tests (AT), students had to obtain a given pass mark.

- **Practice Test (PT)** First students are provided with instructions such as the pass mark that they have to obtain in order to move to AT as shown in Figure 3.17.

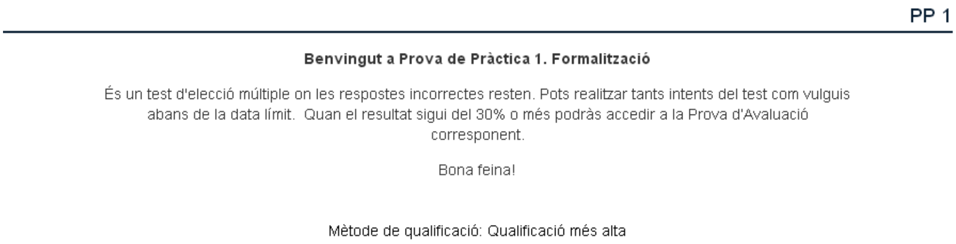
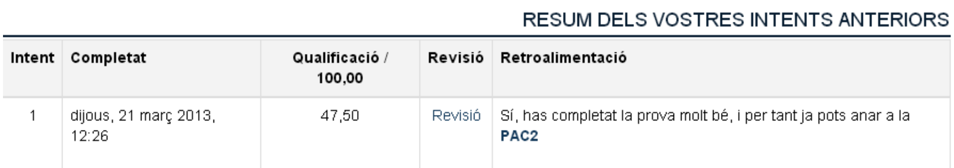


Figure 3.17: Instructions provided for Practice Test (PT)

For PT, students were provided with an unlimited number of attempts without any time restriction on an attempt. The number of questions provided within each PT depended on the particular section or topic of the subject. Questions may have one or more correct answers. Students were penalized with minus marks for giving the wrong answers. After completion of the test, students were provided with an overall detailed feedback as shown in Figure 3.18.



RESUM DELS VOSTRES INTENTS ANTERIORS

Intent	Completat	Qualificació / 100,00	Revisió	Retroalimentació
1	dijous, 21 març 2013, 12:26	47,50	Revisió	Sí, has completat la prova molt bé, i per tant ja pots anar a la **PAC2**

Figure 3.18: Marks with the overall detailed feedback

There was an option for students to review the answers they had marked. The answers were colour coded such as correct answers in green, partially correct answers in yellow and incorrect answers in red. For each answer, students were provided with feedback. If the answer was wrong students were asked to refer to a particular section of the learning material. In addition to this, students were provided with marks obtained for each question as shown in Figure 3.19.

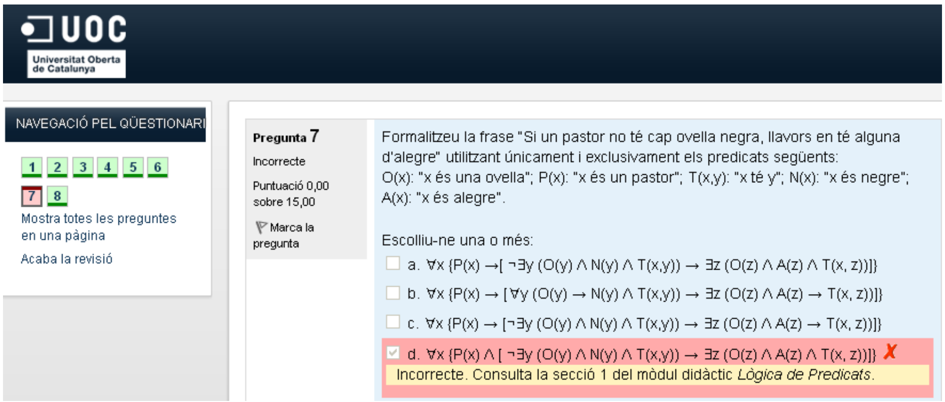
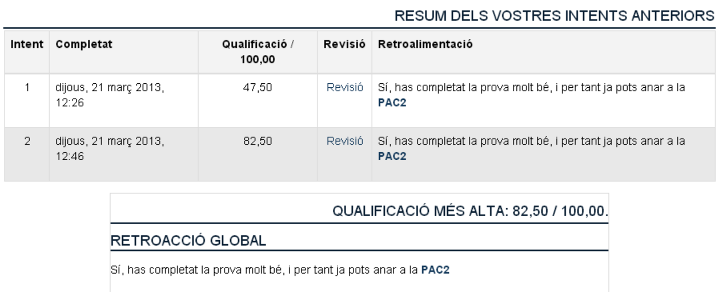


Figure 3.19: Review of questions with feedback and marks

Finally, after completion of all the attempts the highest mark obtained was taken as the final mark. This can be displayed as shown in Figure 3.20.


RESUM DELS VOSTRES INTENTS ANTERIORS

Intent	Completat	Qualificació / 100,00	Revisió	Retroalimentació
1	dijous, 21 març 2013, 12:26	47,50	Revisió	Sí, has completat la prova molt bé, i per tant ja pots anar a la PAC2
2	dijous, 21 març 2013, 12:46	82,50	Revisió	Sí, has completat la prova molt bé, i per tant ja pots anar a la PAC2

QUALIFICACIÓ MÉS ALTA: 82,50 / 100,00.

RETROACCIÓ GLOBAL

Sí, has completat la prova molt bé, i per tant ja pots anar a la PAC2

Figure 3.20: Display of marks obtained with feedback and the highest qualification

After obtaining the minimum pass mark, students were allowed to move to Assessment Test (AT). Before obtaining the required pass marks, the AT were not accessible to students. AT was disabled and grayed with a message saying that it is needed to obtain a pass mark for PT in order to attempt AT.

- **Assessment Test (AT)**

  All the sections of the Logic course had both knowledge and skill type of questions except for “Formalization” in “Propositional Logic”, “Formalization” in “Predicate Logic” and “Semantics and Sets” in Predicate Logic”

  AT consisted of two parts where Part A was comprised of MCQ whereas Part B consisted of skill questions offered through the ITS. Under AT, before starting the assessment tests, students were provided with some instructions such as, it is essential to complete both parts of the knowledge and skills questions in order to obtain the highest score for that particular section. Also the marks allocated for each part such as 20% marks for Part A and 80% for Part B were also shown. Students were also advised to move to qualification (grades) to see the total score obtained for that particular section of the subject.

  AT consisted of two parts as mentioned before and this was only visible if students had obtained the required pass mark for the relevant PT. Part A consisted of MCQ which have to be completed within a given time and restricted number of attempts. The questions were selected in a randomized manner through a question bank to discourage cheating. Also minus marks were given for incorrect answers to discourage guessing and random answering. Also a deadline was imposed on AT and students were obliged to complete the test before the required date. Same as with PT, students were provided with a detailed feedback after their completion. In PT, soon after the completion of the tests, students were displayed with the correct/incorrect answers as well as the reasons for the incorrect answers. However, in AT, this option was available only after the completion of the allocated deadline for AT. This restriction was imposed to prevent students from writing down the correct answers after the completion of a particular attempt. The following Figure 3.21 shows the feedback and data given after the completion of Part A. It shows the feedback for each attempt as well as the overall attempt which contains the highest mark obtained for the test. Revision link can be used to view the answers after the particular deadline was over.

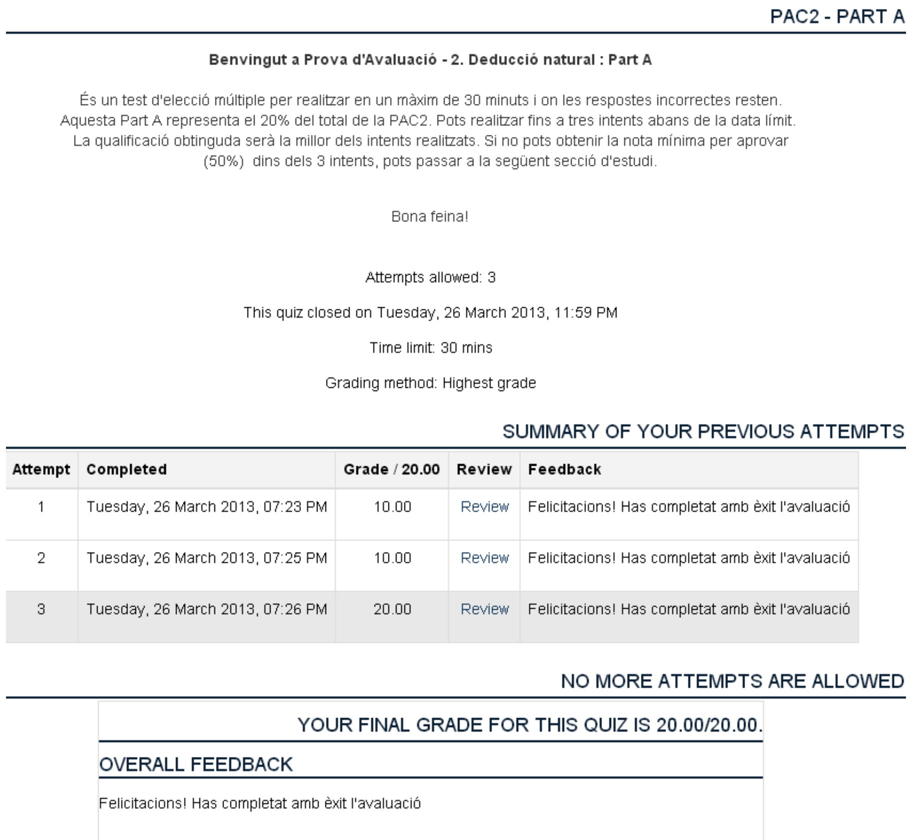


Figure 3.21: Feedback and data given after the completion of Part A

3.4.3.6 Progress Bar

The progress bar is a visual guide for helping students to understand their progress with respect to their course. This is a pre-defined module which was customized to meet the requirements (Moodle, 2013b). The progress bar consists of features such as a visual display of tests a student is supposed to interact within a course. Colour coded blocks were used to aid students to quickly view what they had or had not completed. It also gave an indication about the progress of the rest of the classroom by using a pointer entitled "NOW". At the same time, it indicates the overall progress percentage with respect to the tests completed. Students had the possibility to obtain more info about each test through mouse over action. The progress bar is illustrated in Figure 3.22 below.

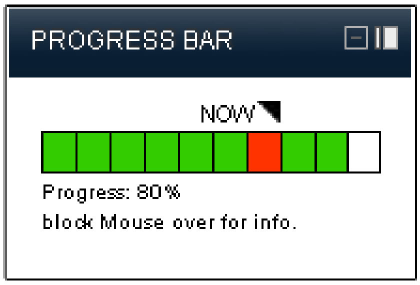


Figure 3.22: Progress Bar

With this tool the teacher also had the facility to select which pre-existing tests are to be included in the progress bar and when they should be completed. Also teachers can view the progress of all students through the overview page as shown in Figure 3.23.

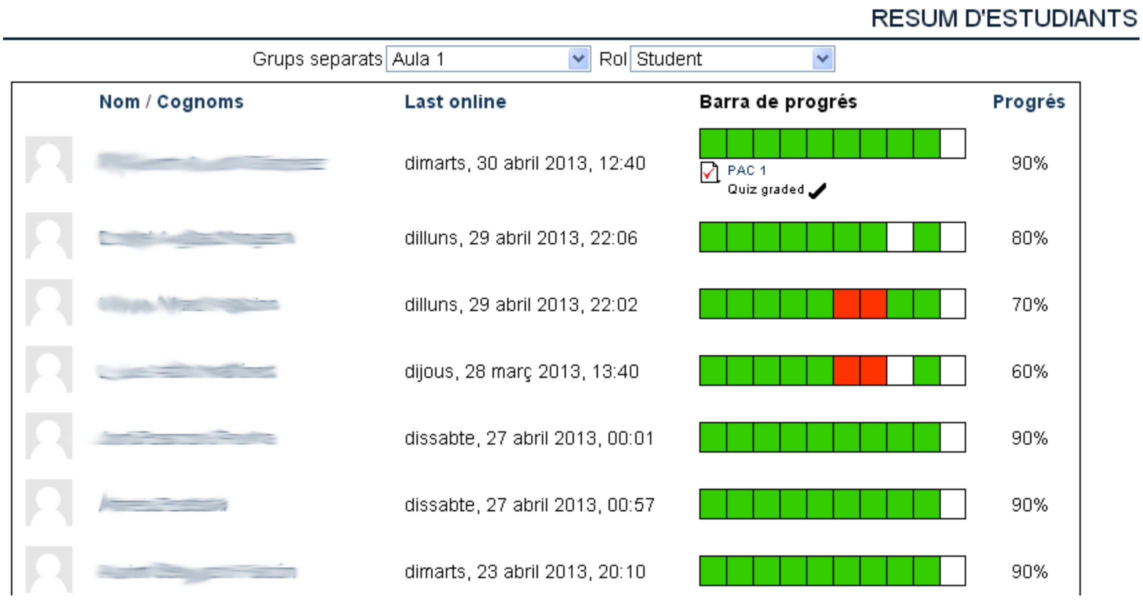


Figure 3.23: Overall progress of all the students

3.4.3.7 Competencies Module

This was also a pre-defined module which was modified according to the requirements (Moodle, 2013a). Since this is a prototype, existing modules were used instead of developing new modules. The goal of this block was to evaluate students' competencies based on the marks they have obtained for a particular topic of the subject. Therefore, a taxonomy was required which consisted of the competencies that should be achieved by students. This was done through an XML file which was uploaded to the competency module using "Module configuration" tab. Overall the tool was developed using PHP. The block was developed to store only the essential information needed for this research project. Therefore, only few tabs such as "Subjects & topics", "Assign activities", "Overview of competencies" and "Assessment of competencies" were needed as shown in Figure 3.24.

Figure 3.24: Overview of Competencies Module

"Subjects & topics" tab allows selecting the appropriate subject and the topics based on the subjects available through the uploaded XML file. Here it was also necessary to add the new activity types, quizzes and tests from the ITS tool. Therefore, a link was added to display both quizzes and the tests from the ITS tool which directed teachers to a page consisting of marks. In the case of test completed using the ITS tool, these marks were passed from the ITS tool to the technology-enhanced assessment system. Also some developments were made in order to display the marks of the tests from the ITS tool, when teachers use the mouseover facility. Additionally, some changes were made to the look and feel of the module to suite the requirements.

After carrying out the required modifications and after the selection of the required subject, the related competencies were displayed in the "Assign activities" tab. Then teachers had to select appropriate competencies related to each activity by marking a tick in the appropriate box. Here the activities were displayed horizontally and competencies were displayed vertically as a grid.

In the “Overview of competencies” tab, a table of competencies and students of the course was generated. The names of the students were displayed in a row and the marks they had obtained for each activity were visible by hovering over the given icon. The attainment of a competency was assessed on the level of individual activities. Based on the marks, if the students had acquired the competencies, the teacher could mark a tick next to the competence. For all students, the competencies can be ticked off as a whole. The Overview of competencies tab can be displayed as shown in Figure 3.25.

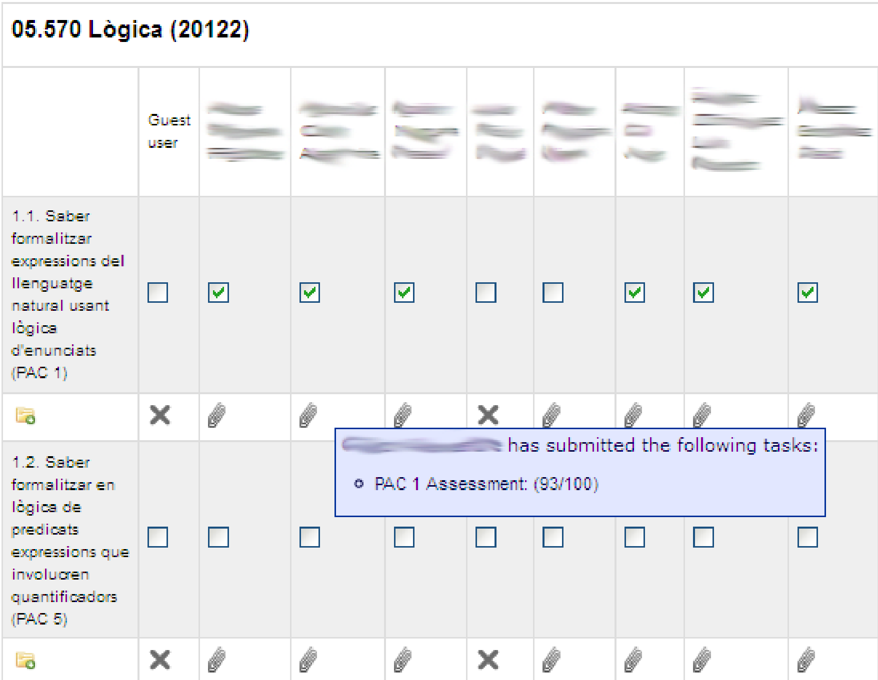


Figure 3.25: Overview of Competencies Tab

In the competency module, the tabs including “Module configuration”, “Subjects & topics”, “Assign activities” and “Overview of competencies” were only visible to teachers and administrators. Only tab that was visible to students was the “Assessment of competencies” tab.

Then finally, in the “Assessment of competencies”, students could view the competencies they had achieved as a progress bar as well as a list of tables. The assessment of competencies for a particular student can be displayed as shown in Figure 3.26.

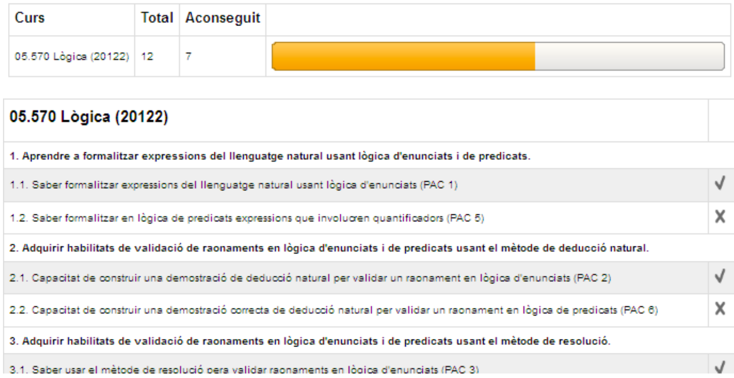
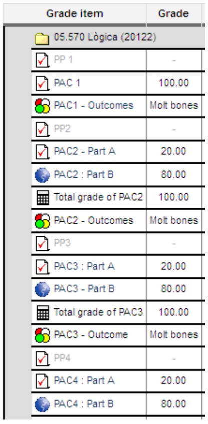


Figure 3.26: Assessment of competencies for a particular student

3.4.3.8 Gradebook

Gradebook was used to display grades and outcomes obtained by students for each activity or test. Outcomes are similar to sub components of a grade. A grade is an assessment of overall performance that may include tests, participation, attendance and projects. Outcomes assess specific levels of knowledge through a series of statements, which may be coded with numbers or letters. Therefore, outcomes were predefined based on a range of marks. Thus an overall grade could be given for a course, along with statements about specific competencies in the form of outcomes. Students were displayed with their own grade and outcome soon after the completion of a particular assessment test which allowed them to understand their performance. Teachers had the possibility to see the overall grades and the outcomes of all the students with respect to each practice test and assessment test along with the marks for each attempt. This helped teachers to understand whether the learning process of students had improved through the attempts as well as the overall performance for a particular test.

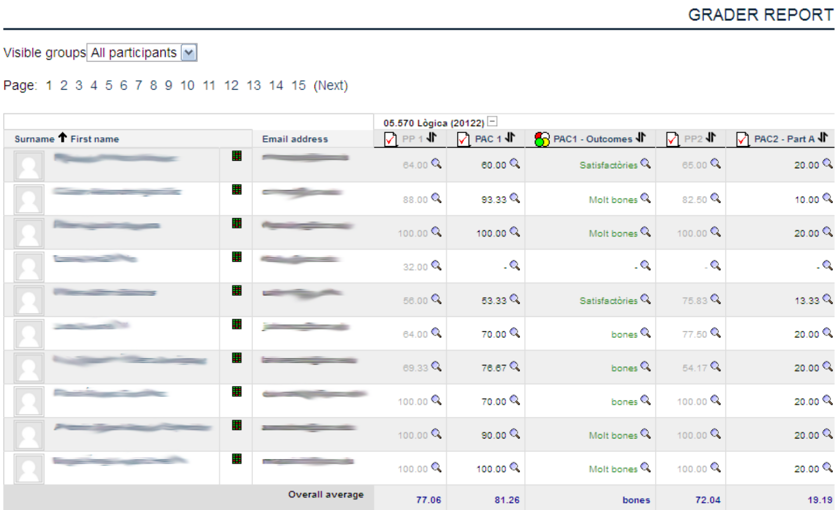
Students could view the marks and outcomes they had obtained for each activity using the qualifications section available with the technology-enhanced assessment system as shown in Figure 3.27.



Grade item	Grade
05.570 Lògica (20122)	
PP 1	-
PAC 1	100.00
PAC1 - Outcomes	Molt bones
PP2	-
PAC2 - Part A	20.00
PAC2 : Part B	80.00
Total grade of PAC2	100.00
PAC2 - Outcomes	Molt bones
PP3	-
PAC3 : Part A	20.00
PAC3 - Part B	80.00
Total grade of PAC3	100.00
PAC3 - Outcome	Molt bones
PP4	-
PAC4 : Part A	20.00
PAC4 : Part B	80.00

Figure 3.27: Marks and outcomes of a particular student

When it comes to teachers, they had the possibility to view marks of all the students as shown in Figure 3.28.



GRADER REPORT

Visible groups All participants

Page: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 (Next)

Surname ↑ First name	Email address	05.570 Lògica (20122) PP 1	PAC 1	PAC1 - Outcomes	PP2	PAC2 - Part A
		64.00	60.00	Satisfactòries	65.00	20.00
		88.00	93.33	Molt bones	82.50	10.00
		100.00	100.00	Molt bones	100.00	20.00
		32.00	-	-	-	-
		56.00	53.33	Satisfactòries	75.83	13.33
		64.00	70.00	bones	77.50	20.00
		69.33	76.67	bones	54.17	20.00
		100.00	70.00	bones	100.00	20.00
		100.00	90.00	Molt bones	100.00	20.00
		100.00	100.00	Molt bones	100.00	20.00
	Overall average	77.06	81.26	bones	72.04	19.19

Figure 3.28: Teachers view of marks and qualifications

Also from this view, teachers could assign outcomes to each student for the respective activities from a drop-down list.

In addition to the modules mentioned above, the TEA system was capable of producing statistics and reports as explained below.

Statistics

For each test or activity the technology-enhanced assessment system was able to store statistics in the form of data and graphs as shown in Figure 3.29.

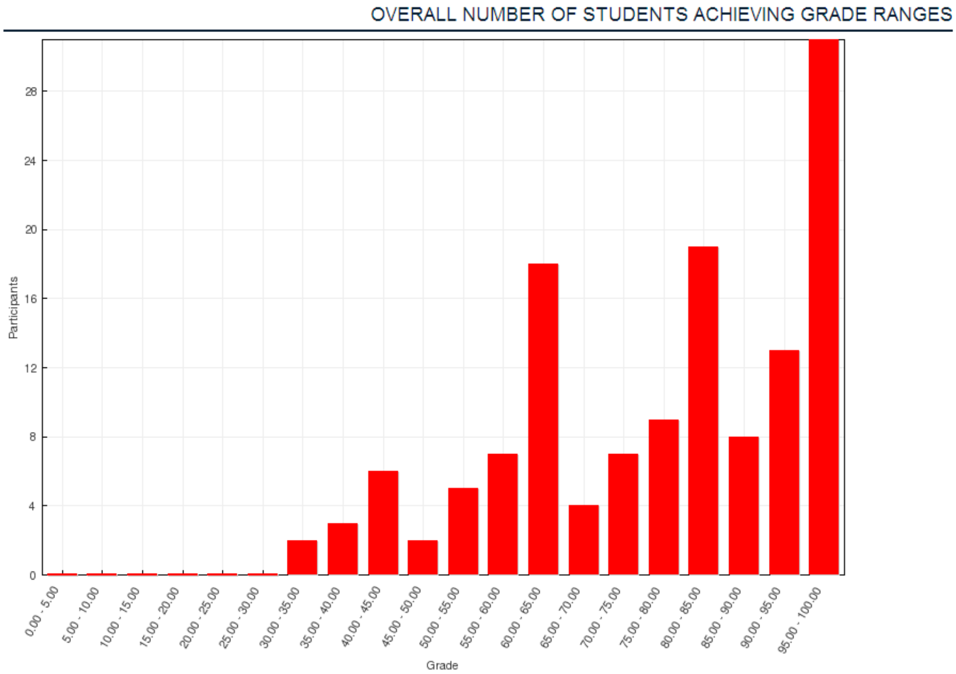


Figure 3.29: Graph showing the qualifications achieved by students for a particular test

Reports

The system was able to produce some reports as described below:

- **Records**

  As records, the system was able to produce reports of individual students or whole groups of students in a particular classroom. Additionally these records could be filtered for a particular event (such as a test), particular date or a particular action (such as view, edit, update or delete). It was also possible to view records online as a page or download it as a report.

- **Live logs**

  This included a live report of activities carried-out recently such as within the past hour.

- **Activity Report**

  An activity report contained the number of views for each activity along with the last access date.

- **Course Participation**

  A participation report for a particular activity could be generated for any duration and any action such as views or posts. Here it was possible to select a particular number of students and send a common message.

3.4.4 Collection of Students' Real-Time Data

The real time data were produced during the students' interaction with the complete system. All the actions that students performed with the components were recorded and teachers and administrators had the possibility to view them as reports. These include students' access records, live logs, activity reports and course reports as mentioned under the "reports" section. Additionally the marks obtained for the tests were stored within each modules and gradebook within real-time. Also the progress bar was updated on a real-time basis.

3.4.5 System Installation

The system installation is briefly explained here to benefit anyone who is interested in using the system for their own use or to customize the system for their own institution.

It is necessary to install Apache, PHP and MySQL where the Moodle 2.3.2 or higher version is installed. Then, it is needed to add the zip folders for "progress bar" and "competency module" in the "block" folder and "ITS URL" in the "mod" folder. Then, login to the system using the administrator credentials and then move to "notifications" selection under "site administration". It is also necessary to install the ITS tool or any other tool and then add the code files and appropriate changes as mentioned before under *" Section 3.4.3.2 Communication between the UOC LMS and the TEA System" and "Section 3.4.3.3 Communication between the Basic TEA System and the Skill assessment module"*. Then test whether each module works correctly as expected. It is also needed to check whether the communication between the systems work correctly without errors and check whether it is possible to pass data between the systems.

3.4.6 System Verification

In order to demonstrate that the technology-enhanced assessment system works correctly, the completed system was shown to the teachers explaining the functionalities of the system and the way it works. After modifying the system with the findings in an iterative way, the system was tested again and was applied into the real online environment. The additional functionalities that should be integrated into the system in the future were also discussed. This is explained in the "Chapter 4 - Evaluation".

3.4.7 Summary

This section outlined the way the system was produced with the languages, tools and standards used. Some of the major modules and codes of the system were also illustrated with their functionalities and how they were developed with their interfaces. Also the communications carried-out between systems according to standards were also explained. The system installation was also presented here. System verification was carried-out in a real online environment and is explained in the "Chapter 4 - Evaluation" under testing and validation.

4

Evaluation

Evaluation is the forth step related to the design and creation strategy used in this research project. This examines the developed artefact and looks for an assessment of its worth and deviations from expectations (Oates, 2006). Evaluation is the process for determining the quality and the performance of the system. An effective evaluation process includes the use of reliable data for conducting the evaluation, the establishment of predefined standards against performance to be measured, and the monitoring of product or performance outcomes (Rossi et al., 2004). As Oates (2006) stated, the evaluation can lead to conclusions about the design process as well as the design product, and may suggest that further modifications to either or both are needed.

This chapter presents the evaluation of the research with respect to testing and validation of the system.

During testing, the technology-enhanced assessment system is tested to examine that the modules and the complete system works correctly without any errors. First, the testing is explained with the different types of testing and the way it is carried-out under the testing methodology and plan. The errors identified and corrected are explained. Also, some of the research questions are addressed in this section.

During validation, the technology-enhanced assessment system together with the proposed formative e-assessment model is applied in the real context to verify that it satisfies user needs and requirements as stated in the "Section 3.1.4 - Summary of Requirements Analysis" of the "Chapter 3 - Design and Development of the Technology-Enhanced Assessment (TEA) System". First, the validation of the system is explained with the validation methodology and the plan followed. The different pilot studies carried-out are explained with data analysis techniques, evaluation of results and conclusions. Finally, some of the research questions addressed are also stated.

The time plan of the design, development and evaluation stages of the system can be displayed as in Figure 4.1.

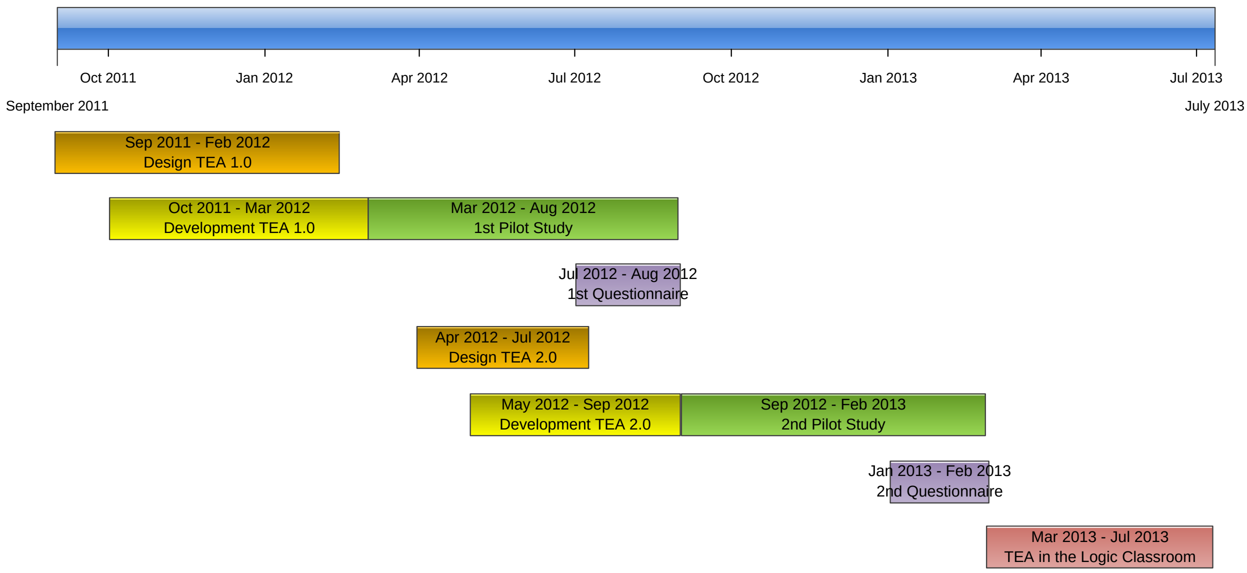


Figure 4.1: The time plan of the design, development and evaluation stages of the system

4.1 Testing

Testing is an investigation conducted to provide information about the quality of the product or service under test (Kaner, 2006). It can also be stated as the process of confirming that the IT artefact works correctly while meeting the needs of the users and requirements that guided its design and development. According to Kaner et al. (1999), testing is recognized as an important part of quality assurance process which proceeds in parallel with the design and development of the system.

4.1.1 Testing Methodology and Plan

For testing the technology-enhanced assessment system, a testing methodology and a test plan was developed in parallel with the system design and development process. Testing methodology is a set of procedures used to perform testing of the system.

Therefore, testing proceeds through a number of steps which are carried-out under three main tests such as unit, integration, and system testing (Hawryszkiewycz, 2002).

Test plan ensures that a product or system meets its design specifications and other requirements. This is developed in parallel with the system design and development process and includes items to be tested, features to be tested, approach, and item pass/fail criteria. For testing these features, test cases are used. Test cases are a set of actions executed to verify that a particular feature or functionality of the system works correctly as expected.

According to the testing methodology, the unit testing is carried-out after the development of the modules. Once the individual modules are tested, the next step is to check whether they could be combined with the main system. This is known as integration testing. The goal is to determine whether the interfaces between modules work correctly. Then the entire system was tested under system testing to verify that it meets the stated requirements. These testings are performed in an iterative manner while fixing the bugs, errors that might have occurred during different stages of the testing process. To carry-out these tests, it is important to design test cases. These are designed in parallel with the design and development of the system (Hawryszkiewycz, 2002). The testing methodology with different types of testing is illustrated as in Figure 4.2.

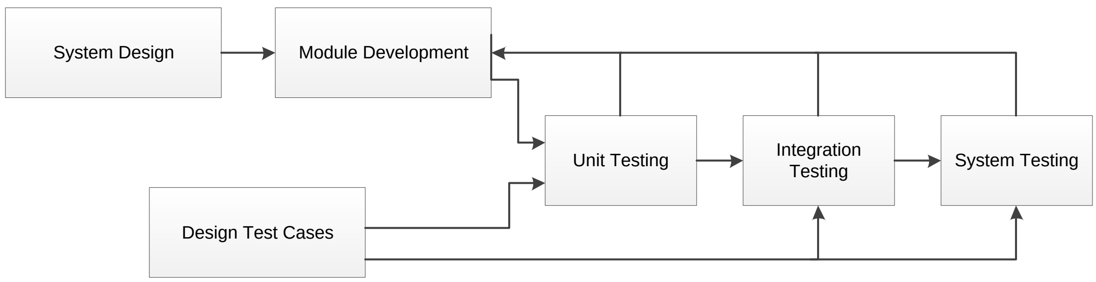


Figure 4.2: Testing Methodology

Testing methodology is comprised of three main tests such as unit, integration and system testing. In addition to that, user acceptance testing was carried-out with the real users of the Logic course as pilot studies. This is explained under the "Section 4.2 Evaluation" of this chapter. Also, since this research project was designed and developed according to user centred design process, usability testing was carried-out with the real users of the system. This is an irreplaceable usability practice, since it gives direct input on how real users use the system (Goodwin, 2009; Nielsen, 1994).

The way these testings was performed can be explained as below.

Unit Testing

Unit testing is a method by which individual units of source code, sets of one or more program modules together with associated control data, usage procedures, and operating procedures, are tested to determine if they are fit for use. This is carried-out during and after the development of the modules.

Under this, individual modules such as knowledge assessment module, skill assessment module, progress bar, competencies module and gradebook were tested separately to check whether each part was able to perform well without any code errors.

Integration Testing

Integration testing occurs after the unit testing and under this, individual software modules are combined and tested as a group. The purpose of integration testing is to verify functional, performance, and reliability requirements placed on the major design of the system.

Under this, the integration of the skill assessment module and the Basic TEA system was tested to verify whether the communication of data worked correctly as expected. Whether the marks were transferred correctly from the skill assessment module to the other modules such as gradebook, progress bar and competencies modules were also tested. The statistics and reports of the Basic TEA system were tested to check whether all statistics and log data were stored correctly after the integration. Finally, the communication between the UOC LMS and the TEA system was also tested to verify that it worked correctly without any errors.

System Testing

System testing is conducted after complete integration of the system to verify that it meets the expected requirements. This is carried-out before giving it to the real users. After integration of the TEA system with the UOC LMS, it was tested with different user logins before presenting the system to the real users. Under this, whether the overall system was capable of meeting the requirements expected by the system as described under the "Section 3.1.4 - Summary of Requirements Analysis" was tested.

Also under system testing, usability testing was carried-out. The purpose of usability testing is to observe people using the system to discover errors and areas of improvement. Usability testing generally involves measuring how well users respond in four areas: efficiency, accuracy, recall, and emotional response (Goodwin, 2009; Nielsen, 1994). Since, usability heuristics were considered during the design of the TEA system, it was important to carry-out usability testing as well. This was carried-out through observations of students and teachers, paper-prototype evaluations with teachers, and questionnaires given to students.

The interoperability of the system was tested by connecting the TEA system with another LMS and checking whether it was possible to carry-out the communication as well as to transfer data among the TEA system and the LMS. At the same time to check the security of the TEA system, SQL injection attack was performed. Also the browser security capability assigned through JavaScript for the quizzes were tested to check whether it was possible for students to copy the questions and answers from the system to a document.

Test Plan

The test plan outlines the main items to be tested with respect to the TEA system and the features that are needed to be tested within each item. Then the test cases drawn during the design and development stage of the system are used to check these features and through that pass/fail criteria is proved. This process is explained as follows:

Test Items :

Main test items were derived from the five main modules of the TEA system. Therefore, knowledge assessment module, skill assessment module, progress bar, competencies module and gradebook were selected as main test items. In addition to that single sign-on facility was selected as it played a major role in the communications between the LMS and the TEA system as well as between the Basic TEA system and the skill assessment module. Through this facility, students who were logged into the LMS could easily move to the TEA system and then to the skill assessment module.

Features to be Tested :

After identifying the test items, it was needed to decide on the important features to be tested under each item.

As single sign-on facility is an important part for the communications, features such as login and transferring of data between the LMS, TEA system and the skill assessment module were needed to be tested.

Features for the other items were selected based on the user scenarios, main characteristics of a technology-enhanced assessment system (mentioned under the "Section 2.4.4 - E-Assessment tools for Logic") and the expected requirements of the system ("Section 3.1.4 - Summary of Requirements Analysis").

The complete list of features tested is given in the "Appendix E.1 - Test plan : Features to be tested".

Test Cases :

Based on the features to be tested, the test cases were identified. These were tested based on a given input and testing whether they satisfied the expected result. If test cases failed, the respective modifications were done and tested again. Test cases used are given in the "Appendix E.2 - Test plan : Test Cases" along with the pass/fail criteria.

4.1.2 Errors Identified and Corrected

In this section, the errors identified during the three main testing; unit, integration and system are explained along with how they were corrected.

1. **Unit Testing**

   During unit testing, the only error identified was with the competencies module. As it was difficult to include the quizzes and the tests of the ITS tool into the list of activities in the competencies module. Initially, it was built only to support an assignment module and the whole module malfunctioned, when changing it to support quizzes and the activities of the ITS tool as well as when displaying the students' marks. The errors were identified as selection of the wrong MySQL queries, selection of marks from the wrong tables and not making appropriate changes to all the respective code segments.

After identifying these errors, three iterations of code modifications and testing were performed to make the competencies module free of errors. All the other modules passed the initial unit testing without any errors.

2. **Integration Testing**

   Under integration testing, errors occurred in communications between different tools. One problem was with the communication between the UOC LMS and the TEA system. It was identified as a reason of having fixed parameters defined in the communication link between the UOC LMS classroom and the TEA system. The other error was with the communication between the Basic TEA system and the ITS tool. Here, the problem was that student information such as user name, grades, time spent, date submitted and launch data were not transferred back to the TEA system from the ITS tool.

   To solve this error, several modifications had to be completed. To pass data from the ITS to the Basic TEA system an automated cron job had to be created. At the same time several modifications were required for the IMS Basic LTI and OAuth communication code files. Even the MySQL query, used to extract data had to be changed since the correct tables had not been used earlier. After correcting all the errors, the communications were tested in a local server version. Then it was tested on the production server version under different user roles before allowing the real users to access the complete TEA system.

3. **System Testing**

   Under system testing, the TEA system as a whole was tested. First, this was done with the local server version and then tested again after uploading it to the production server. The complete system was tested with different user roles to check whether it provided the expected outcomes.

4.1.3 Addressing Some of the Research Questions

One of the research activities for reaching the main objective of this research is to "Design and develop a technology-enhanced assessment system for assessing both skills and knowledge in online education". As testing is associated with the design and development process to confirm that the IT artefact works correctly, the research questions related to design and development are addressed here.

Here, the research questions are answered based on the first discussions on the concrete TEA system developed. However, these research questions are addressed generally under the "Chapter 5 - Conclusions, Findings and Future Research.

- *Which e-learning and e-assessment standards and specifications should be followed in order to develop an e-assessment system which is interoperable and secure?*
  One of the goals of this research is to design and develop a general e-assessment system which can be easily adapted to any subject or organization. As a result, the system was developed according to modular architecture. The modules were connected to the e-assessment system using a standardized plug-in to maintain security and interoperability. For this research IMS Basic LTI specification was used together with OAuth protocol for secure message interaction. This was selected after studying the currently available standards as mentioned in the "Section 2.4.2 - Standards and Specifications". The reason for selecting this specification was that it allowed single sign-on facility between modules and at the same time through the aid of OAuth it was possible to securely transfer data between modules. The interoperability and security were tested by connecting the UOC LMS with the TEA system, Basic TEA system with the ITS and TEA system with another LMS.

- *Which tools can be used for assessment of skills and knowledge subjects?*
  Knowledge can be specified as the recall or recognition of specific items. It can be more elaborated as remembering of previously learned materials. This may involve the recall of a wide range of material, from specific facts to complete theories, but all that is required is the bringing to mind of the appropriate information. In this research, since the MCQ were used, the Moodle MCQ quiz module was taken as the knowledge assessment module. For the assessment of knowledge simple type of questions such as multiple choice questions, multiple responses, short answers, fill in the blanks, matching and crossword puzzles can be used. In general, any tool which is capable of offering these simple types of questions can be used for knowledge assessment.

When it comes to skill assessment, it is needed to go beyond simple type of questions mentioned above. In this research, the ITS tool of the UOC Logic course was used. This tool was enhanced into an assessment tool by introducing additional features such as randomization, timer and different difficulty levels. For skill assessment, it is needed to introduce a tool which is capable of offering questions in a dynamic and an interactive manner, where students can construct the answers while engaging in the tool. The tool should be able to offer both practice and assessment facilities with feedback and guidance in a stepwise manner. But any tool which is capable of supporting these features can be used.

In addition to that, to incorporate the characteristics of a general e-assessment system, a basic technology-enhanced assessment system which consists of features such as progress bar, competencies and grades can be used.

To provide a complete assessment experience, tools for skill and knowledge assessment can be integrated with a basic technology-enhanced assessment system. In this case, the general e-assessment system should provide the characteristics such as: different types of questions for both practice and evaluation of skill and knowledge acquisition; immediate grading facility; immediate feedback at various stages of the assessment process; facilities to minimize the level of cheating; display of progress and overall competencies to students; facilities for teachers to evaluate marks, progress, competencies, outcomes, and statistics.

- *Can a technology-enhanced assessment system be developed as a series of modules to support both skills and knowledge while maintaining interoperability and security?*

  Yes, it is possible to develop the technology-enhanced assessment system as a series of modules. This was explained under the "Chapter 3 - Design and Development of the Technology-Enhanced Assessment (TEA) System". In this research, the technology-enhanced assessment system consists of main modules such as Basic TEA system, knowledge assessment module and skill assessment module. The Basic TEA system consists of modules for grades, progress, and competencies to aid both students and teachers. As stated in the previous question, for knowledge and skill assessment, any tool which comprises of related characteristics can be used. To maintain security and interoperability, these tools can be connected to the Basic TEA system through a standardized plug-in as described in the "Chapter 3 -Design and Development of the Technology-Enhanced Assessment (TEA) System".

4.1.4 Summary

As a summary, this section gave an overall explanation about how the TEA system was tested based on the testing methodology and the plan. Unit, integration, and system testing was presented. Under system testing, usability testing was also explained. User acceptance testing is addressed in the next section as pilot studies. Also, the errors identified and corrected were explained. Finally, some of the research questions aligned with the design and development of the system were discussed.

4.2 Validation

Validation is used to confirm the quality of the performance after application of the system and the process in the real life context. In other words, the objective of validation is to show 'proof of demonstration' in the real life and show that the system and the overall process fulfill its intended purpose (Oates, 2006).

4.2.1 Validation Methodology and Plan

Validation of the technology-enhanced assessment system and the formative e-assessment model was based on a methodology and a plan.

The validation methodology was defined with respect to a validation plan to verify the quality and the performance of the product and the process (Baehr, 2004; Frechtling, 2002; Glenaffric Ltd, 2007). This consists of four main steps such as: define the purpose and the expected results of the validation, data collection methods, data analysis, and evaluate results and draw conclusions. These steps can be described as:

- **Purpose and the expected results of the validation**
  The purpose for setting up the validation is identified. Based on the purpose, propositions are defined to identify the expected results of the validation. In this case, the propositions are theoretical explanations of observations and measurements used for the validation.

- **Data collection methods**
  In this step, scientific methods based on empirical and measurable evidence are established. Besides, the data collection methods and how they can be collected are determined. The data collection plan should include how, when and where the information should be collected.

- **Data analysis**
  After completion of the data collection process, data analysis is performed for each proposition. Then the results obtained for each proposition are stated.

- **Evaluate results and draw conclusions**
  In this step, interpretation of results is used to draw the conclusions. At this stage, it is also possible to understand the work that is needed to be completed in the future.

Under the validation methodology, as the technique for validation, mixed method evaluation techniques were used (Frechtling & Sharp, 1997; Fuente-Valentín et al., 2013; Martínez et al., 2003).

Based on validation methodology and the plan, the validation of the proposed TEA system along with the formative e-assessment model was performed with respect to two pilot studies completed during two stages of this research. This is also associated with the user acceptance testing, where the overall performance and the quality of the system and the process is validated by the end-user.

Pilot studies were conducted in the Logic course of the UOC, where both the technology-enhanced assessment system and the formative e-assessment model were applied. The first pilot study was carried-out after completion of the first stage of the development process. During this stage, the skill assessment module was independent of the technology-enhanced assessment system. The aims of the first pilot study were to find out whether the knowledge assessment module and the skill assessment module satisfy the requirements expected of the formative e-assessment model, whether the system was capable of supporting student learning process, whether practicing using the formative e-assessment model has helped students to improve their learning process, evaluation of students' engagement with the system, students' perceptions about the overall system, and the improvements that is needed to be carried-out.

The suggestions for improvements obtained from the first pilot study were applied to the system and the overall process. Then, the second pilot study was performed after the completion of the whole system. In this pilot study, in addition to the findings mentioned above, the possibility for teachers to track student learning process throughout the whole course was evaluated.

The pilot studies completed based on the above validation methodology and the plan is explained in the following sections.

4.2.2 First Pilot Study

The first pilot study was carried-out from March 2012 to August 2012 after completion of the first stage of the development. At this time both the knowledge assessment module and the skill assessment module were not integrated with the TEA system. Therefore, they were used separately for the validation together with the proposed formative e-assessment model as described in the "Section 3.2.1 - Definition of the Formative E-Assessment Model".

Steps of the first pilot study are explained according to the validation methodology described above.

1. **Purpose**

   The purpose of the first pilot study was to validate the individual modules used for skill and knowledge assessment as well as the proposed formative e-assessment model.

   Based on the above purpose, the following propositions have been defined.

   (a) The system supported student learning process

   (b) Using the system and the formative e-assessment model to perform continuous formative assessment helped in the final examination marks

   (c) Using formative e-assessment model helped students to improve their learning process

   (d) Students had engaged more in the classroom

   (e) Students had a good perception about their learning experience and formative e-assessment model through the support provided by the TEA system

For this pilot study, two classrooms of the online Logic course of the UOC were used. One classroom was taken as the pilot group whereas the other was taken as the control group.

Overall the Logic course consists of 8 learning modules divided under two main topics namely, Propositional Logic and Predicate Logic. Propositional Logic consists of four modules such as Formalization, Natural deduction, Resolution and Truth tables. Predicate Logic consists of another four modules such as Formalization, Natural deduction, Resolution and Semantics.

In both control and pilot group, practice was based only on skill acquisition and for this purpose both paper-based and ITS tool was used. As for the summative assessment, both groups were provided with the same final face-to-face examination and 4 Continuous Assessment Tests (CAT) offered through the ITS tool. Even the questions provided in the CAT were the same for all the students.

In the pilot group, in addition to the summative assessment, the formative assessment was introduced through the TEA system according to the formative e-assessment model proposed in the "Section 3.2.1 - Definition of the Formative E-Assessment Model". Through this model, students were provided with both practice and e-assessment facilities for skill and knowledge acquirement of Logic. In order to do that, they were provided with a set of Practice Tests (PT) and Assessment Tests (AT).

As a summary the assessment methods used in the two groups can be shown as in Table 4.1.

Table 4.1: The assessment methods used in the two groups

	Learning practice	Formative assessment	Summative assessment	
Control Group	Skill (Paper-based + ITS)		Skill (CAT)	Skill Face-to-Face examination
Pilot Group	Skill (Paper-based + ITS)	Skill + Knowledge (TEA : PT + AT)	Skill (CAT)	Skill Face-to-Face examination

In the pilot group, formative assessment was carried-out for the 8 learning modules mentioned before. Therefore, students had to do 8 Practice Tests (PT) and 8 Assessment Tests (AT) which were offered randomly. As a result, the questions offered through AT were different for all students. In addition to that, students in the pilot group had to do another 4 CAT and a face-to-face examination under summative assessment as with the control group. But, students in the control group had to do only summative assessment which comprised of 4 CAT and a face-to-face examination. For continuous assessment tests, in both groups, 2 modules were taken as a CAT. These CAT were same for all the students. The CAT and the corresponding learning materials are shown in Table 4.2.

Table 4.2: The Continuous Assessment Tests and the corresponding learning modules

Activities	Modules
CAT 1	1(Formalization) and 2 (Natural deduction)
CAT 2	3 (Resolution) and 4 (Truth tables)
CAT 3	5 (Formalization) and 6 (Natural deduction)
CAT 4	7 (Resolution) and 8 (Semantics)

In the pilot group, as mentioned in the formative e-assessment model, for each learning module students were first given a set of questions based on both knowledge and skill as a PT with an unlimited number of attempts. After obtaining a pass mark of 50% or more for each PT, students were allowed to move to the corresponding AT. Assessment test consisted of knowledge type of questions offered as MCQ and skill type of questions offered using the ITS. Assessment test questions were offered in a randomized manner according to different difficulty levels and within a time restriction of 2 hours and 3 possible attempts. The reason for selecting a time limit of 2 hours is that, according to the standard schedule of a classroom, it was considered as the normal recommended daily working session and also because the final examination was set to 2 hours. The 3 attempts were used to give a bit of a pressure for students in the formative e-assessment model and to make them practice more if needed, to pass the AT. This process was illustrated in the Figure 3.4 of the "Section 3.2.1 - Definition of the Formative E-Assessment Model". After completion of the formative assessment through PT and AT, students attempt the CAT. In the control group, students carry-out self-assessment and then move to CAT.

In Figure 4.3, a comparison between the students learning and assessment process for the first two modules and the first CAT is presented.

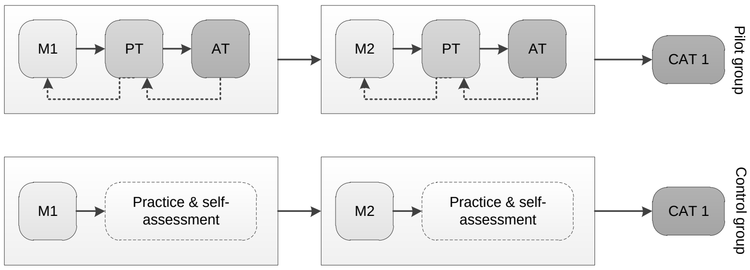


Figure 4.3: Comparison between pilot and control groups learning process before a CAT

In both groups, for summative assessment, 65% of marks was given for the final face-to-face examination (EX) and the remaining 35% of marks was given for the Continuous Assessment (CA). In the control group, CA corresponded only to 4 CAT. In the pilot group, CA comprised of 4 CAT and 8 AT. In both cases, CAT offered same questions to all the students.

The organisation structure of activities in the pilot group is illustrated in Figure 4.4.

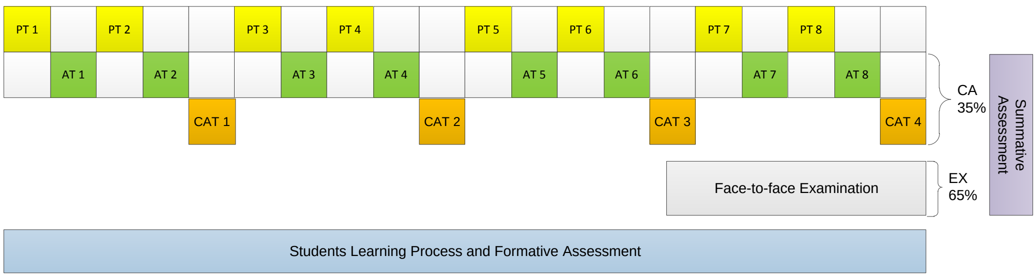


Figure 4.4: Organisation structure of activities in the pilot group

As a summary, the main difference between the control and the pilot groups is that, in the pilot group students were constantly engaged in the TEA system, for both practice and assessment purposes, through the introduction of the formative e-assessment model. Every week students had to do one PT, AT or CAT based on a specific topic on the Logic subject. Both PT and AT was offered through the introduction of the formative e-assessment model. Throughout this model data such as marks obtained, time spent, pass rate, data about the quality of questions, participation and system logs were recorded. Also the final summative assessment marks in both group differed based on the continuous assessment marks. As mentioned before, in the pilot group it comprised of 4 CAT and 8 AT whereas in the control group it was only based on 4 CAT. These CAT were same for both groups and additionally, the same face-to-face examination was also given.

2. **Data collection methods**

   Quantitative research methods provide statistical scientific measurements and analysis techniques of empirical research and qualitative research methods provide evidence based on "proof of demonstration" in the real context.

   As the data collection methods, both quantitative and qualitative research methods were used. In this case, the mixed method evaluation technique (Frechtling & Sharp, 1997; Fuente-Valentín et al., 2013; Martínez et al., 2003) approach was followed. Mixed methods combine quantitative techniques, such as data obtained from the system and closed questions from the questionnaire, and qualitative techniques such as open questions from the questionnaire and observations.

   For this pilot study, one Logic classroom of the UOC consisted of 29 students was used as the pilot group whereas another consisted of 35 students was used as the control group. Both classrooms were based on the Catalan language.

   In this pilot study, data were collected in two sources. On the one hand, data such as participation, the student marks for PT, AT, were obtained using the real-time data capture embedded in the TEA system. In order to analyze the marks between the pilot and control group, the Continuous Assessment (CA) marks through the 4 CAT and the final face-to-face examination (EX) were obtained. On the other hand, close to the end of the training, a questionnaire was sent to the students. The objective was to capture student performance and learning experience about the knowledge and skills acquired and the use of the TEA system.

It was anonymous, voluntary, and had no effect on the grade. Students could answer it until the final examination. The survey contained open-ended questions, yes/no and five-point Likert scale questions. The questionnaire consisting of 20 questions was divided into three parts. The first part comprised of questions about the students' general information, the activities, feedback provided by the TEA system and the assessment process. The second part questions was about students performance, practice of skills and the overall formative e-assessment process in the course. Questions of the last part was given to obtain information about students' learning experience regarding the schedule and the recommendations provided about the TEA system (from both, technological and educational point of view).

3. **Data analysis**

The analysis of data with respect to the propositions is presented as below.

(a) **The system supported student learning process**

To analyse this, t-student statistical distribution was carried-out among the pilot group and the control group. This was done based on the means of the qualifications obtained for the final face-to-face examination. In this pilot, students had used the TEA system for practice and evaluation purposes before moving to the final face-to-face examination. Therefore, the aim was also to check whether the use of the TEA system had a positive impact on the students' marks in the final examination.

As the null hypothesis, H0 : "The mean of the final face-to-face examination marks of the pilot group was equal to the mean of the control group", was taken.

The results of the t-student analysis, can be stated as below in Table 4.3.

Since the p value is less than 0.05, the null hypothesis (H0) can be rejected and that shows that the means are not the same. In addition to that, the mean value of the pilot group is a bit higher than the control group. By considering both the t-student hypothesis test and the mean values, it can be stated that students learning process have been improved in terms of

Table 4.3: First pilot study results of the t-student analysis assuming unequal variances

	Pilot Group	*Control Group*
Mean	6.155172	4.294286
Observations	29	35
Statistical t	2.990247	
P (T <=t) one tail	0.001997	
Critical value of t (one-tailed)	1.669804	
P (T<=t) two tails	0.003994	
Critical value of t (two- tailed)	1.998971	

students' performance through the formative e-assessment model using the TEA system.

(b) **Using the system and the formative e-assessment model to perform continuous formative assessment helped in the final examination marks**

To analyse this, the Pearson Correlation Coefficient was calculated between the final mark of the Continuous Assessments (CA) and the final face-to-face examination. Correlation is a statistical relationship involving dependence between two variables and it does not imply causation.

The Pearson Correlation Coefficient between the final mark of the Continuous Assessments (CA) and the final face-to-face examination is shown in Table 4.4.

Table 4.4: Pearson Correlation Coefficient for CA final mark and the final face-to-face examination

	Correlation coefficient	No. of students
Pilot group	0.61	29
Control group	0.54	35

It can be noted that students in the pilot group had a higher correlation between online continuous assessment marks and final face-to-face marks;

and they also had a higher final face-to-face marks than students in the control group.

According to the above data, even though the correlation in the pilot group is higher than the control classroom, the difference is not that significant. This could be due to the fact that control classroom might have got students with higher ability. Even though, due to ethical reasons the ability of the students was not measured in this research. Correlation is further analyzed in the second pilot study.

(c) **Using formative e-assessment model helped students to improve their learning process**

One of the main purposes of proposing the formative e-assessment model is to allow students to practice more based on the feedback offered and improve their learning process as a result of it.

For this proposition, the correlation coefficient between completing AT and then doing CAT was calculated along with the correlation coefficient between final marks of the PT and AT. This was further analysed with the average marks obtained for PT and AT. If the correlations between AT and CAT as well as between PT and AT were significant, then it can be concluded that doing practice based on formative e-assessment model had helped students to improve their learning process. If the average marks of AT were higher than PT, it can further be proved that the practice had improved students' performance in the assessments. Furthermore, with respect to the PT, the marks obtained by each student for each attempt were obtained.

The correlation coefficient between completing AT and then doing CAT were calculated in the pilot group as shown below in Table 4.5. This indicates that, there is a high correlation between AT and CAT and this have helped students to improve their learning process significantly.

Table 4.5: Pearson Correlation Coefficient for AT and the CAT

	Correlation coefficient	No. of students
Pilot group	0.987	29

The CAT were the same for all the students and therefore, students had the possibility to cheat by copying the answers from others. But, AT questions were selected randomly from a question bank and as a result, each student were offered a different set of questions. Therefore, the possibility of cheating is less. In the pilot group, as there is a high correlation between AT and CAT, this could be due to the reason that students had practiced more using the formative e-assessment model.

Then, to see the impact of doing practice and then doing the assessment tests, the correlation coefficient between final marks of the PT and AT were calculated. The correlation can be displayed as in Table 4.6.

Table 4.6: Pearson Correlation Coefficient for PT and the AT

	Correlation coefficient	No. of students
Pilot group	0.916	29

Even from Table 4.6, it can be seen that there is a high correlation between doing the PT and AT.

Then student data were analyzed with respect to Practice Tests (PT) in the pilot group of the first pilot study. The number of attempts taken by all 29 students in the pilot classroom and the way their scores have improved during attempts by illustrating data (example: attempts = 6, attempts = 8) is given in the "Appendix F.1 - Analysis of First Pilot Study Data for Practice Tests (PT)".

Based on these data, it can be seen that in most cases students have attempted the PT at least twice except in the case of PT 3 and PT 4. In all the other tests the mode of attempts was equal to 2. Therefore, students have used a minimum of 2 attempts to obtain the pass mark of 50% in PT and AT. Also for some PT, students have made more than three attempts and in the case of the PT1, some have made 9 attempts. But it was interesting to see that students' marks have improved through these attempts.

A comparison between Practice Tests (PT) and Assessment Tests (AT) To analyze the student improvements with respect to doing PT and then AT, the average marks obtained by the students for given eight PT and eight AT were analyzed (see Table 4.7). These PT and AT are related as students had to pass the PT to move to AT. Here the aim was to analyze the impact on AT after doing PT. As can be seen from the Table 4.7 and Figure 4.5, average marks of student in AT had improved after completing PT. This was also proved before with a higher correlation of 0.916 between doing the PT and then AT.

Table 4.7: Comparison of average marks between PT and AT for all tests

Test number	PT	AT
1	75.01	77.33
2	75.28	79.29
3	80.89	81.54
4	78.65	79.23
5	70.87	72.58
6	78.26	80.00
7	75.94	77.62
8	73.42	75.83

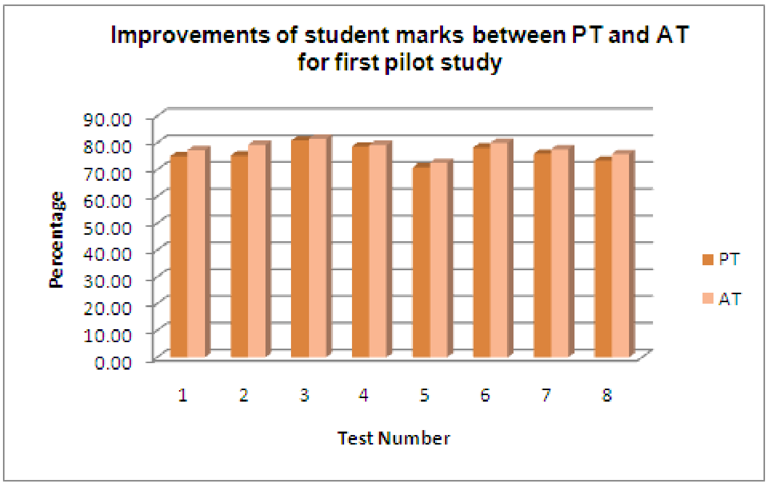


Figure 4.5: Improvements of student marks between PT and AT for first pilot study

Analysis of first pilot study for Assessment Tests (AT)

Also in AT, the average scores between the given three attempts (see Table 4.8) were analyzed to see whether there is an improvement among assessments through practice.

As shown from the Table 4.8 and the Figure 4.6, it can be seen that average marks of students had improved through the attempts. Therefore, as a summary, it could be seen that more students practice with the formative e-assessment model it has enhanced the student learning experience.

Table 4.8: Average marks between the three attempts

Assessment Test	Attempt 1	Attempt 2	Attempt 3
1	66.25	74.27	82.00
2	59.29	69.44	74.26
3	63.60	67.50	70.00
4	58.70	65.45	72.50
5	63.33	73.10	74.60
6	60.80	65.63	76.67
7	57.17	67.50	69.33
8	54.39	71.88	75.00

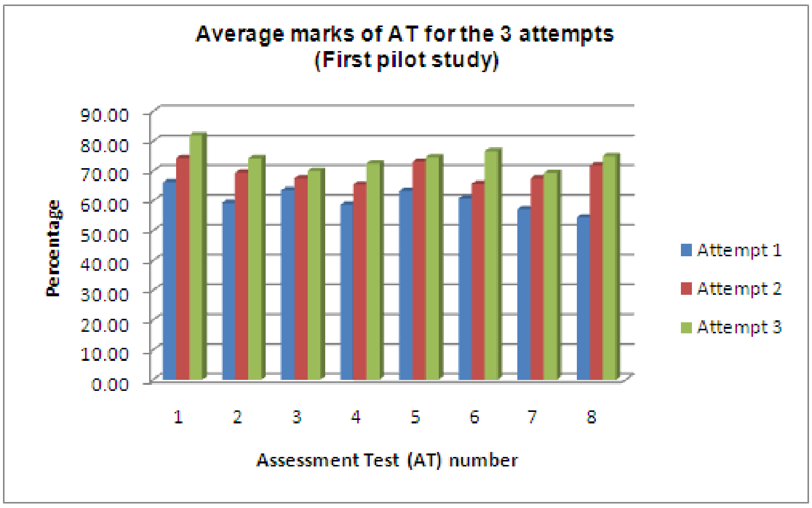


Figure 4.6: Average marks of AT for the 3 attempts (First pilot study)

(d) **Students had engaged more in the classroom**

Students' engagement with the TEA system in the pilot classroom was analysed based on the system log data about student participation in the system. Based on Figure 4.7, all students in the pilot group 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). The TEA system have consisted of session time-out duration and therefore, students might have 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 the diagram. But it can be noted that the majority of these peaks had occurred when it was near the deadline of AT. The high peaks at the beginning shows that students have used the system more at the beginning to get familiar. At the same time students had used the system even after the final deadline of the AT was over. This can be taken as a reason that students have used the TEA system to practice for the final examination.

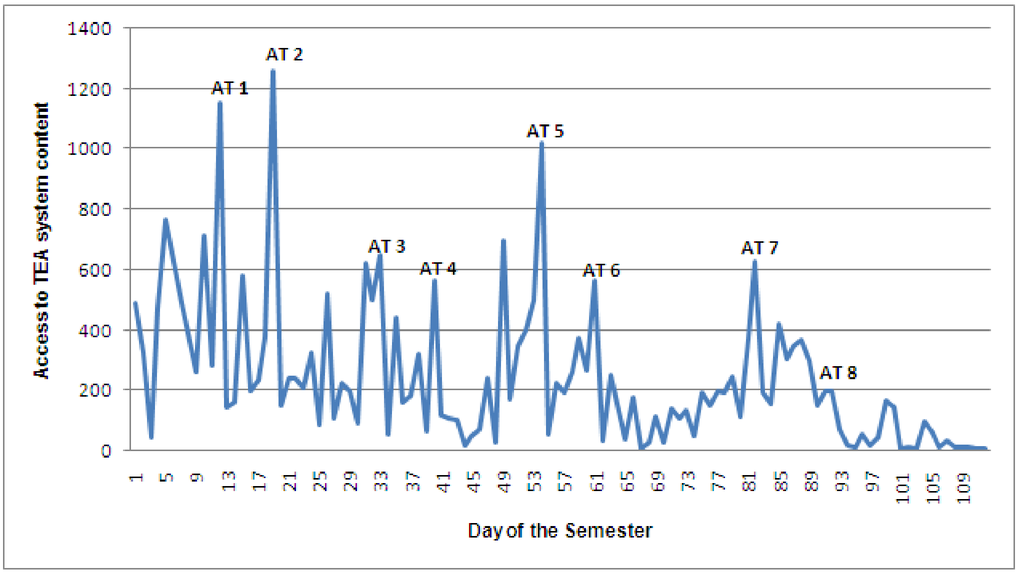


Figure 4.7: Students' participation in the TEA system

The students' participation data only in the ITS in both the pilot group (ITS was used as the skill assessment module) and the control group can be shown as in Figures 4.8 and 4.9. It can be seen that students in the pilot group have used the ITS more for practice and assessment compared to the control classroom since the skill assessment module includes the ITS tool.

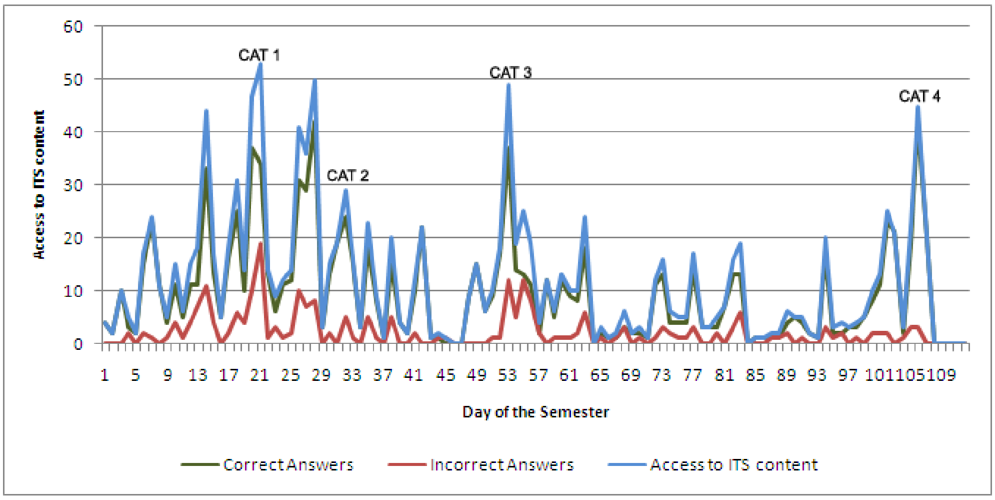


Figure 4.8: Students' participation in the ITS tool and skill assessment module (Pilot group)

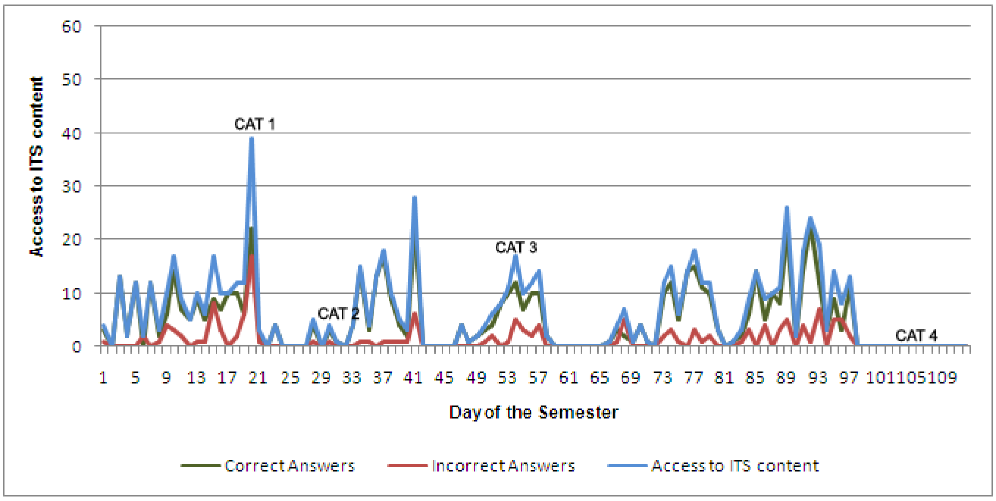


Figure 4.9: Students' participation in the ITS tool (Control group)

In both Figures 4.8 and 4.9, it shows the number of correct answers in green color, incorrect answers in red color and access to the ITS tool in blue color. In the pilot group, it shows that there is a high peak near the deadlines of the CAT, compared to the control group. Also, in the pilot group, the highest correct answers equals to 42 whereas in the control group it is 23. Therefore, it shows an increase of student performance and engagement in the pilot group.

(e) **Students had a good perception about their learning experience and formative e-assessment model through the support provided by the TEA system.**

Regarding the student learning experience a set of questions was introduced in the questionnaire.The questionnaire is given in the "Appendix G.1 - Questionnaire of the First Pilot Study". The questionnaire was voluntary and maybe as a result of that only 15 students have answered. The main results are related to skills and knowledge acquisition of the activities completed through the TEA system, the course scheduling and system time restrictions, formative e-assessment process, feedback, and marks provided in the Logic course.

About the skills acquired, students have considered that their skill level was improved through the AT. In fact 86% of students considered that grades provided by the system were good and majority has agreed with a median and mode value of 2, where strongly agree is equal to 1 and strongly disagree is equal to 5 as shown in Figure 4.10.

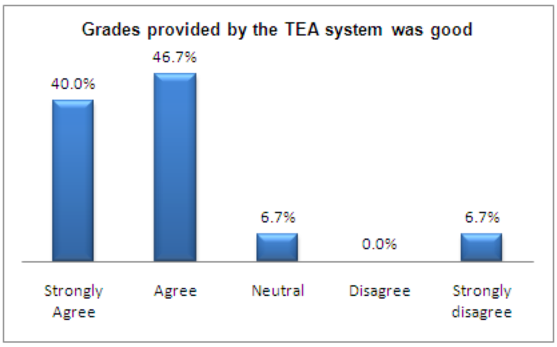


Figure 4.10: Student responses to "Grades provided by the TEA system was good"

Also 86% of students considered that PT and AT helped them in their learning process based on both knowledge and skills acquisition. Regarding the difficulty of the AT, when asked about the average number of attempts they had to do in order to achieve a minimum score, 93% of students answered by saying 2 attempts as shown in Figure 4.11. This can be taken as an indication that the assessments were of medium difficulty level and they were suitable for assessments of skill and knowledge.

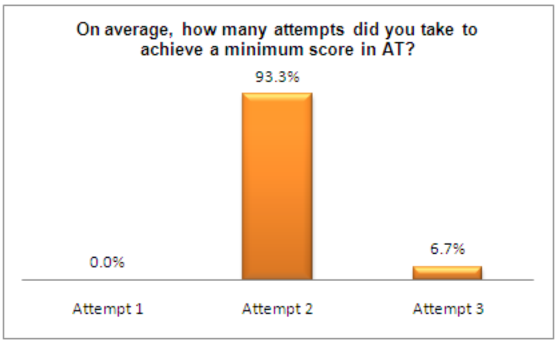


Figure 4.11: Student responses to “On average, how many attempts did you take to achieve a minimum score in AT?”

With respect to formative assessment provided by the system, when asked whether students agree with the automated marking facility provided by the system, 93% of them agreed with a median and mode of 2, where strongly agree is equal to 1 and strongly disagree is equal to 5 as shown in Figure 4.12.

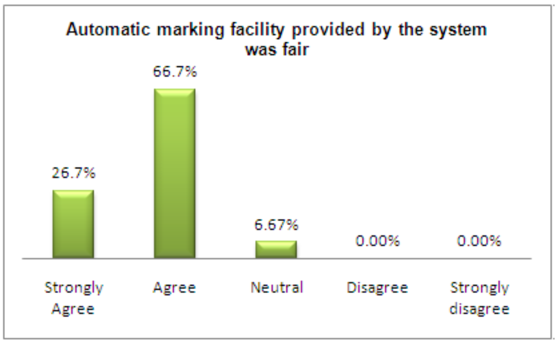


Figure 4.12: Student responses to “Automatic marking facility provided by the system was fair?”

Also another 80% of students mentioned that doing PT and AT have helped them to evaluate their strengths and weaknesses in the Logic course as shown in Figure 4.13. As can be seen from the Figure 4.13, most of the students agreed with a median and mode value of 2, where strongly agree is equal to 1 and strongly disagree is equal to 5.

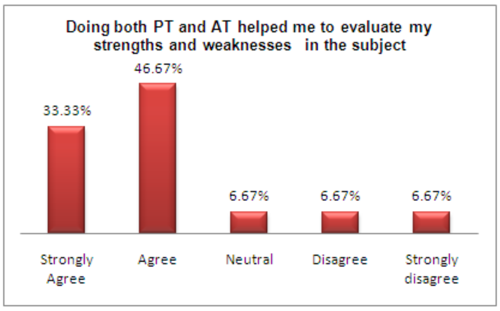


Figure 4.13: Student responses to "Doing both PT and AT helped me to evaluate my strengths and weaknesses"

Students also mentioned that, through both PT and AT they were able to weekly monitor their learning progress of the subject.

With respect to the final examination 67% of students agreed that the completion of PT and AT were useful for preparing for the final examination. When it comes to feedback 80% of students agreed that feedback provided by the system was also satisfactory as shown in Figure 4.14. This means that the feedback and the marks provided by the system for formative assessment have helped them for advancing in their skills learning process with the TEA system. However, during this pilot as the feedback for each question only correct and incorrect was given. As mentioned by 20% of students, it is needed to give more detailed feedback including the reasons for incorrect answers with hints.

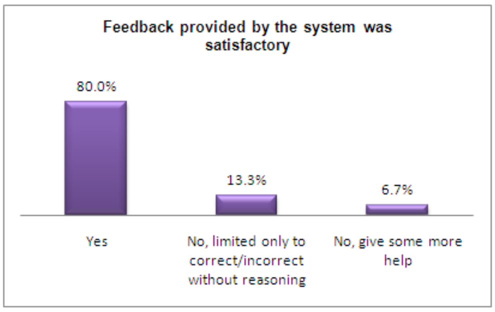


Figure 4.14: Student responses to "Feedback provided by the system was satisfactory"

When considering the formative e-assessment model of the Logic course, it was needed to find out whether it was a good schedule to give assignments every consecutive week. Therefore, the question: "What would be the best time difference to perform frequency of assignments?" was asked and 67% of students have mentioned, 2 weeks as shown in Figure 4.15.

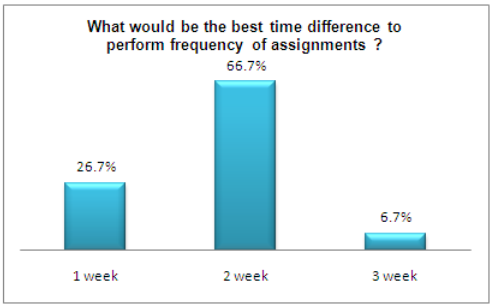


Figure 4.15: Student responses to "What would be the best time difference to perform frequency of assignments"

All AT had a time restriction of 2 hours to accomplish the given task. When asked, students' opinions about this, 93% of students agreed by saying it was enough. At the same time, another restriction was imposed where students had to obtain a minimum pass mark of 50 in the PT to move to the corresponding AT. The 73% of students either agreed or strongly agreed that having a minimum score for PT is a good method to obtain a better score at AT because they get a chance to practice using PT before moving to AT. This was done with the intention of obtaining the maximum benefit of the system and at the same time for giving students a considerable amount of time to practice. Therefore, they had mentioned *"overall system is good but it is really stressful to complete all tasks within the allocated time"*.

An open-ended question was also given to obtain students' suggestions about the estimated weight in the continuous formative assessment and the final examination. They commented that *"it is better if a higher weight is given for the assessments conducted through the system as well as adding it to the final examination"*. Then from the students' point of view and learning experience, the formative e-assessment model based on the continuous formative assessment combined with a final examination was a good evaluation model.

Nevertheless they considered that the formative assessment mark had to be increased with respect to the final examination. Students highlighted that this mark have to be upper than 35%.

4. **Evaluate results and draw conclusions**

   Interpretation of results for the propositions based on the data analysis can be stated as below.

   (a) **The system supported student learning process**
   Based on the t-student statistical analysis, it can be stated that students learning process had improved through the formative e-assessment model and the facilities provided by the TEA system. One of the reasons could be that students' had engaged more in the course through the system as discussed under "**(d) Students had engaged more in the classroom**". Another reason could be that the formative assessment followed by the pilot group gave students a more reliable score in relation to their learning performance. Thus, their possibilities to pass the final examination were higher. This could be proved with the correlation coefficient calculated between the final continuous assessment and the final face-to-face examination.

   (b) **Using the system and the formative e-assessment model to perform continuous formative assessment helped in the final examination marks**
   As can be seen from the data analysis based on correlation between the final continuous assessment (CA) marks and the final face-to-face examination (EX) marks, the correlation was higher in the pilot classroom compared to the control classroom. Additionally, students in the pilot classroom had a higher mark for the final face-to-face examination. Therefore, considering above, it could be seen that using the TEA system and the formative e-assessment model to perform the continuous formative assessment helped in the final examination marks.

(c) **Using formative e-assessment model helped students to improve their learning process**

In the previous section, it showed that there was a high correlation between completing the Assessment Test (AT) and then completing the Continuous Assessment Test (CAT) as well as attempting the PT and then attempting the AT. In the pilot group, since AT questions were selected randomly from a question bank the possibility of cheating was also less. Therefore, the high correlation between AT and CAT could be due to the reason that students had practiced more using the formative e-assessment model. Based on the statistics obtained from the practice tests, it showed that students have used at least 2 attempts to obtain the given pass mark and in some cases they had used more attempts. This shows that students have used the benefits provided by the system for practice purposes. It could be seen that students marks had improved with these attempts. According to the comparison of average marks between practice tests and assessment tests, it seems that practicing using the PT had helped students to improve their marks in the AT. This can be taken as an interpretation to the high correlation between PT and AT. Even in the AT, it showed that students average marks had improved through subsequent attempts.

Considering all the mentioned data, as a conclusion to this proposition, it can be stated that practicing using the formative e-assessment model had helped students to improve their learning process.

(d) **Students had engaged more in the classroom**

Based on the student participation data, in the TEA system, students had used the system even after the final completion date of the AT and CAT was over. This shows that students had used the system for practice purposes in order to prepare for the final face-to-face examination. Also, the student participation data in the skill assessment module showed that students in the pilot group have used the ITS system more for practice compared to control group. Pilot group had a higher number of correct answers in the ITS compared to control group and this showed the increase of performance in the pilot group. Overall it can be concluded that students had engaged more in the pilot classroom compared to control classroom and this could be taken as a reason for the improved results in the final examination as mentioned under "(a) system supported student learning process" proposition.

(e) **Students had a good perception about their learning experience and formative e-assessment model through the support provided by the TEA system**
As a summary, students learning experience with the TEA system is positive. At the same time, they preferred the support provided through the formative e-assessment model with immediate feedback, automatic grading, practice tests and assessment tests. Nevertheless, students suggested some recommendations related to the scheduling and system improvements. On the one hand students had mentioned *"it is better, if we are informed about the starting and ending dates of each assignment from the beginning and displaying it in a calendar, otherwise the chances of forgetting them is high"*. Also, students had mentioned that it was stressful to complete the work allocated within a week. 67% of students had mentioned that they prefer to have the assessments over 2 weeks compared to the one week frequency given in the pilot. Although students found that the instructions of the questions were presented in a clear and concise manner, still it was needed to improve the frequency of assignments. On the other hand they suggested creating a link between the two tools because it was stressful to move between different tools separately. Therefore, as an improvement, it showed the need to integrate both the skill and knowledge assessment modules together in the future.

Conclusions based on the propositions

The purpose of the first pilot study was to validate the individual modules used for skill and knowledge assessment and the proposed formative e-assessment model.

This purpose was evaluated with respect to five propositions. In this pilot, knowledge assessment was performed using the MCQ questions and skill assessment using the ITS. Overall, based on the analysis of results it can be stated that the

TEA system was capable of supporting student learning process because students in the pilot classroom were able to obtain higher marks in the final examination.

At the same time, using the system and the formative e-assessment model for doing Continuous Assessments (CA) had helped in the final face-to-face examination (EX). Also, more practice with the formative e-assessment model had helped students as their marks had improved with subsequent attempts. Attempting PT and then attempting AT as well as attempting AT and then attempting CAT had also helped students to improve their performance.

It could be seen that students were constantly engaged in the TEA system for both practice and assessment purposes. They have even used the system for practice purposes after the completion date of the assigned assessments were over. From the student participation data in the skill assessment model, it showed that students performance in the pilot group is higher compared to the control group.

As a summary, it can be stated that both skill and knowledge levels of students could have improved as a result of practice and support provided by the formative e-assessment model and the TEA system.

Based on the students perceptions, they were satisfied with the learning experience, support and facilities offered by the TEA system and the formative e-assessment model. According to feedback and suggestion of students few improvements has to be carried-out for as mentioned above.

4.2.3 Second Pilot Study

The Second pilot study was carried-out from September 2012 to February 2013 in the Logic course at the UOC. During this stage, the whole system along with the formative e-assessment model was used for the validation.

Steps of the second pilot study are explained according to the validation methodology and the plan described.

1. **Purpose**

   The purpose of the second pilot study was to validate the complete system as well as the proposed formative e-assessment model. Since the TEA system was equipped with additional functionalities such as progress, competencies and outcomes, it was needed to validate the support provided by these modules as well. Even in the second pilot, it was decided to obtain students' perceptions about the modules, TEA system and the formative e-assessment model to make improvements to the second stage of the development.

Based on the above purpose, the following propositions have been defined.

(a) The system supported student learning process

(b) Using the system and the formative e-assessment model to perform continuous formative assessment helped in the final examination marks

(c) Using formative e-assessment model helped students to improve their learning process

(d) Using the system, it is possible for teachers to track the student learning process throughout the whole course

(e) Students had engaged more in the classroom

(f) Students had a good perception about their learning experience through the support provided by the TEA system

Even for this pilot study, two classrooms of the online Logic course of the UOC were used. One classroom was taken as the pilot group whereas the other was taken as the control group. Also, the overall Logic course consisted of eight learning modules divided under two main topics namely Propositional Logic and Predicate Logic.

In the control group, same assessment method followed in the first pilot study was used where students used the same practice method, and only summative assessment. The CAT was the same for all the students and in addition to that a final face-to-face examination was given.

However, when it comes to the second pilot group, one of the main differences with respect to the first pilot study was that, Continuous Assessment Tests (CAT) offered through the skill assessment module was integrated into the formative assessment, where it was taken as part of the AT. In this case, students had less work compared to the first pilot study. AT consisted of 2 parts, where both were presented to students in a randomized manner selected from a question bank of different difficulty levels. In the second pilot study, AT were used to offer a fully formative assessment experience for students based on the formative e-assessment model.

In the first pilot study, CAT was used as part of the summative assessment, where the same questions were offered to all the students. At the same time, formative assessment consisted of both PT and AT.

As a summary, the assessment methods used in the three groups can be shown as in Table 4.9.

Table 4.9: The assessment methods used in the different groups

	Learning practice	Formative assessment	Summative assessment	
Control Group	Skill (Paper-based + ITS)		Skill (CAT)	Skill Face-to-Face examination
Pilot Group (First pilot study)	Skill (Paper-based + ITS)	Skill + Knowledge (TEA : PT + AT)	Skill (CAT)	Skill Face-to-Face examination
Pilot Group (Second pilot study)	Skill (Paper-based + ITS)	Skill + Knowledge (TEA : PT + AT)		Skill Face-to-Face examination

Even in this pilot study, formative assessment was carried-out for the 8 learning materials as mentioned before. As with the first pilot study, in both groups 2 modules were taken as a CAT as shown in Table 4.2 under the first pilot study.

The same formative e-assessment model as in Figure 3.4 under the “Section 3.2.1 - Definition of the Formative E-Assessment Model” was also used in the second pilot study. Therefore, based on the 8 learning modules, students had to do 8 Practice Tests (PT) and 8 Assessment Tests (AT). AT was divided into 2 parts where Part A worth 20% of marks for knowledge assessment and Part B worth

80% of marks for skill assessment. Altogether formative assessment consisted of 35% of the total mark. The rest of the 65% was given for the summative assessment consisting of only a 2 hour final face-to-face examination. The organisation structure of activities in the second pilot study can be illustrated as in Figure 4.16.

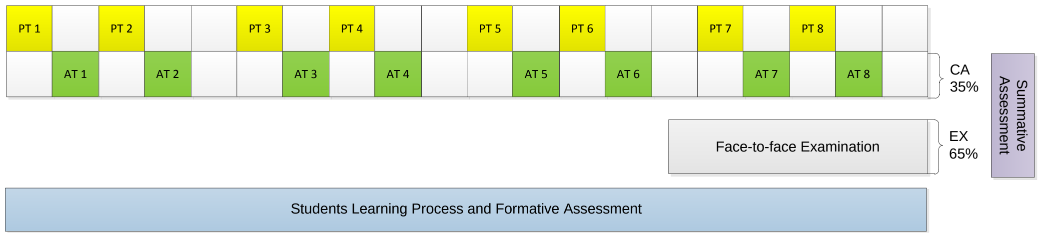


Figure 4.16: Organisation structure of activities in the pilot group (Second pilot study)

As a summary, the main difference between the control group and the two pilot groups used in the two validations was that students are constantly engaged in the TEA system for both practice and evaluation purposes. The main difference between the first pilot study and the second pilot study was that, in the second pilot study, final Continuous Assessment (CA) marks consisted of only 8 AT instead of the combination of 4 CAT and 8 AT, in the first pilot.

Also, the frequency of assessments in the second pilot study was changed. Therefore, every 2 weeks students had to do one PT and AT based on a specific topic on the Logic course, according to the formative e-assessment model. Throughout this model data such as marks obtained, time spent, pass rate, data about the quality of questions, participation and system logs were recorded. In addition to that marks obtained for the final face-to-face examination was also recorded.

2. **Data collection methods**

   Even in this pilot study, as the data collection methods, both quantitative and qualitative research methods were used. These propositions were also analyzed following a mixed evaluation technique(Frechtling & Sharp, 1997; Fuente-Valentín et al., 2013; Martínez et al., 2003). Mixed methods combine quantitative techniques, such as data obtained from the system and closed questions from the questionnaire, with qualitative techniques such as open questions from the questionnaire and observations.

For this pilot study, one Logic classroom consisted of 38 students was used as the pilot group whereas another consisted of 28 students was used as the control group. Both classrooms were based on the Catalan language.

To conduct data analysis in the second pilot study, data were collected in two sources. On the one hand, data such as participation, student marks for PT, AT and quality of questions were obtained from the real time data capture in the TEA system. The marks obtained in the final continuous assessment and the final examination were also analyzed to draw conclusions. Additionally, data such as competencies report, progress report, outcome report and grade report were also obtained using the real-time data capture modules of the system.

On the other hand a questionnaire was given to the students of the pilot group. The objective was to capture student performance and learning experience with the TEA system. Also to obtain students' perceptions about the system, the improvements needed to be carried-out to the system and the learning process 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.

The validation results of this pilot study of the complete TEA system were used to arrive at the conclusions, whether the system is able to support the students learning process and whether using the TEA system and the formative e-assessment model to perform continuous formative assessment has helped students in the final examination. At the same time, based on the formative e-assessment model whether practicing and then later doing the assessment has helped students to improve their knowledge and skill levels were also studied. Based on the added functionalities in the TEA system, whether the system can support teachers to track student learning throughout the whole course was also validated. The way students have used the system was also evaluated based on the students' engagement with the system. Students' perceptions about their learning experience and formative e-assessment model through the support provided by the TEA system was also obtained. Through this, the modifications that were needed to be carried-out for the future as well as the future work were also obtained as a result of this pilot study.

3. **Data analysis**

   (a) **The system supported student learning process**

   To answer this proposition, a quantitative study was used for hypothesis testing. Under that t-student statistical distribution was carried-out among the pilot group and the control group. This was based on the mean of the qualifications obtained in the final face-to-face examination. As mentioned before, based on the formative e-assessment model, students had used the TEA system for practice and assessment purposes before moving to the final face-to-face examination. Therefore, the main aim was to check whether the use of the TEA system had a positive impact on the students' marks in the final examination. However, the data between the first pilot study and the second pilot study was not compared because as shown in Table 4.9, the assessment methods used between the two evaluation studies were different. In the first pilot study, all students did the same CAT which was part of the summative assessment where in the second pilot study, students used the AT marks instead of the CAT marks.

   H0 was taken as the null hypothesis, where the mean of the pilot group is equal to the mean of the control group. The results obtained can be displayed as below in Table 4.10.

Table 4.10: Second pilot study results of the t-student analysis assuming unequal variances with formalization marks

	Pilot Group	*Control Group*
Mean	5.2	5.942857
Observations	38	28
Statistical t	-1.25963	
P(T <=t) one tail	0.106188	
Critical value of t (one-tailed)	1.669013	
P(T <=t) two tails	0.212377	
Critical value of t (two-tailed)	1.99773	

By looking at the above data, it can be seen that the $P > 0.05$ and it is not possible to reject the null hypothesis. At the same time, the mean value of the pilot classroom is less than the control classroom. It could be due to other non controlled factors like, for instance, the fact that the control group had smarter students provided that the ability of the students were not evaluated due to ethical reasons.

Then an interview with the teacher of the pilot classroom was carried-out and the teacher pointed out, that after the final examination most of the students complained about the formalization questions. Students had mentioned that, using the system they were able to select the correct answer but in the final examination, they had to construct the correct answer on paper rather than selecting the correct answer from a list of choices. This was difficult as they were not used to memorizing the rules and constructing the answer on paper, it took more time and as a result they were not able to answer those questions properly.

Also when looking into the marking scheme of the final examination, it was understood that the higher weight of the marks was given for the formalization questions compared to other questions. This could be the reason that the hypothesis could not be rejected and that the mean value was low. This problem did not occur in the first pilot study as students practiced formalization in the same way as the control group.

To evaluate this assumption, the final examination marks were calculated by omitting the marks of the formalization questions in both pilot and control groups. Then the t-student statistical analysis was again calculated and the data obtained can be displayed as in Table 4.11.

Table 4.11: Second pilot study results of the t-student analysis assuming unequal variances without formalization marks

	Pilot group	*Control group*
Mean	3.86303	3.51071
Observations	38	28
Statistical t	0.608551	
P(T <=t) one tail	0.027251	
Critical value of t (one-tailed)	1.669402	
P(T <=t) two tails	0.04501	
Critical value of t (two-tailed)	1.99834	

Based on Table 4.11, it can be seen that the assumption is valid as P <0.05. Also the mean value of the pilot group is a bit higher than the control group. Since there is not a much difference in the mean value, the assumption of having smart students in the control classroom can also be taken as true. After looking into these data, teachers decided to introduce MCQ for formalization in the final examination paper for the formalization section from the next semester. Another possibility mentioned by teachers was that in the future, questions for the formalization section could be introduced in the skill assessment module.

(b) **Using the system and the formative e-assessment model to perform continuous formative assessment helped in the final examination marks**

To analyse this, as in the first pilot study, the Pearson Correlation Coefficient was carried-out between the final mark of the Continuous Assessments (CA) and the final face-to-face examination (without formalization) as shown in Table 4.12.

Table 4.12: Pearson Correlation Coefficient for CA final mark and the face-to-face examination

	Correlation coefficient	No. of students
Pilot group	0.701621517	38
Control group	0.22837603	28

Therefore, it can be noted that students in the pilot group had a higher correlation between the online continuous assessment marks and the final face-to-face marks. Even the difference of correlation between the two groups is higher than in the first pilot study.

It showed that using the system and the formative e-assessment model to perform continuous formative assessment helped in the final examination because it prevents students from cheating during the continuous assessments and as a result, students are more prepared for the final examination.

(c) **Using formative e-assessment model helped students to improve their learning process**

Under this proposition, first the impact of doing practice and then doing the assessment tests were validated. Therefore, the Pearson Correlation Coefficient between final marks of the PT and AT (Comprised of both MCQ and CAT) were calculated. The results of the correlation can be displayed as in Table 4.13.

Table 4.13: Pearson Correlation Coefficient for PT and the AT

	Correlation coefficient	No. of students
Pilot group	0.915054	38

From Table 4.13, it can be seen that there is a high correlation between doing the PT and then doing the AT. Then student data with respect to practice tests (PT) 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 by illustrating some data (example:

attempts = 6, attempts = 8) is given in the "Appendix F.2 - Analysis of Second Pilot Study Data for Practice Tests (PT)". As with first pilot study, students had spent 8 attempts in the first PT. This could be due to the reason that at the beginning students had used the tests more to get familiar with the system and the practice tests. In all other cases except in PT 3, mode of attempts was equal to 2. For some tests, students have made more than three attempts and in the case of PT1, PT5 and PT8, some students have made 8 or 9 attempts. But it is interesting to see that students' marks have improved through these attempts. It shows that more students practice using the system, the more probability of obtaining a higher mark and improving their learning process.

A comparison between Practice Tests (PT) and Assessment Tests (AT) As with first pilot study, to analyze the student improvements with respect to doing PT and then AT, the average marks obtained by the students for the given 8 PT and 8 AT were analyzed. These PT and AT were related as students had to pass the PT to move to AT. Here the aim was to analyze the impact on AT after doing PT. As can be seen from the Table 4.14 and Figure 4.17, students average marks in AT had improved after doing PT. This was also proved before with a higher correlation of 0.915 between doing the PT and then doing AT.

Table 4.14: Comparison of average marks between PT and AT for all tests

Assessment Test	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

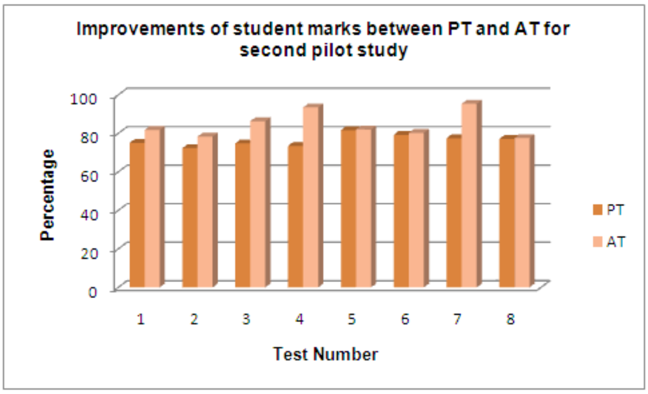


Figure 4.17: Improvements of students marks between PT and AT for second pilot study

As can be seen from the above Figure 4.17, in all the tests, the assessment test marks are higher than practice test marks. This shows that doing PT had helped students to obtain higher marks in the AT.

Analysis of second pilot study for Assessment Tests (AT)

As with the first pilot study, the average between first, second and third attempt marks for all 8 tests in the second pilot study was analyzed. As shown from the Table 4.15 and the Figure 4.18 it can be seen that average marks had improved through the attempts. Therefore, as a summary, it can be seen that more students practice with the help of the automatic feedback has enhanced the learning experience of students.

Table 4.15: Average marks of AT between the three attempts

Assessment Test	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

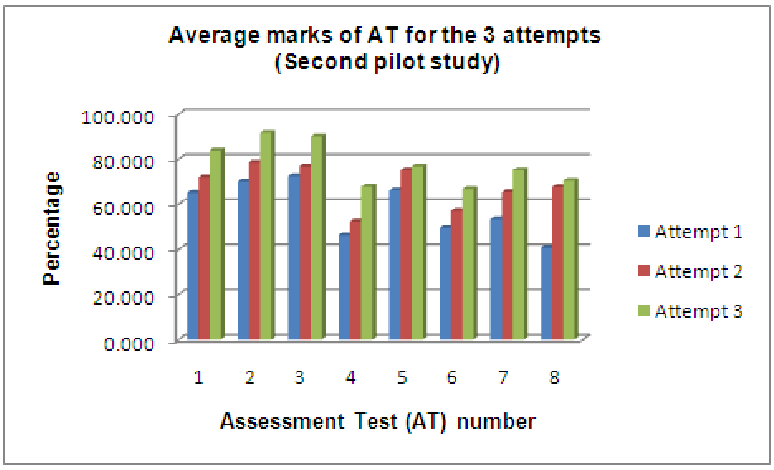


Figure 4.18: Average marks of AT for the 3 attempts (Second pilot study)

Analysis of improvements between attempt 1, 2 and 3 in both the first and the second pilot studies

Figures 4.19, 4.20, 4.21 shows the improvements between attempts (1 and 2), (2 and 3) and (1 and 3) for both the first and the second pilot studies.

In most of the cases, the average improvements in marks between attempts in the second pilot study are higher compared to the first pilot study. It can be seen that there is not a significant difference between attempt 1 and attempt 2. However, when it comes attempt 2 and 3, in some tests such as 1, 2, 3, 4 and 7, there is a considerable significant difference. As a summary, this shows that students learning process has improved with more practice through attempts. This shows that the use of the complete TEA system with enhanced features and feedback during the second pilot has helped students to improve their learning process.

Overall, from the quantitative data analysis carried-out it, can be seen that the practice with the complete TEA system using the formative e-assessment model has enhanced the student learning process.

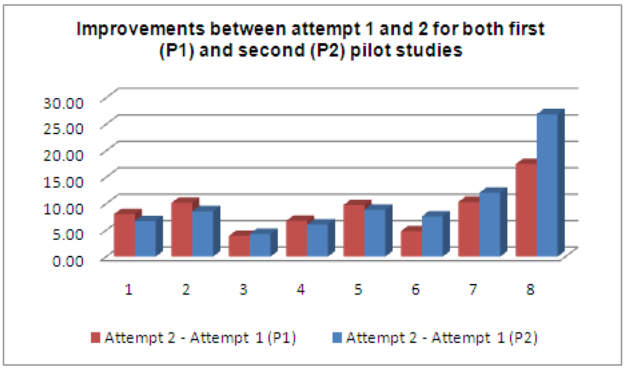


Figure 4.19: Improvements between attempt 1 and 2 for both first (P1) and second (P2) pilot studies

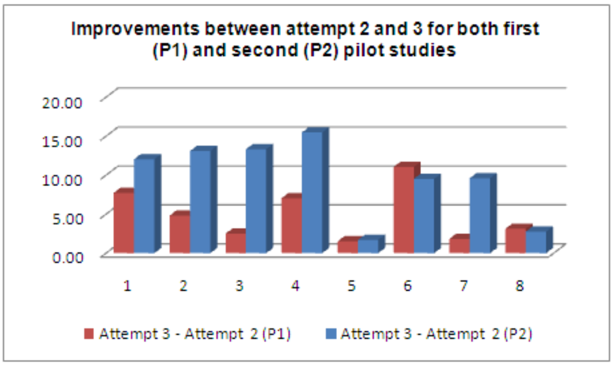


Figure 4.20: Improvements between attempt 2 and 3 for both first (P1) and second (P2) pilot studies

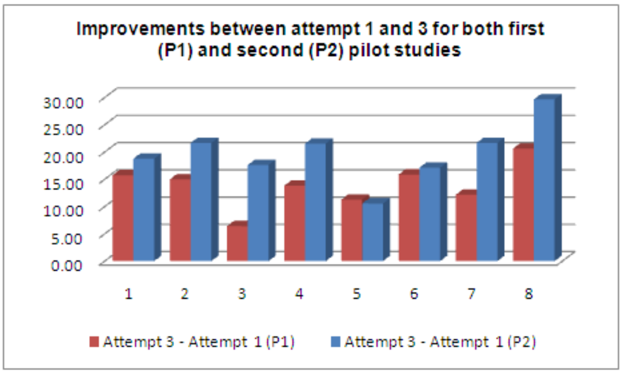


Figure 4.21: Improvements between attempt 1 and 3 for both first (P1) and second (P2) pilot studies

(d) **Using the system it is possible for teachers to track the student learning process throughout the whole course**

To track students learning throughout the course, data can be obtained from modules such as progress bar, competencies module and gradebook (outcomes are provided within this module).

Progress module was used to obtain the progress records of all the students. The average progress of students in the Logic course can be stated as 71%. The progress was calculated only after assessment tests had been marked and graded. As a conclusion, students had spent a considerable amount of time with the system and had also completed the AT assigned to them.

As for the competencies module, 12 competencies were assessed under 4 CAT (2 AT were taken as a CAT). Based on the student performance in the CAT, the progress of competencies achieved for each CAT can be displayed as in Table 4.16. In order to obtain a particular competency, students had to obtain a minimum of 50 marks for the test. Therefore, from the Table 4.16, it can be seen that overall students had performed well in the Logic course with an average of 62% progress for all competencies. Even for the individual competencies, students were able to obtain a progress of more than 50%.

Statistics obtained from the gradebook module regarding outcomes in the TEA system showed that the average course outcome was equal to “Good”. The average outcomes obtained for each topic can be displayed as in Table 4.17. According to the table it can be seen that for all modules, student outcomes were either equal or above satisfactory. This can be taken as another indicator where students have performed well in the course.

Therefore, through progress bar, competencies module, gradebook with outcome facility, it is possible for teachers to track student learning throughout the whole course.

Table 4.16: Progress of competencies achieved for each CAT

Competency	Progress
CAT 1	**81%**
1. Know to formalize expressions of the natural language using propositional logic	98%
2. Capacity to build a natural deduction proof to validate a reasoning in propositional logic	63%
CAT 2	**63%**
3. Know how to use the method of resolution to validate reasonings in propositional logic	57%
4. Know the application of the truth tables for the validation or refutation of reasonings of propositional logic	65%
5. Know how to manipulate algebraically the variables and the boolean operators and to form truth tables	65%
6. Understand the application of the boolean logic to the digital circuits	65%
CAT 3	**54%**
7. Know how to formalize in logic of predicates expressions that involve certain quantifiers	55%
8. Capacity to build a correct natural deduction proof to validate a reasoning in logic of predicates	53%
CAT 4	**51%**
9. Know how to use the method of resolution to validate reasonings in logic of predicates	51%
10. Know how to give counterexamples of a reasoning that is not valid in logic of predicates	51%
11. Know how to properly define conditions of belonging to a set	51%
12. Know the formal symbols of the set theory	51%
Course Average	**62%**

Table 4.17: Data obtained for the outcomes

Course average	Activities	Average
Good (2.22)	1.1. Formalization	Very good (1.83)
	1.2. Natural deduction	Satisfactory (3.18)
	1.3. Resolution	Good (2.14)
	1.4. Truth tables	Very good (1.78)
	2.1. Formalization	Very good (1.75)
	2.2. Natural deduction	Satisfactory (3.14)
	2.3. Resolution	Very good (1.87)
	2.4. Semantics	Good (2.03)

(e) **Students had engaged more in the classroom**

For this purpose, data were obtained from the system logs about the student participation in the TEA system. Through these data, it can be seen that students had spent a considerable amount of time in the TEA system as shown in Figure 4.22. 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).

As mentioned in the first pilot study, the TEA system have consisted of session time-out duration and therefore, students might have 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 4.22. It is interesting to note that most of these high peaks had occurred when it was close to the deadlines of AT. At the same time as with the first pilot study, it can be seen that student have used the TEA system until the final examination for practice purposes. This is due to the fact that students had appreciated the facilities provided by the system for practice purposes as well.

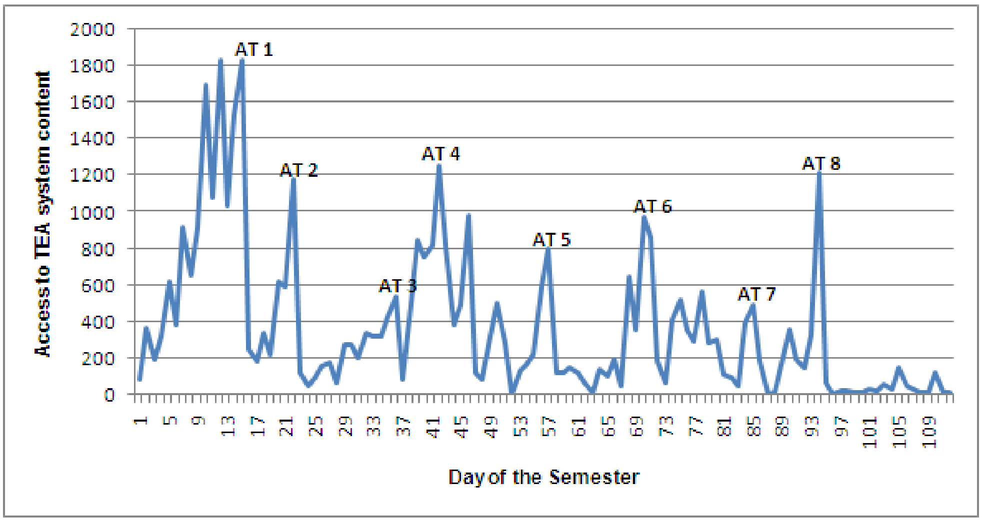


Figure 4.22: Students' participation in the TEA system

The students' participation data was also obtained from the ITS tool in both the pilot and the control groups as has shown in Figures 4.23 and 4.24. It can be seen that students in the pilot group have used the ITS more for practice and assessment compared to the control classroom since the skill assessment module includes the ITS tool. These figures shows the number of correct answers in green color, incorrect answers in red color and access to the ITS tool in blue color. In the pilot group, students have actively engaged in the system to complete the CAT, as can be seen from the high peak near the deadlines of the CAT. In the control group, students have mostly used the system after the completion dates of the CAT, this could be due to the fact that they have mostly used the ITS tool to prepare only for the final examination. In the pilot group, highest number of correct answers equals to 86 whereas in the control group it is 38. Therefore, it shows an increase of student performance and engagement in the pilot group.

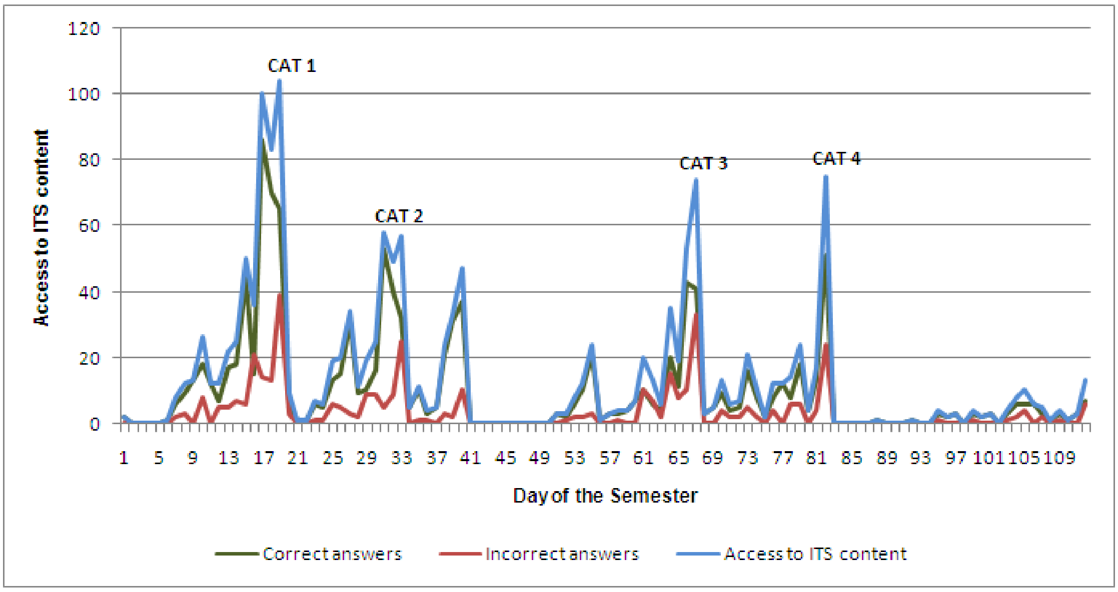


Figure 4.23: Students' participation in the ITS and skill assessment module (Pilot group)

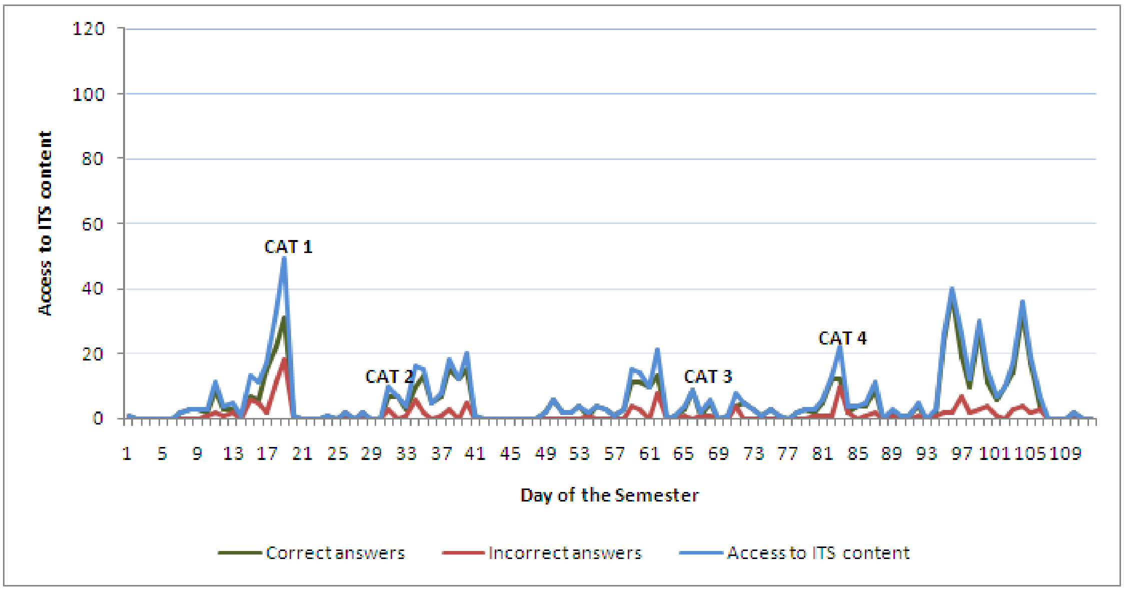


Figure 4.24: Students' participation in the ITS (Control group)

When comparing the student engagement between the first pilot study and the second pilot study, the students' performance in the skill assessment model is higher in the second pilot study compared to the first pilot study.

and this shows that students in the second pilot study had benefited from the facilities offered through the complete TEA system. When comparing the pilot studies, The student engagement between the two pilot studies can be displayed as in Figure 4.25.

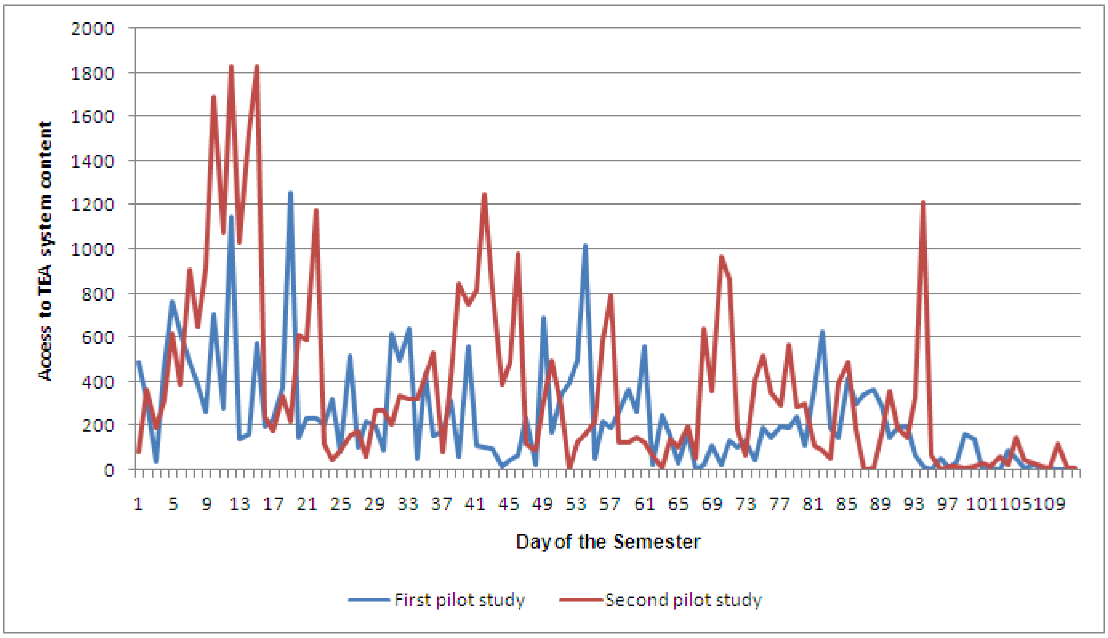


Figure 4.25: Students' participation in the TEA system - Comparison between pilot groups in the first and second pilot studies

Overall students in the pilot group had been constantly engaged in the TEA system throughout the course duration. Also student participation in the TEA system is higher in the second pilot study compared to the first pilot study. Therefore, it could be seen that in the second pilot study, students have used the system more for practice and evaluation purposes based on the formative e-assessment model with improved feedback.

(f) **Students had a good perception about their learning experience through the support provided by the TEA system**

To obtain students feedback about their learning experience, a set of questions was introduced into the questionnaire. The questionnaire is given in the

"Appendix G.2 - Questionnaire of the Second Pilot Study". The questionnaire was voluntary and as a result of that only 19 students have answered. The main results are related to skill and knowledge acquisition of the activities completed through the TEA system, the course scheduling and system time restrictions, the whole formative e-assessment, feedback and marks provided in the Logic course. These were addressed under four sections such as learner information, student satisfaction, formative assessment and assessment model. Most of the students who have answered the questionnaire were doing the Logic course for the first time. Therefore, it was interesting to obtain their comments about the use of the TEA system in the overall Logic course.

Student satisfaction

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 a clear and concise manner as shown in Figure 4.26.

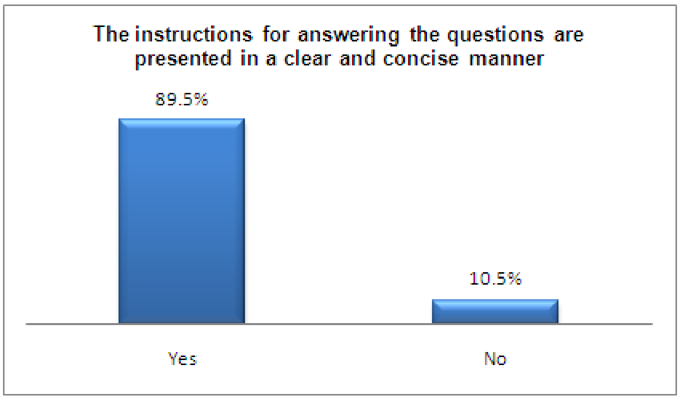


Figure 4.26: Student responses to "The instructions for answering the questions are presented in a clear and consice manner"

When it comes to obtaining students satisfaction about the automatic grades offered through the system for all tests such as PT and AT, 68% of students agreed either by saying good or very good whereas another 16% mentioned that the automatic grades were satisfactory. Here, the median was calculated as 2 and the mode as 1. Therefore, as a conclusion out of 68%, most 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 in the PT and AT. Overall it can be seen that the students were satisfied with the TEA system.

Formative assessment

Under formative assessment, students comments about the practice tests, assessment tests, feedback given within the tests, the relationship between PT and AT, improvement of learning skills, strength and weakness with respect to completing the AT, and the average number of attempts needed to accomplish the goals were obtained. First, it was needed to understand whether it was helpful to give PT before attempting the AT and 74% of students agreed as shown in Figure 4.27 and they further went on to mention that doing PT 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 AT.

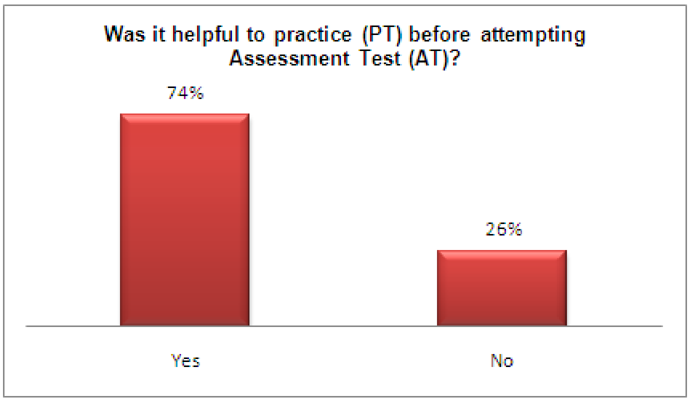


Figure 4.27: Student responses to "Was it helpful to practice (PT) before attempting assessment test (AT)?"

When it comes to the automatic feedback, 89% of students agreed that feedback provided by the TEA system about their performance was satisfactory as shown in Figure 4.28. When comparing with the first pilot study, it can be seen as an improvement from 80% to 89%. This can be taken as a reason due to the improvements made to the feedback such as detailed feedback, hints and suggestions introduced in the second pilot study.

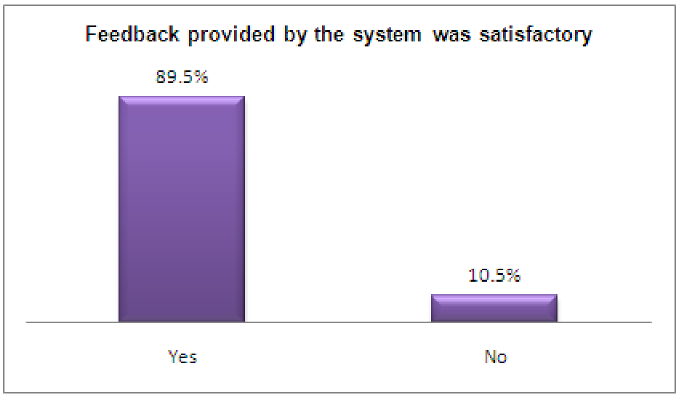


Figure 4.28: Student responses to "Feedback provided by the system was satisfactory"

For comparing the knowledge and skills acquired in the second pilot study, 89% students agreed that the marks they have obtained through the TEA system fit their knowledge and skills developed as shown in Figure 4.29. This shows a similar finding to the first pilot study of 86%. Therefore, the TEA system was capable of offering correct marks or grades to fit the skills and knowledge acquired by students.

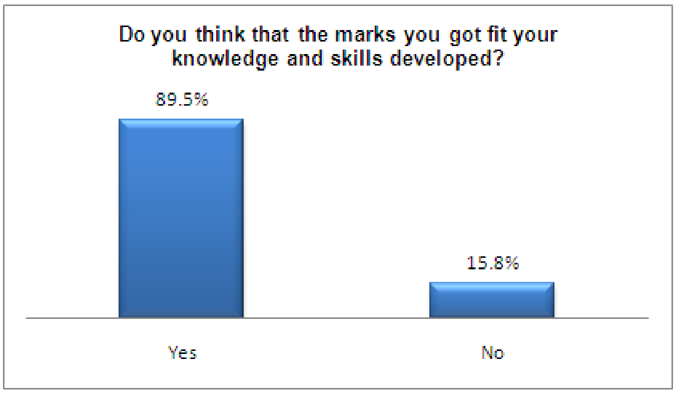


Figure 4.29: Student responses to "Do you think that the marks you got fit your knowledge and skills developed"

Also, 79% of students considered that doing PT and AT were helpful for learning skills related to the course. Detailed analysis indicated that the median was equal to 2 and mode to 1. Therefore, it can be seen that most of the students strongly agreed that doing both PT and AT were helpful for learning skills. Furthermore, students also agreed that both PT and AT helped them to understand the topics covered in the materials with an equal mode and median of 2. By comparison with the first pilot study, in this case there is a decrease of 7%, it is due to the fact that the introduction of new questions with different difficulty levels could be difficult compared to first pilot study.

Therefore, to find the difficulty of the AT, 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 shown in Figure 4.30. At the same time median and mode both equals to 2. Therefore, as a conclusion an average of 2 attempts was needed to obtain the minimum score. At the same time, it can be seen that the assessments were of medium difficulty level and they are suitable for assessment of knowledge and skills.

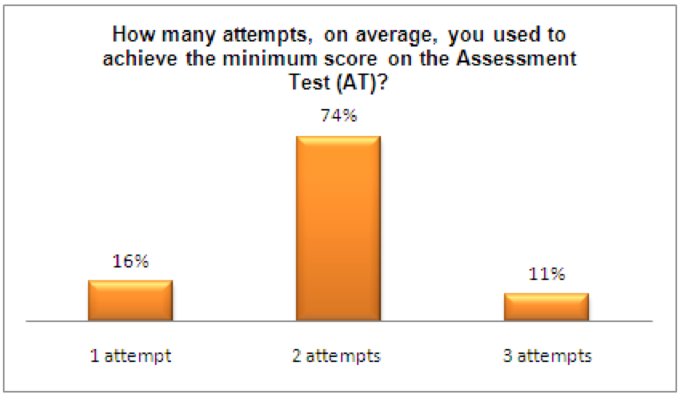


Figure 4.30: Student responses to "How many attempts, on average, you used to achieve the minimum score on the Assessment Tests (AT)?"

As with the first pilot study, even in the second pilot study 79% of student strongly agreed with a mode and median of 1, where strongly agreed correspond to value 1 and strongly disagree with value 5, that doing PT and AT have helped them to evaluate their strengths and weaknesses in the Logic subject as shown in Figure 4.31.

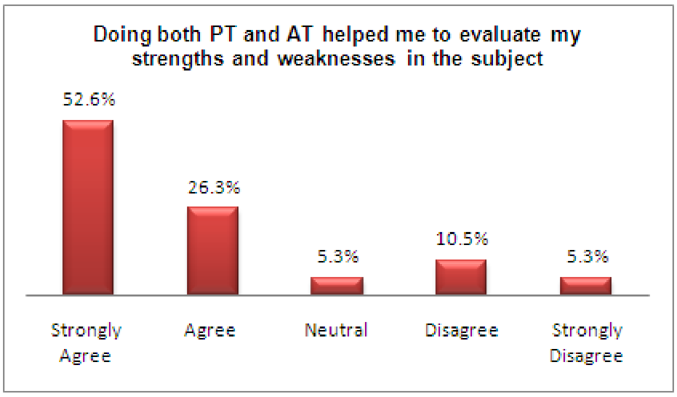


Figure 4.31: Student responses to "Doing both PT and AT helped me to evaluate my strengths and weaknesses in the subject"

Then to get students' opinions about the use of assessment tests in the subject, a question was given to ask, whether they would have learned the same if they didn't have assessment tests and 89% of students answered by saying no as shown in Figure 4.32. Therefore, students value the importance of AT in the learning process.

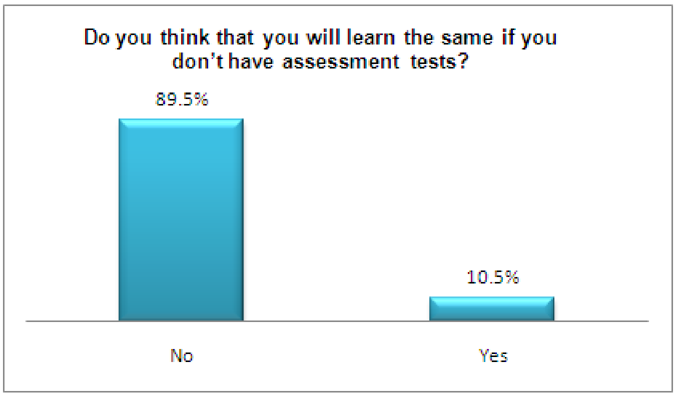


Figure 4.32: Student responses to "Do you think that you will learn the same if you do not have assessment test"

Assessment model

To compare the TEA system with the traditional method offered in the control group, students' preferences with respect to CAT, PT and AT were obtained. For this, 89% students preferred PT and AT instead of CAT.

Therefore, students preferred TEA system over traditional methods of assessments using CAT. This can be displayed as shown in Figure 4.33.

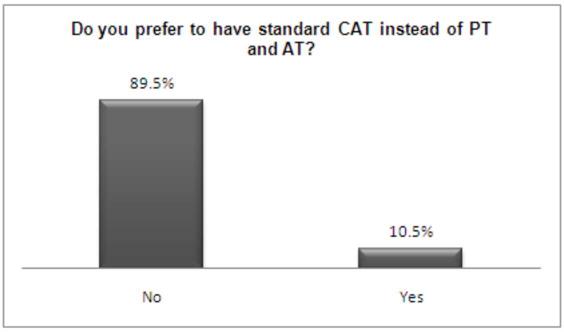


Figure 4.33: Student responses to "Do you prefer to have standard CAT instead of PT and AT?"

In the first pilot study, students have mentioned that they preferred to have a higher weight for the final continuous assessments comprising of PT and AT. Students' opinion about having a 35% of marks for the final continuous assessments and the other 65% of marks for the final examination were obtained. 58% of students agreed with this. For the students who did not agree, they were asked to give their preferred weight and 11% mentioned 50% for CAT and 50% for final examination. Another 16% mentioned 45% for CAT and 55% for final examination, also another 5% mentioned 40% for CAT and 60% for final examination and the rest of the 11% mentioned, higher weight for CAT as shown in Figure 4.34.

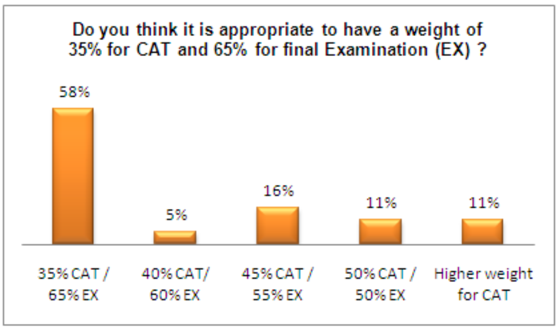


Figure 4.34: Student responses to "Do you think it is appropriate to have a weight of 35% for CAT and 65% for the final examination (EX)?"

In the first pilot study, the majority of the students preferred to have assessments within a time gap of 2 weeks, this was taken into consideration when designing the assessments in the second pilot study. Therefore, to obtain students' comments after modifications, students were given the same question as "what would be the best time difference to perform frequency of assessments" and 84% answered 2 weeks. Also, both the median and mode is equal to 2. As a conclusion the frequency of assessment in the TEA system should be set to 2 weeks. Since in the first pilot study as students have mentioned, they found it really stressful to complete all the tasks allocated within the given time, the minimum pass mark of PT was changed to 30 and the time gap to 2 weeks. When asked about the students' option about the minimum pass mark of 30% that has to be obtained in the PT to move to AT, 68% agreed with this restriction. This can further be proved with a median and mode of 2 for the question.

Second pilot study comprised of the complete TEA system with additional modules such as a progress bar, gradebook with outcomes and a competencies module. Since students were not informed about the progress bar throughout the duration of the course, a question was asked as "Did you pay attention to the progress presented in the progress bar?" and 89% students mentioned "yes". Then students were asked whether it was useful for them to see the progress in a graphical way and 84% agreed with this. However, 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. Therefore, it can be seen that some have used the benefits of having a progress bar whereas others have not.

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. This can be shown as in Figure 4.35.

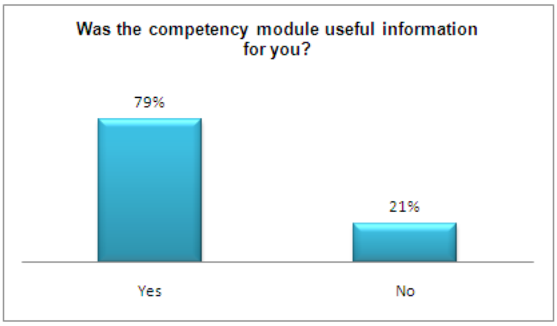


Figure 4.35: Student responses to "Was the competency module useful information for you?"

However, when asked about grades and outcomes, interesting 100% agreed that both grades and outcomes were useful information as shown in Figure 4.36.

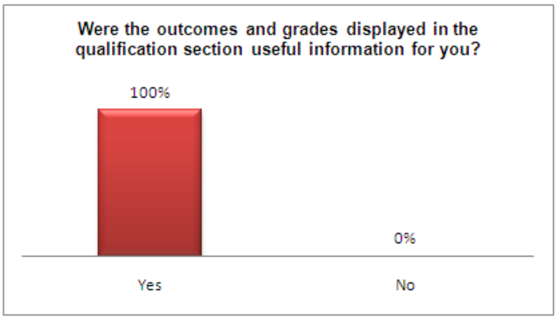


Figure 4.36: Student responses to "Were the outcomes and grades displayed in the qualification section useful information for you?"

Finally, an open-ended question was given to obtain students comment 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 of 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"*. Some students have mentioned, the time given as 2 hours for the AT was not enough as some questions take a long time to construct the solution. Some also mentioned that the schedule of the assessments should be more elaborated in the course schedule as: *"Everything perfect, except that the dates of the AT should also appear in the course schedule, which currently has only the dates of the CAT"*.

4. **Evaluate results and draw conclusions**

   As mentioned under the data analysis, the following propositions have to be addressed.

   (a) **The system supported student learning process**

   Based on the t-student statistical data analysis carried-out (without formalization marks), it can be seen that the system supported student learning process. However, this was not the case when the formalization marks were included in the final examination. After looking into the data analysis, teachers decided to introduce MCQ type of questions in the final examination paper for the formalization section from the next semester. Another possibility mentioned by teachers was that in the future, questions for the formalization section could be introduced in the skill assessment module. After making the appropriate changes, this has to be further analysed in the future.

   As a summary, by looking into the second pilot study (without formalization), it can be stated that the students' learning process has been improved through the support provided by the TEA system.

   (b) **Using the system and the formative e-assessment model to perform continuous formative assessment helped in the final examination marks**

   After analysing the correlation data between completing the Continuous Assessment (CA) and the completing the final face-to-face examination, it indicates that there is a high significant in the pilot group compared to the control group. In the pilot group as CA, students completed 8 AT (comprised of both MCQ and CAT) whereas in the control group students had only 4 CAT which was same for all the students. Based on this, it shows that students had obtained the benefit provided by the TEA system and the formative e-assessment model for both practice and assessment purposes. Also practicing using the system had helped students in the final examination.

(c) **Using formative e-assessment model helped students to improve their learning process**

Based on the comparison between completing the PT and then completing the AT, it showed a higher correlation. Also it indicates that through practice student marks have improved in the subsequent attempts. Also average marks of AT after the completion of PT were also high. Further AT average marks had also improved 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 improve their learning process.

(d) **Using the system it is possible for teachers to track the student learning process throughout the whole course**

Based on the data obtained from the progress bar, it showed that students had spent a considerable amount of time with the system and had also completed the AT assigned to them. Based on the data obtained from the competencies module, students had used the TEA system considerably and as a result they were able to achieve a higher competency in the Logic subject. Data obtained through outcome module is another indicator which showed that students had performed well in the course.

From the statistical data obtained from progress bar, competencies and outcomes, it showed that students skills were at a considerable level. Therefore, as a summary, it can be stated that through progress bar, competencies module, gradebook with outcome facility, it is possible for teachers to track student learning throughout the whole course.

(e) **Students had engaged more in the classroom**

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. Also students had used the system even after the completion of dates of the AT. This showed that students had used the system to prepare for the final examination.

Comparing with the first pilot study, the students engagement in the system is higher in the second pilot study. This showed that with the added functionalities and the complete system, students had used the system more to obtain the maximum benefits through practice and assessment.

Also from the data obtained from the skill assessment module, it showed that the performance of pilot group students were higher than the control group students. When comparing with the first pilot study, it showed that students performance in the skill assessment module has increased in the second pilot study.

Overall, as a conclusion, it can be stated that students in the pilot group had constantly engaged in the TEA system throughout the course duration compared to the control group.

(f) **Students had a good perception about their learning experience through the support provided by the TEA system**

Overall students were satisfied with the TEA system, formative e-assessment model, course scheduling, marks and feedback provided. Students were also satisfied with the improved feedback and they believe that completing PT had helped them to complete AT better, and to evaluate the skill and knowledge acquired. Also, according to students, PT and AT 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 AT, mostly for the sections where students have to construct the answer using the skill assessment module. At the same time, a complete schedule with PT, AT and CAT has to be displayed in the main course page.

Conclusions based on the propositions

The purpose of the second pilot study was to the complete system as well as the proposed formative e-assessment model.

This purpose was evaluated with respect to six propositions. With respect to supporting student learning process, in both cases of first and second pilot studies, this was addressed based on the t-student data obtained through the final examination marks. In both cases (the second pilot study was considered without formalization marks), it showed an increase of marks in the pilot classrooms. Therefore, it can be concluded that the TEA system was capable of supporting student learning process.

At the same time, using the system and the formative e-assessment model for doing Continuous Assessments (CA) had helped in the final face-to-face examination (EX) as there was a high correlation between the CA and the EX. In the case of second pilot study, the correlation difference between the pilot group and the control group was significantly higher compared to the first pilot study.

Also, more practice with the formative e-assessment model had helped students in both pilot studies to improve their learning process. In both pilots, there was a high correction between doing the Practice Tests (PT) and then doing the Assessment Tests (AT). In both pilot studies, it has shown that students have used the system for practice to obtain the maximum benefits. It was shown that the more students practice, the more marks they have obtained in the subsequent attempts. Even through average marks obtained, it was also shown that doing PT have helped students to perform better in the AT. Furthermore, when comparing the first pilot study and the second pilot study, where the second pilot study consisted of more detailed information rich feedback, improvements in the average scores between attempts were higher in the second pilot study. This shows that the use of the complete TEA system with enhanced features and feedback in the second pilot study had helped students to improve their learning process. As a summary, from the quantitative study, it can be seen that the practice with the complete TEA system using the formative e-assessment model had enhanced the student learning experience.

At the same time, the TEA system supported teachers by providing the facility to track students learning process throughout the whole course. For this, data provided through modules such as progress bar, competencies module, gradebook with outcomes facility and statistics module was used.

It could also be seen that students were constantly engaged in the TEA system for both practice and assessment purposes. They have even used the system in both pilot studies, for practice purposes after the completion date of the assigned assessments were over. Comparing among the pilot studies, the student engagement is higher in the second pilot study.

Also, from the student participation data in the skill assessment model, it showed that students' performance in the pilot groups are higher compared to the control group. When comparing the pilot studies, the students' performance in the skill assessment model is higher in the second pilot study compared to the first pilot study.

Based on the students' perceptions, they were satisfied with the learning experience, support and facilities offered by the TEA system and the formative e-assessment model. According to feedback and suggestion of students, few improvements has to be carried-out for as mentioned under the "(4) Evaluate results and draw conclusions" which will be carried-out as future work.

As a summary, it can be stated that the introduction of the technology-enhanced assessment system along with the formative e-assessment model for knowledge and skill assessment process has yielded some interesting research results.

4.2.4 Addressing Some of the Research Questions

One of the research activities of this research is to "Validate the proposed technology-enhanced assessment system in a real online environment by conducting pilot studies". Since both pilot studies were discussed under the "Section 4.2 - Validation" of this chapter, it is interesting to address the research questions which are related to this section based on the data obtained from the pilot studies. However, these research questions are addressed generally under the "Chapter 5 - Conclusions, Findings and Future Research.

The research questions and the way they were addressed can be listed as follows:

- *Can the technology-enhanced assessment system support student learning process?*
  Yes. In both pilot studies (second pilot study without formalization marks), it showed that the final examination marks were higher. Furthermore, there was a high correlation between the final Continuous Assessments (CA) and the final face-to-face examination (EX) in the pilot classroom than in the control classroom. Additionally, student performance in the pilot classrooms is a bit higher than in the control classrooms with respect to the final grade. This is due to the reason that in the pilot classrooms students have practiced more compared to the control classrooms. This was proved in both pilot studies using the log data obtained from the TEA system. It could also be seen that in second pilot study students have used the system more compared to the first pilot study. Therefore, as a summary it could be seen that the technology-enhanced assessment system had supported the student learning process through the formative e-assessment model and as the result students' performance were better.

  However, when it comes to second pilot study, there was a problem with the formalization questions (this was mentioned under the "Section 4.2.3 - Second Pilot Study") as students were not prepared for the questions offered in the final examination. After analysing the problem, teachers agreed to introduce MCQ questions into the final examination in the next semester. They also mentioned that there is a possibility of introducing formalization questions through the skill assessment module in the future. This can be further analysed in the future. In fact this shows that, the format of questions offered in the summative assessment must be related to the formative assessment.

- *Does practice with the formative e-assessment model, enhance the student learning experience?*
  Yes, this was proved based on the quantitative study with respect to practice and assessment tests. In both pilot studies, there was a high correlation between completing the PT and then doing the AT. Then student data with respect to PT in both first and second pilot studies were analyzed. It can be seen that

most of the students have used at least 2 attempts for practice purposes. It was observed that there was an impact on scores in AT after doing PT, as the average marks of AT had improved in both pilot studies. It was seen that the marks had improved through the attempts. It was also observed that in most cases, the average improvements in marks between attempts were higher in the second pilot study compared to the first pilot study. This showed that the use of the complete TEA system with enhanced features and feedback in the second pilot study had helped students to improve their learning process.

Even based on the student perceptions obtained from the questionnaire, they had agreed that doing PT and AT had helped them to understand the topics covered in the materials. They also agreed that the automatic feedback provided by the system was satisfactory. Furthermore they agreed that doing both PT and AT helped them to identify their strengths and weaknesses as well as to learn skills related to the course. Therefore, as a summary, it can be stated that practicing with the formative e-assessment model has enhanced the student learning experience.

- *Is it possible for teachers to track student learning process throughout the whole course?*
  Yes, to track students learning throughout the course, data were obtained from progress bar, competencies module, gradebook with outcome facilities and statistics module. Teachers used the progress bar to track students' progress throughout the whole course. This module provided teachers with the overall progress of each student and this helped to track students' average progress and performance with respect to the tests provided in the system.

  Competencies module was used to track the competencies and sub-competencies achieved by students. Teachers had the possibility to obtain the competencies and sub-competencies achieved as a percentage and this helped to understand where special consideration had to be given with respect to the particular content in the subject area.

  Gradebook module was used to track grades obtained by students for both PT and AT along with the average grades for each test. In addition to grades, outcomes were also provided for each PT and AT along with an outcomes report which gave the overall average for the course and the average outcome obtained for each test.

Additionally, inbuilt statistics module was used to track information with respect to student performance in each PT and AT, suitability and quality of each question given within the test, students' participation details in the system and system logs.

This information was used to track student learning throughout the whole course. Data analysis associated with these modules was given under the "Section 4.2.3 - Second Pilot Study" section As a summary it can be stated that through the facilities provided by the system it was possible to track student learning throughout the whole course.

4.2.5 Summary

This section explained the validation of the TEA system and the formative e-assessment model with respect to the validation methodology and the plan. Under this, two pilot studies carried-out were explained along with the conclusions deduced from them. Then some of the research questions associated with this section were also addressed. The results of both pilot studies had shown that technology-enhanced assessment system was capable of supporting student learning process, practicing using the system with the help of formative e-assessment model had enhanced the student learning process, the student learning experience was better through the support provided by the system and teachers could track students learning throughout the whole course with the help of the facilities provided by the system.

5

Conclusions and Future Research

This chapter presents the conclusions, findings and future work related to this research. First, it starts off with a discussion on meeting the objectives of the research while addressing the related research questions. Also, it presents the original contributions of this research and the chapter concludes with future research work and closing remarks.

The fundamental aim of this research is to propose a general technology-enhanced assessment system to provide a new learning experience for students in both skill and knowledge assessment in an online educational environment. This was achieved through a design and development of a general technology-enhanced assessment system which can be adapted to any context. As practice is an important aspect of e-assessment which allows students the opportunity to act on the feedback, a formative e-assessment model which include both practice and assessment facilities was proposed and used within the technology-enhanced assessment system.

The system was designed and developed according to "Design and Creation" research strategy which involved five steps; awareness, suggestion, development, evaluation and conclusion. These steps were followed in an iterative manner according to User Centered Design (UCD) process.

Finally, the system was validated after applying it into the Logic course of the UOC. The Logic course was selected as it is a subject which requires a higher level of skill and knowledge in order to qualify in it.

The results obtained through the design, development and validation stages are used to address the research activity, questions and objective as follows.

5.1 Meeting the Objectives

This research consisted of two main research activities, one was based on the design and development stage and the other on the evaluation stage of the research. Under each research activity, related research questions were addressed.

This section revisits the research activities and questions which have been set out in the “Section 1.2 - Research Objectives and Questions” of the Chapter 1. Since these research questions were addressed with respect to the case study of the Logic course, in the “Chapter 4 - Evaluation” under both “Section 4.1 - Testing” and “Section 4.2 - Validation”, here the research questions are addressed in a more general way.

The research activities and questions accomplished can be addressed as follows:

1. **Design and develop a technology-enhanced assessment system for assessing both skills and knowledge in online education**

    (a) *Which e-learning and e-assessment standards and specifications should be followed in order to develop an e-assessment system which is interoperable and secure?*

    As described under “Section 2.4.2 - Standards and Specifications”, several standards and specifications related to e-learning and e-assessment can be listed as IMS Basic LTI, IEEE PAPI, O.K.I., IMS QTI, IMS LIP, LOM and SCORM. Out of them, IEEE PAPI and IMS LIP can be used for exchange of learner information between different systems. Also, O.K.I offers an architecture with Java API, that specifies how the components of a learning technology environment communicate with each other and with other campus systems. IMS Basic LTI can be used for integrating rich learning applications with other platforms.

    At the same time, standardized and a flexible e-assessment system should include features such as; flexible design, user-friendly interfaces, assessment environment for various learning and assessment settings, management and semi-automatic support, rubrics design and implementation interfaces on learning objectives to assess learners performance against a set of criteria, support of various educational objectives and subjects, results analysis and feedback provision (immediately or timely), standard-conform information and services and security and privacy as explained under "Section 2.4.2 - Standards and Specifications".

These features were considered while deciding on the appropriate standard for the design and development of the e-assessment system. In this research, as described under the "Chapter 3 - Design and Development of the Technology-Enhanced Assessment (TEA) System", since the TEA system was developed according to modular architecture, it was needed to find an appropriate standard which can communicate and transfer data between modules in a secure manner. Also, interoperability was another important factor which was considered as any tool should be able to easily connect and exchange data between them. Although in general, several standards and specifications can be used, considering the factors mentioned above, IMS Basic LTI specifications were used as a standard way of integrating rich learning applications with platforms like learning management systems, portals, or other educational environments. Along with this, OAuth protocol was used for secure message interactions between the modules to transfer data (user information and grades) back and forth.

(b) *Which tools can be used for assessment of skills and knowledge subjects?*

Knowledge can be specified as the recall or recognition of specific items. It can be more elaborate as remembering of previously learned materials. This may involve the recall of a wide range of material, from specific facts to complete theories, but all that is required is the bringing to mind of the appropriate information. Knowledge represents the lowest level of learning outcomes in the cognitive domain and therefore, exercises that require knowledge to be memorized only account for a fraction of the overall examinations. When the core of knowledge is a fundamental base for the study of the subject, knowledge assessment can be used. This type of assessment is quicker in delivery, gives more specific and directed feedback to individuals and can also provide greater curricular coverage. At the same time, they can be limited in scope and can occasionally degenerate into a quiz of facts about the area of study. Therefore, any tool which consists of 'usual type' of questions such as multiple choice questions, multiple responses, short answers, fill in the blanks, matching and crossword puzzles can be used for this.

Skills 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. Skill-based questions are more aligned towards modeling of information flows; constructing processes and problem solving, where students have to apply their analytic, creative, and constructive skills to obtain an answer. Therefore, skills cannot be assessed via multiple-choice tests and equivalent forms of basic assessment items. For the assessment of skills it is needed to go beyond these types of questions and introduce a tool which is capable of offering questions, where students have to construct the answer while engaging in the tool. In this case, each step of action performed by the student is monitored and feedback is offered in a personalized manner based on the actions. The skill assessment tool should also guide the student if they are moving too far away from the correct answer. One example can be taken as the construction of program codes.

At the same time, since these tools are used for assessment they should adhere to the general characteristics of an e-assessment system such as different types of questions for both practice and evaluations of skill and knowledge acquirement; immediate grading facility; immediate feedback at various stages of the assessment process; facilities to minimize the level of cheating; display of progress and overall competencies to students; facilities for teachers to evaluate marks, progress, competencies, outcomes, and statistics.

Based on the literature review, most of the current assessment systems use 'usual type' of questions mentioned before. At the same time, literature did not provide a general system which can be used for both skill and knowledge assessment.

Therefore, considering the above, it was decided to design and develop a general e-assessment system which can be integrated with any tool that supports skill and knowledge assessment.

For knowledge assessment, MCQ type of questions were used. For skill assessment, it was decided to make use of an existing ITS tool and enhance it into an assessment tool. The reason for doing this was to make the system general which allows any tool to be easily integrated with the system in a secure and interoperable manner to provide skill and knowledge assessment.

(c) *Can a technology-enhanced assessment system be developed as a series of modules to support both skills and knowledge while maintaining interoperability and security?*

Yes, it is possible to develop a technology-enhanced assessment system as a series of modules and, in this research, the TEA system was developed in this way.

The key elements of the technology-enhanced assessment system should be the skill and knowledge assessment modules. Other than that, the system should be incorporated with features for the students' progress, competencies, grades and outcomes.

As mentioned in the previous research question, these modules should adhere to the general characteristics of an e-assessment system. At the same time, skill and knowledge assessment modules should consist of the question types mentioned in the previous research question.

To maintain interoperability and security, these modules should be designed and developed in a standardized manner. To maintain interoperability, they should be integrated with each other through appropriate standards and specifications. For security, interaction of information and data between these modules should be carried-out through appropriate standards and protocols.

Conclusions of the research activity

In order to design and develop an e-assessment system, different e-learning and e-assessment standards and specifications can be used. To integrate with different learning applications or exchange data between these tools, standards and specifications such as IEEE PAPI, IMS LIP, O.K.I and IMS Basic LTI can be used. To maintain both security and interoperability while integrating with other platforms and exchanging both student information and grades IMS Basic LTI specification can be taken as the most suitable standard. This is a specification that is currently being evolved and therefore, some applications and platforms are also looking into the possibility of integrating this standard into their system. OAuth protocol can be used together with the IMS Basic LTI specification to exchange data such as user information, grades and statistics.

It is possible to design and develop a technology-enhanced assessment system as a series of modules according to the modular architecture. This is a good solution because it does not require to design and develop the system from scratch and as a result, it saves time. In this case, to maintain security and interoperability among modules appropriate standards and specifications should be selected.

When selecting a tool for skill and knowledge assessment, the literature did not provide a general tool which can be used for this purpose. Therefore, different tools for knowledge and skill assessment can be used and integrated together through the standards and specifications mentioned before. When selecting a tool for knowledge assessment, any tool which consists of 'usual type' of questions such as multiple choice questions, multiple responses, short answers, fill in the blanks, matching and crossword puzzles can be used. For skill assessment, a tool which is capable of offering questions, where students have to construct the correct answer can be used. This tool should monitor each step of action performed by the student and offer personalized feedback based on the actions. At the same time, the system should adhere to the general characteristics of e-assessment systems mentioned under the research question, *Which tools can be used for assessment of skills and knowledge subjects?*.

Overall as a summary, it can be stated that the research activity, design and develop a technology-enhanced assessment system for assessing both skills and knowledge in online education, was achieved as a result of this research. Moreover, guidelines are provided for, a design and development of a general TEA system and how the proposed solution can be adapted to any context.

2. **Validate the proposed technology-enhanced assessment system in a real online environment by conducting pilot studies**

   (a) *Can the technology-enhanced assessment system support student learning process?*

   For supporting the student learning process, a formative e-assessment model was introduced through the TEA system. This model provided both practice and assessment facilities for students to improve their learning process. As a result of this model, students were constantly engaged in the system mostly for practice purposes and as a result their performance in the formative assessments and final examination had improved.

   The TEA system was designed and developed to support both skill and knowledge assessment. The practice and assessment tests offered through the formative e-assessment model consisted of questions which was used for evaluating both skill and knowledge acquirements. Therefore, it was easy for students to master the knowledge and skills needed for a particular topic through practice as well as through the detailed feedback provided.

   Also, the information provided through the progress bar and competencies module helped students to evaluate their own progress. Mostly, progress bar helped in this context as it was clearly visible throughout the whole course duration. It showed the tests completed, not completed and the ones to be completed within the allocated deadline. At the same time, it showed where the rest of the students in the classroom were at that particular moment. This helped students to understand their learning progress and to act accordingly, as well as to complete the tests in order to match up with the rest of the classroom.

   Competencies module also helped to contribute to students learning process as it showed the competencies that students were able to achieve as well as the competencies that they were not able to achieve. This supported students to understand their weak areas in the course and practice more to improve them.

   At the same time, gradebook indicate the marks, grades and outcomes obtained by students for each test. This also supported students to understand their strong and weak areas of the subject content. As a result they could practice more in the weak areas to improve their marks and outcomes.

Therefore, as a summary, the technology-enhanced assessment system had supported the students learning process through the formative e-assessment model and as a result students' performance were better.

(b) *Does practice with the formative e-assessment model, enhance the student learning process?*

Formative e-assessment model used in the technology enhanced assessment system was designed based on both skills and knowledge activities, thinking in the iterative process that students had to follow in the course. This means that students were doing activities and obtaining feedback and marks. If the feedback and marks obtained were not positive, they had to do more practice in order to pass the corresponding unit of learning. Therefore, formative e-assessment model implies spending time with the system in practice and learning activities and through the data analysis carried-out, it can be seen that practicing using the formative e-assessment model had improved students learning process.

This was analysed by validating how much students had practiced using the formative e-assessment model and the impact it had on the given assessment tests.

In the pilot studies, completing the practice tests and then completing the assessment tests showed a higher correlation between them. This was also confirmed through the marks obtained for the assessment test after the completion of the practice tests. Based on the average marks, students' marks in the assessment tests had improved after completion of the practice tests. Even the marks of assessment tests had improved with each attempt taken. Based on the analysis of practice test data, in both pilot studies, it showed that the students' marks had improved through the attempts carried-out.

(c) *Is it possible for teachers to track students learning process throughout the whole course?*

Yes, it is possible to track students' learning process throughout the whole course. For this, the TEA system modules such as progress bar, competencies module, gradebook with outcome facilities and statistics were used. In addition to that, students' practice and assessment data are visible to teachers through the reports provided in the system such as logs, live logs, activity participation and course participation. Through activity participation, it was possible for teachers to obtain students' practice data for each test. In a traditional classroom consisting of paper-based practice method, students' practice data are invisible and teachers could not track students' learning process.

Conclusions to the research activity

For supporting the student learning process, a formative e-assessment model which provided both practice and assessment facilities was introduced through the TEA system. As a result of this model, students' performance in both the formative assessment and summative assessment had improved. Also, both progress bar and competencies module helped students to evaluate their own progress. Gradebook provided valuable information such as marks, grades and outcomes obtained by students for each test. Overall, it can be stated that the technology-enhanced assessment system had supported students learning process and as a result students' performance had improved.

Formative e-assessment model implies spending time with the system in practice and learning activities and through the data analysis it showed that students had obtained the benefit of this model. Based on pilot studies, it showed a high correlation between completing the practice tests and then completing the assessment tests. Also, based on the average marks, students' marks in the assessment tests had improved after completion of the practice tests. The marks of assessment tests had also improved with each attempt taken. Altogether, it has shown that practicing using the formative e-assessment model had improved students learning process.

Through the modules of the TEA system such as progress bar, competencies module, gradebook with outcome facilities and statistic, it was possible for teachers to track the student learning process. Additionally, teachers could also obtain the students' practice and assessment data through reports such as logs, live logs, activity participation and course participation.

Overall as a summary, it can be stated that the research activity, validate the proposed technology-enhanced assessment system in a real online environment by conducting pilot studies, was achieved.

After addressing both research activities and questions, it is the time to revisit the main objective of the research as follows.

Objective of the research :

Propose a general technology-enhanced assessment system for skill and knowledge assessment in online education.

This was achieved through a design and development of a technology-enhanced assessment system which was compatible with the current standards of such technology. This system was capable of offering both skill and knowledge assessment in a fully online environment. In order to introduce a new learning experience through practice and assessment, a formative e-assessment model was proposed. Also to aid teachers with the assessment and monitoring of students learning process, features such as progress bar, competencies, grades, outcomes and statistics were integrated into the TEA system.

5.2 Original Contributions

With respect to this research in the case of Logic, the following contributions are found to be new.

- ***Proposal of a fully automated formative e-assessment model for both skill and knowledge assessment***

  When considering the existing research, most of the systems which offered formative assessment consisted of 'usual type' of questions such as MCQ, true/false, short answer and fill in the blanks, which cannot be used for assessment of higher cognitive skills. One of the objectives of this research was to go beyond MCQ type of questions and introduce a dynamic skill and knowledge assessment into the formative assessment process.

  Logic was taken as the case for this research, which is an example of a wider set of subjects with high level of skills were practice is needed. In the context of Logic, before the introduction of the technology-enhanced assessment system, for practice purposes students only used paper-based methods and the ITS tool. Even the student participation in the ITS tool (only capable of offering practice based on skill acquirements for some topics of the subject) was low. When it comes to topics such as formalization and semantics, the only way of practicing was through the traditional pen and paper method. Proposed formative e-assessment model went a step above the assessment model and introduced practice with feedback into the process as well. This was done with the intention of allowing students to practice more and act on the feedback obtained to improve their learning process. Based on the data analysis carried-out, it can be stated that this research was able achieve that objective. The TEA system provided benefits not only for practice but also for assessment purposes.

  With the introduction of the technology-enhanced assessment system, students were provided with a fully automated formative e-assessment process for assessment of both skill and knowledge acquirement. As a result, it was possible to improve students' learning process based on skills as well as to increase student engagement in the Logic subject. Therefore, through the TEA system, it was possible to obtain more benefits of the online environment.

According to the results provided in the "Chapter 4 - Evaluation", it can be seen that students were constantly engaged in the system. At the same time, the results showed that there was a high correlation between completing the formative assessment using the TEA system and then doing the final examination, as well as, between doing the practice tests and then doing the assessment tests. This shows that students' performance in the learning process had improved through the support of the system as well as through practice. Overall performance in both the formative and summative assessments had improved with respect to the introduction of the TEA system in both skill and knowledge assessment. Even though, the system was used in the Logic course context, it was designed and developed in a general way which can be adapted for any other subject.

- ***Introduction of tracking elements such as, progress bar, competency based evaluation and outcome based evaluation into the e-assessment system***

  In addition to the assessment facilities, the technology-enhanced assessment has been enriched with facilities such as a progress bar, competencies module, gardebook with outcomes facilities and statistics. These facilities were mainly introduced to support teachers for evaluating the subject content and questions provided with respect to goals and competencies of the subject. However, they also provide information for students such as their progress with respect to the classroom, the outcomes achieved for a particular activity and the competencies achieved in the whole course. Even though these facilities were not fully utilized in the pilot studies, they will be fully introduced into the e-assessment process in the future to obtain the maximum benefits.

- ***Development of a standardized plug-in which can be used to connect the TEA system with any other tool which provides data communication among the tools***

  Since the TEA system was developed according to the modular architecture, a standardized plug-in was developed for the TEA system which can be used to connect any tool and transfer data back and forth between tools. This tool was developed using the IMS Basic LTI specification and the OAuth protocol. The main reason for developing this, was to maintain the standardization which maintains security and interoperability. In this research, this plug-in was used to connect an ITS tool to the TEA system. But instead of this, any other tool can be easy connected and used with the TEA system. When it comes to most of the e-assessment tools, they are specific to a particular subject area or an organization. Modifying and using them in the appropriate context is not easily as they have to be modified from scratch. Therefore, this research aimed to go beyond this restriction and introduce the flexibility of using any tool for the e-assessment process, as the TEA system is capable of providing assessment facilities through the plug-in developed. As future work, this plug-in has to be tested with other tools and other subjects.

- ***Possibility to incorporate formative assessment to the assessment model of an online classroom as a result of the technology-enhanced assessment system***

  As mentioned in the "Chapter 4 - Evaluation", there was a high correlation between completing the Assessment Tests (AT) using the technology-enhanced assessment system and then completing the final face-to-face examination. These assessment tests were different for each student as the questions provided within each assessment test were randomly selected from a large question bank with different difficulty levels. Also due to enabled browser security features, it was not possible to copy and paste the questions and answers into a document. Thus, teachers can rely on AT to avoid cheating possibilities and give more weight to formative assessment compared summative assessment. Moreover, if the formative assessment which includes both practice and assessment tests has more weight than final face-to-face examination, then more students will follow it.

  Also based on the above, generally this assessment model can be introduced into other classrooms which only make use of the summative assessment. This has many benefits associated with it. The introduction of the TEA system into the assessment model allows students to continuously practice and engage in the subject. As a result, it improves students' learning process and performance in the subject. This also reduces teacher workload as the system is capable of supporting students with the immediate information rich feedback and it helps teachers to track students' learning process. Since there are a number of advantages, it is possible to change the assessment model of an online classroom as a result of the introduction of the technology-enhanced assessment system.

- ***Scientific contributions to conferences and journals***

  With respect to this research, several local and international conference papers and journal articles were published. It is also needed to publish some more papers based on the final results of the thesis, which will be carried-out as future work.

  The papers published in the conferences and journals are listed below:

  - Hettiarachchi, E., & Huertas, M. (2011). E-assessments and how it can be adapted to mathematical e-learning. In 3rd International Workshop on Mathematical E-Learning (E-MATH 2011). eLearn Centre / IN3 / UOC. Barcelona, 21 - 23 June.
  - Hettiarachchi, E., & Huertas, M. (2012). Temporal Aspects of Mathematical e-Assessment Systems. eLC Research Paper Series(4), 37- 42.
  - Hettiarachchi, E., Huertas, Mor, E., & Guerrero-Roldan, A. (2012a). An Architecture for Technology-Enhanced Assessment of High Level Skill Practice. In IEEE 12th International Conference on Advanced Learning Technologies (ICALT), 2012, 38-39.
  - Hettiarachchi, E., Huertas, Mor, E., & Guerrero-Roldan, A. (2012b). A Standard and Interoperable Technology-enhanced Assessment System for Skill and Knowledge Acquirement. In M. Helfert, M. J. Martins, & J. Cordeiro (Eds.), CSEDU (2), 157-160. SciTePress

5.3 Future Research

From the educational point of view, the main goal of this research was to provide a new learning experience for students in both skill and knowledge assessment in an online educational environment. As mentioned earlier, this was done through the introduction of a general technology-enhanced assessment system together with the formative e-assessment model.

Based on that, whether the TEA system is capable of supporting student learning process and whether practice through the introduced formative e-assessment model with feedback helped students in their learning process were studied. At the same time, it was analyzed to find whether the teachers can use the system to track student performance.

From the technological point of view, the main goal was to design and develop a general technology-enhanced assessment system according to standards while maintaining security and interoperability.

This research was performed in the UOC, a fully online university and it was centered on the Logic course of the Computer Science degree. Although this research was carried out in a fully online environment, the created TEA system along with the formative e-assessment model based on skills and knowledge can be extended to blended courses as well. In this research, the TEA system was combined with a final face-to-face examination, which means that other teachers can use this experience with traditional learning approaches as well. The system can also be tested in a blended environment to test the suitability for different educational contexts. A summary of the future work which has to be carried-out with respect to this research can be explained as given below:

- ***Use the technology-enhanced assessment system with another subject in a fully online environment as well as in a blended environment***

  In this research, TEA system was applied into the Logic subject since it is a subject which requires a high level of skills to obtain the required qualification. As a result, it proved that the TEA system along with the formative e-assessment model was able to support student learning process and also practicing with the formative e-assessment model has enhanced the learning process of students. At the same time teachers were able to track the student's learning process throughout the whole course.

The TEA system was developed in a general way while maintaining security and interoperability, which allows any other subject or organization to easily adapt it to their needs. Therefore, the skill assessment module can be easily integrated with the TEA system using the developed standardized plug-in. For general results, it is needed to use the system in different subjects. This was not addressed, as it was not within the scope of this research. Also since the skill assessment module selected was focused on the Logic subject, it is needed to find another subject and an appropriate tool and then integrate with the TEA system. As the TEA system and the module integrations were conducted in a standardized manner, this research of the TEA system lays the foundation and guidance needed for others to use the system for their own requirements while integrating with appropriate tools. Maybe, new features of the general TEA system could be defined after using the system in other subjects.

- ***Introduce competency-based assessment into the assessment process***

  Since competency-based assessment is an emerging area and the fact that the TEA system is also equipped with the required modules, it would be interesting to carry-out competency based assessments along with the assessment process. In this case, several modifications might have to be carried-out into these modules based on the evaluations.

- ***Change the assessment model and evaluate its impact on students' performance***

  One of the more valuable consequences after this research is that teachers have a realistic chance to switch the previous assessment model, more aligned towards formative e-assessment. In the case of Logic course, according to teachers, one possibility is to give 35% of marks for formative assessment and 65% of marks for the face-to-face final examination. Therefore, for future research it is interesting to study the impact on students' performance after the introducing these changes into the assessment model.

- ***Further testing of the TEA system for security and interoperability***

  To test this, it is needed to introduce the TEA system into other courses based on skill and knowledge as well as by connecting with any other tool through the developed plug-in to see whether it works correctly as expected.

- ***Enhance the feedback offered through the TEA system***

  During this research the TEA system was able to offer detailed immediate feedback such as reasons for the correct answers, errors, hints, guidance to refer to a particular topic of the learning materials and overall feedback. According to the information obtained from students, they were satisfied with the feedback offered through the system and they were also able to improve their learning process. However, it is interesting to go beyond this and introduce personalized feedback to suit individual students based on the actions they performed. In this case, the TEA system will be more dynamic and students will also get the feeling of having the presence of a teacher and as a result students will be more engaged in the system.

- ***Extend the TEA system to introduce Open Learner Models***

  Open Learner Models is an emerging research area where the learner model is central to an adaptive educational system, as it is the model of the learner's understanding (and possibly also other attributes such as their goals, motivation, learning preferences, etc.), that enables a system to adapt to the individual user's current learning requirements (S. Bull et al., 2007). Through the open learner model it is needed to allow learners to view and interact with their learner model contents and this can provide a focus for reflective thinking. It uses the active reports integrated in an assessment-based learning environment to enable teachers and students to provide assessment information and to guide the learning process (Dimitrova et al., 2007). This has to be further analyzed to understand what facilities of the TEA system can be used as well as what modifications or new features have to be introduced in order to introduce open learner models.

5.4 Closing Remarks

As the closing remarks, it can be stated that the use of technology-enhanced assessments had a positive impact on students' learning and performance through the proposal of a formative e-assessment model. The learning process based on both skills and knowledge using the TEA system through added functionalities, practice and feedback had improved students' performance; they learnt through more engagement with the system and, as a result, they were more prepared for the final examination. The system also provided added benefits to teachers through automated marking facility as well as by allowing them the facilities to track students' progress throughout the whole course. As for future work, the TEA system along with the formative e-assessment model can be applied and tested in other contexts of both fully online and blended environments. At the same time, through this research, it was possible to address all the mentioned research objectives and questions. Finally, with the ever increasing interest and adaptation of e-assessment, this research had produced a product that is crucial in relation to the online educational environment, thus significant for further investigation.

Appendix A

Moodle

This section presents a brief description to the Moodle Learning Management System (LMS) (Moodle, 2013c).

Moodle (Modular Object-Oriented Dynamic Learning Environment) is the most popular open source learning management system that is currently in use. According to the statistics provided in the Moodle website, there are 84,578 registered sites from 236 countries (plus unregistered sites). This has caused that over 7,623,491 courses are currently active and around 71,495,021 users are using this LMS (Moodle, 2013d).

A.1 History

Moodle was originally developed by Martin Dougiamas to help educators create online courses with a focus on interaction and collaborative construction of content, and is constantly evolving. The first version of Moodle was released on 20 August 2002. A large part of its success is due to its modular structure, which allows any developer to create additional modules and features easily.

A.2 Origin of the name

The acronym Moodle stands for Modular Object-Oriented Dynamic Learning Environment. (In the early years the "M" stood for "Martin's", named after Martin Dougiamas, the original developer). Moodle is also a verb that describes the process of lazily meandering through something, doing things as it occurs to do them, an enjoyable tinkering that often leads to insight and creativity. As such it applies both to the way

Moodle was developed, and to the way a student or teacher might approach studying or teaching an online course. Anyone who uses Moodle is known as a “Moodler” (Moodle, 2013c).

Due to the ease of expansion, a lot of users have developed their own modules and then have shared them with the community. The existence of a powerful community of non-profit users has resulted in the creation of a vast collection of tools.

A.3 Pedagogical Approach

The stated philosophy of Moodle includes a constructivist and social constructionist approach to education, emphasizing that learners (and not just teachers) can contribute to the educational experience. Using these pedagogical principles, Moodle provides a flexible environment for learning communities.

A.4 Features of Moodle

Moodle’s basic presentation structure is organised around courses. These are basically pages or areas within Moodle where teachers can present their learning resources and activities to students. They can have different layouts but they usually include a number of central sections where materials are displayed and side blocks offering extra features or information.

Main user roles can be categorized as Administrator, Student and Teacher. Standard user roles of Moodle can be listed as:

- Site administrator - can “do everything” on the site
- Manager - a lesser administrator role
- Course creator - can create courses
- Teacher - can manage and add content to courses
- Non-editing teacher can grade in courses but not edit them
- Student - can access and participate in courses
- Guest - can view courses but not participate

- Authenticated user - the role all logged in users have
- Authenticated user on the front page role - a logged in user role for the front page only

A course is basically made up of resources and activities. A resource is an item that a teacher can use to support learning, such as a file or link. Moodle supports a range of resource types which teachers can add to their courses. The resources available in a standard Moodle distribution can be listed as follows.

- **Book** - possibilities to create an HTML book
- **File** - allows to upload one or multiple files such as pictures, PDF documents, spreadsheets, sound files or video files
- **Folder** - helpings organize files and one folder may contain other folders
- **IMS content package** - allows to add static material from other sources in the standard IMS content package format
- **Label** - use to display words or an image to separate resources and activities in a particular section
- **Page** - a single, scrollable HTML page created by teachers
- **URL** - a link to another website, for example Wikipedia, YouTube, etc.

An activity is a task in which the teachers want their students to participate actively (Moodle, 2013c). There are 14 different types of activities in the standard Moodle but other activities developed by community members can be included manually as well.

The main activities can be listed as follows:

- **Assignments** - enable teachers to grade and give comments on uploaded files and assignments created on and off line
  - **Upload a single file** - enables the learners to upload a single file
  - **Advanced uploading of files** - allows the students to upload multiple files
  - **Online text** - allows the students to write a text by using the text editor.

  - **Offline activity** - is useful when the assignment is performed outside of Moodle. Students can see a description of the assignment, but can't upload files or anything.

- **Chat** - allows participants to have a real-time synchronous discussion
- **Choice** - a poll where the teacher asks a question and specifies a choice of multiple responses
- **Database** - enables users to create, maintain and search a database of records
- **External tool** - allows users to interact with IMS LTI compliant learning resources and activities on other websites.
- **Feedback** - a survey to collect feedback
- **Forum** - allows users to have asynchronous discussions
- **Glossary** - enables users to create and maintain a list of definitions, like a dictionary
- **Lesson** - allows delivering content in a flexible way
- **Quiz** - allows the teacher to design and set quizzes, which may be automatically marked along with the feedback
- **SCORM** - enables SCORM packages to be included as course content
- **Survey** - allows to gather data about the nature of the course from students
- **Wiki** - A collection of web pages that anyone can add to or edit
- **Workshop** - enables peer assessment where the students must submit their work and assess other students' work.

In addition to resources and activities, Moodle provides other facilities such as gradebook, course backup, course setting, reports and etc.

Gradebook is where all the grades of each student in a course are stored. The grader report collects items that have been graded from the various parts of Moodle, and allows teachers to view, change and sort them out into categories. The total can be calculated in various ways as well. When an assessment item is added into the Moodle course, the gradebook automatically creates space for the grades and also adds the grades as they are generated. Later, students can view the grades for each item along with the total course marks as a report.

Reports consist of logs, live logs, activity reports and course participation reports. Logs can be selected based on participants, date, activities and actions. Live logs display the users who are online for the last one hour along with their IP address, time, username and action. The activity report displays all the activities of the course along with the number of views and last access data and time. Finally course participation shows the user participation throughout the whole course. This can be also selected based on a particular activity, days or user roles.

Additionally, Moodle consist of blocks. Blocks are widgets which add additional functionalities to the course. They can be put into any page. Currently there are 37 blocks in the standard Moodle package. It is also possible to create a block according to the guidelines, standards and themes provided in the Moodle development section and add it into a course.

A.5 Technological Approach

Moodle runs without modification on Unix, Linux, FreeBSD, Windows, Mac OS X, NetWare and any other systems that support PHP and a database such as MySQL, PostgreSQL, Microsoft SQL Server and Oracle.

For the design and development of this research project, Moodle version 2.3.2 was used. This was developed in PHP 5.3.2 and supported MySQL 5.1.33, PostgreSQL 8.3, Microsoft SQL Server 2005 and Oracle 10.2 as DBMSs.

Moodle is interoperable and include features such as:

- Authentication, using LDAP, Shibboleth, or various other standard methods (e.g. IMAP)
- Enrollment, using IMS Enterprise among other standard methods, or by direct interaction with an external database

- Quizzes and quiz questions, allowing import/export in a number of formats: GIFT (moodle's own format), IMS QTI, XML and XHTML.
- Resources, using IMS Content Packaging, SCORM, AICC (CBT), LAMS
- Integration with other Content Management Systems such as Drupal, Joomla or Postnuke (via third-party extensions)
- Syndication, using RSS or Atom newsfeeds

A.5.1 Moodle Code Structure

Moodle mostly follows a transaction script approach which organizes business logic by procedures where each procedure handles a single request from the presentation). Moodle is an aggregate of many different plugins, rather than a single complex application.

Behind that basic transaction script approach, a lot of the core functionality has be refactored out into libraries. This provides elements of a domain model.

There are two layers used to separate presentation from the business logic. The outer layer is the theme of the Moodle course, which controls the more visual aspects of the Moodle interface. Then there are renderer classes which generate the HTML to be output from the data supplied by the transaction scripts and the domain model. Unfortunately, neither PHP, nor the Moodle architecture, enforces a clear separation of the UI layer.

A.5.2 Moodle database

The Moodle database comprises of many tables (more than 250) because the whole database is an aggregate of the core tables and the tables belonging to each plugin. However, this large structure is understandable, because the tables for one particular plugin typically only link to each other and a few core tables.

All these information were obtained from the Moodle official site (Moodle, 2013c).

Appendix B

The Universitat Oberta de Catalunya (UOC)

This appendix gives a brief introduction about the Universitat Oberta de Catalunya (UOC), where this research was carried-out. As the case for this research, Logic course of the first year undergraduate Computer Science degree was used.

B.1 History

The Universitat Oberta de Catalunya (http://www.uoc.edu/) began its activities in the academic year 1995/1996, with 200 students on officially recognized courses in Educational Psychology and Business Studies in Catalan. In the intervening years, the UOC has grown and 200,000 people now form part of the UOC's university community.

Over these years, the university has increased and diversified its course offering, adding studies in Spanish and English. It has improved its educational methodology, creating a student-centred learning model. It has progressively expanded through Catalonia and Spain with a wide network of centres and information points, and also has expanded into the international market. The UOC consist of two research centres specializing in the information and knowledge society and in e-learning.

B.2 Educational Model

The Universitat Oberta de Catalunya's educational model includes three essential elements such as learning resources, collaboration and accompaniment. UOC's educational model gives the central focus on the students learning activity. Depending on the content and specific roles of the three essential elements, each teaching activity has the flexibility to adapt the educational model to the diversity of training possibilities offered by the UOC. The educational model of the UOC can be displayed as in Figure B.1.

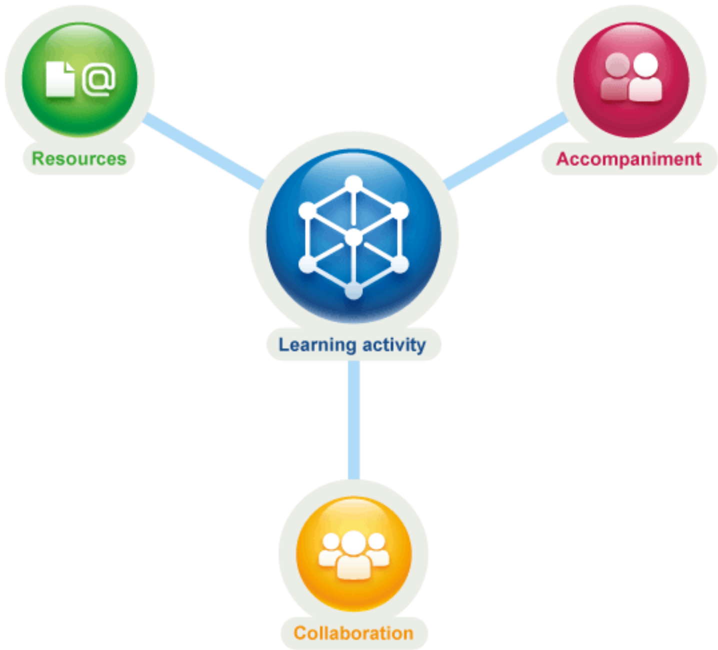


Figure B.1: The UOC Educational Model

A brief description to the three essential elements can be presented as below.

Resources any item that is needed to perform a learning activity, e.g. document, audio, video, simulation, remote laboratory, etc. They can also be additional elements that allow students to increase their knowledge further than the scope of the course.

Collaboration set of tools (e.g. forums, wikis, etc.) that encourages communication and teamwork among peer-students.

Accompaniment group of actions that is carried out by the teaching collaborators. These actions are basically to track and guide students. This can also be reflected by aiding organisation of resources and designing the most appropriate ways of interacting and collaborating to achieve the learning objectives in each case, encouraging the highest levels of personalisation possible.

The teacher role can be categorised into two as teachers and course coordinators. Teachers are involved in guiding, advising, supporting students, monitoring student activities, and answering questions in the online classroom. Course coordinators are in charge of the course design, structuring and scheduling.

B.3 Assessment Model

The assessment offered through the UOC education model is a perfect strategy integrated in the learning process, in the sense that it is conceived as a mechanism to learn and give reciprocal feedback of this process. Therefore, the assessment is continuous and educational. According to the UOC, the assessment activities foster the achievement of learning objectives and competence acquisition. In this way, the student can be assessed while doing their activities and obtaining competences.

For the assessment, the UOC promotes Continuous Assessment (CA) in all its subjects. The CA is a mechanism that assesses the students at different moments in the course of the semester and provides the students with feedback on their learning process. Therefore, Continuous Assessment Tests (CAT), are scheduled throughout the semester. Teachers grade the CAT and give feedback to the students. At the end of the each course, all the students get a CA grade, which is the average of the grades obtained in the CAT. Depending on the course type, the students can get the CA grade as the final mark or they had to do a face-to-face examination that can be a 2 hour exam or a short validation test.

B.4 Virtual Classroom

The virtual campus is the UOC LMS, the environment which provides access to learning resources and content and makes a certain kind of interaction possible through them. The virtual campus is a fundamental element for the development of the educational model therefore it needs to provide a student-friendly environment.

The virtual classroom, which is offered through the virtual campus is the specific area where cognitive, social and teaching presence come together and interrelate. Therefore virtual classroom consist of content and resources, classmates and the teacher.

The cognitive presence refers to the design of the interaction between the student and the specific learning content. Social presence is defined as the students' ability to become involved in the working areas with peer-students and teachers. The teaching presence is developed on the basis of the action of designing, facilitating and guiding cognitive and social processes with the aim of obtaining educational results which are meaningful for students and increase the feeling that the teaching staff support them throughout.

Each virtual classroom is divided into four areas such as communication, planning, resources and assessment. A brief description about these four areas can be explained as follows:

- **Communication -** there are three different communication spaces in the UOC classroom such as notice board, forum and discussion.

  Notice board is a space where only teachers are allowed to write notices and messages to students. This area is normally used to give reminders or post important notices.

  Forums are used for the informal interaction between students as well as between students and teachers. Therefore, both students and teachers can write and read messages. This is often used by students to ask questions and clarify doubts while interacting with peer-students and teachers.

  Discussions are identical to the forum, but it is normally related to learning activities. The writing style of the discussions is formal and therefore the quality of the messages are assessed.

  Additionally through "Class participants", students can see other peer-students who are online at that particular moment.

- **Planning -** in this area, students can access the syllabus. Moreover, there is a calendar in which shows the key events of the course, such as assignments' start and end dates. Mandatory assignments Continuous Assessment Tests (CAT) can also be found in a link called activities.

- **Resources -** this section provides learning materials of the course in a digital format which can be easily downloaded by students.

- **Assessment -** this area provides the instructions for the CAT. If the CAT is an offline test, then this area also provides the facility to upload the completed CAT, which can be downloaded by the teacher for marking. Furthermore, students can see their grades for each CAT as well as the overall Continuous Assessment (CA) grade.

The virtual classroom consist of areas can be displayed as in Figure B.2.

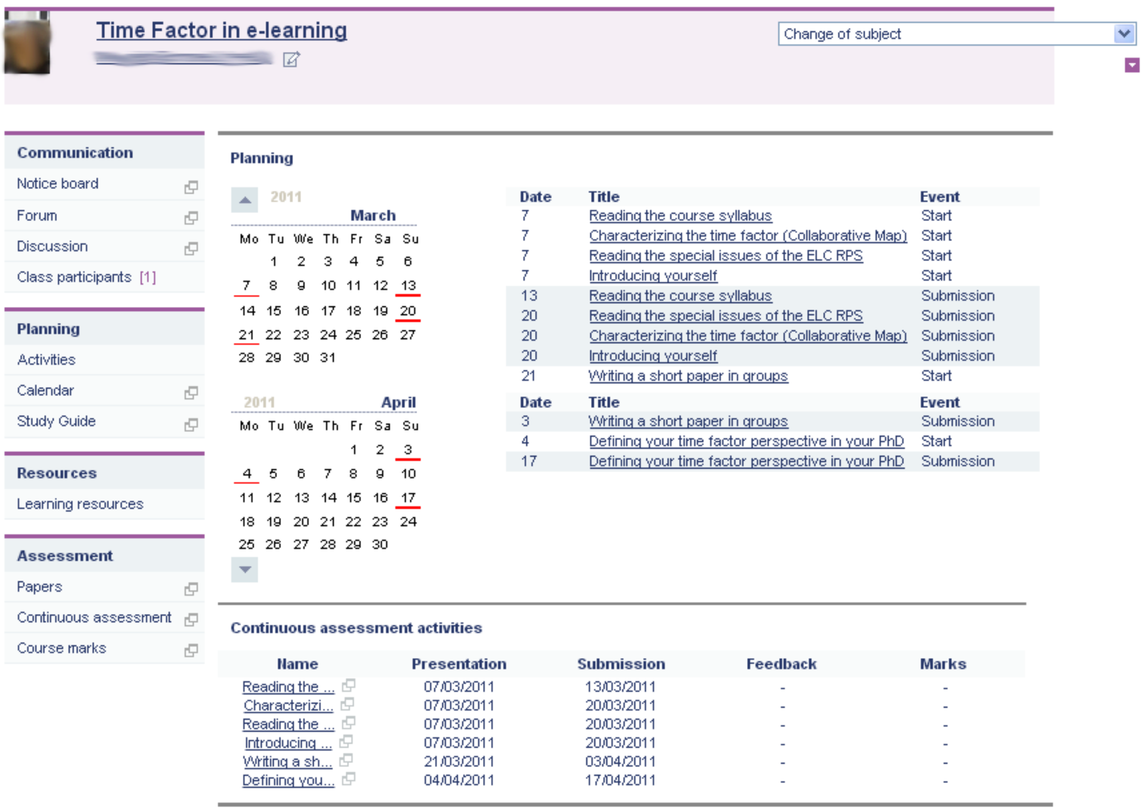


Figure B.2: The UOC virtual classroom

These information were obtained from the (García, 2013; UOC, 2013)

Appendix C

User Interface Designs for the Components of the TEA System

This section presents the main interface designs created for the TEA system.

Knowledge assessment module

This module provides the Mutiple choice type of questions. Basically after the commencement of a test, this module displays the number of questions available in a gird as well as the remaining time. One question is displayed per page. Students can move between questions by clicking on the question number. A typical knowledge assessment module with an initial view of a test can be displayed as shown in Figure A1.

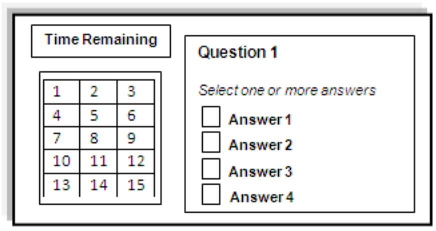


Figure A1: Overview of the knowledge assessment module

Skill assessment module

The initial look of the skill assessment module can be displayed as in Figure A2, where the instructions and type of test are provided to students. It displays the total marks allocated as well as the marks obtained by students for each test.

Students can attempt a test by clicking on the "Attempt" button. They can also view the official solution only after the expiration of the deadline for the given test.

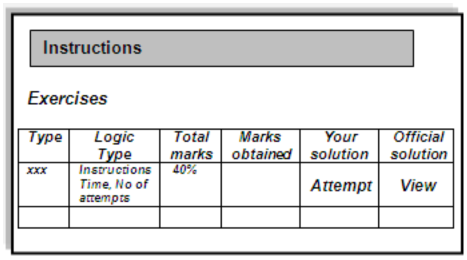


Figure A2: Overview of skill assessment module

After clicking on the "Attempt" button, the student will be directed to another screen where they are provided with a question. Students can construct the answer with the help provided through feedback, error messages and hints as shown in Figure A3.

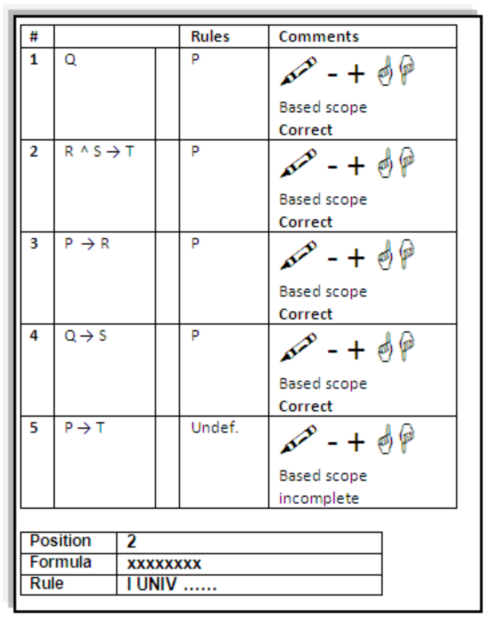


Figure A3: Skill questions with hints, feedback and error messages

Progress bar

The progress bar is a visual guide for helping students to understand their progress with respect to the course. The progress bar is colour coded and therefore it gives an indication to students about what they have to complete, the tests they have completed and as well as failed to complete. It also gives an indication about where the rest of the classroom is at that moment with a pointer titled “NOW. At the same time, it indicates the overall progress as a percentage with respect to the tests completed. Students have the possibility to obtain more information about each test through the mouse over action. The initial screen of the progress bar design can be illustrated as in Figure A4.

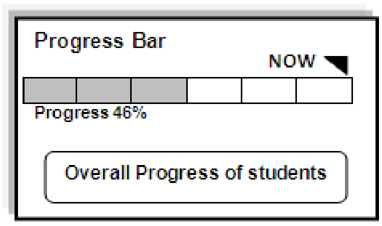


Figure A4: Overview of Progress Bar

Teachers can view the overall progress of all the students as shown in Figure A5.

Overall Progress of Students

Picture	Full Name	Last Online	Progress Bar	Progress
	AAAAAAA	Friday, 26 December 2012, 19.03		50 %
	BBBBBBBB	Monday, 15 December 2012, 9.03		16.67 %
	CCCCCCCC	Wednesday, 26 October 2012, 15.06		100 %
	DDDDDDD	Thursday, 24 December 2012, 19.03		50 %
	EEEEEEEEE	Friday, 26 December 2012, 8.03		66.67 %
	FFFFFFFFF	Friday, 26 December 2012, 6.28		16.67 %

Figure A5: Overall progress of all the students

Competencies module

Competencies module is used to evaluate students’ competencies based on the marks they have obtained for a particular topic of the subject. Therefore it is needed to have a taxonomy which consists of the competencies that should be achieved by students. Competencies module consists of several tabs such as "Module configuration", "Subjects & topics", "Assign activities", "Overview of competencies" and "Assessment of competencies" as shown in Figure A6.

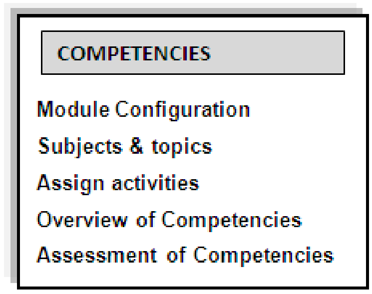


Figure A6: Overview of Competencies Module

Taxonomy for a particular subject is uploaded to the competency module using the Module configuration tab. Subjects & topics tab allows to select the appropriate subject and related topics for a particular competency. After selecting the desired subject, all the related competencies are displayed in the Assign activities tab. In addition to that, all the activities available within the course are also displayed here. Then teachers have to select appropriate competencies related to each activity by marking a tick in the appropriate box. In the "overview of competencies" tab, a table of competencies and students of the course is generated. Students are displayed horizontally and the marks they have obtained for each activity is visible by hovering over the given icon. Here the attainment of a competency is assessed on the level of individual activities. Based on the marks, if students have acquired the competencies, the teachers can put ticks next to the competency. For all students, the competencies can be ticked off as a whole.

In the competencies module, all the tabs including "Module configuration", "Subjects & topics", "Assign activities" and "Overview of competencies" are only visible to teachers and system administrators. Only tab that is visible to students is the Assessment of competencies tab.

Using the "Assessment of competencies" tab, students can view the competencies they have achieved as a progress bar as well as a list of tables. The assessment of competencies for a particular student can be displayed as in Figure A7.

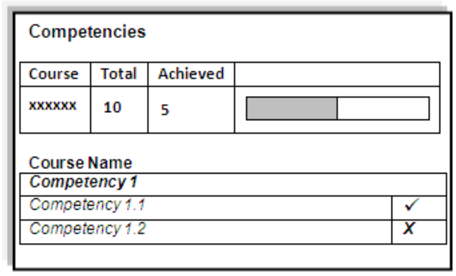


Figure A7: Assessment of competencies for a particular student

Gradebook

Students can view the marks and the outcomes they have obtained for each activity using the Gradebook of the technology-enhanced assessment system along with the outcome obtained. When it comes to teachers, they have the possibility to view marks of all the students and they also have the possibility to assign outcomes to each student for the respective activities from a drop-down list. Outcomes can be assigned based on the following scale.

[100% - 85%] - Very good

[84% - 65%] - Good

[64% - 50%] - Satisfactory

[49% - 35%] - Low

[0% - 34%] - Very low

The gradebook view for a particular student with marks and outcomes can be displayed as shown in Figure A8.

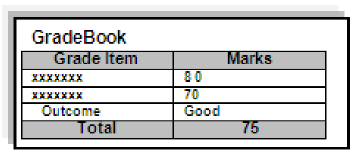


Figure A8: Overview of the Gradebook with marks and outcomes

Appendix D

Major Codes of the Development

This Appendix presents the most important codes of the TEA system. Under this, the credentials of IMS Basic LTI specification is explained. The way the communications were carried-out between the UOC LMS and the TEA system, and Basic TEA system and the ITS is also presented.

D.1 IMS Basic Learning Tool Interoperability Specification

Basic LTI specification has three patterns for the credentials as follows : (IMS GLC, 2013d):

Credentials associated with a tool provider domain - These credentials authorize access to all tool provider URL from the tool consumer. Once the tool provider domain credentials are established for a provider, all Basic LTI tool launches to the providers will use this same secret. Using TP domain credentials gives provider the option of trusting user information and context information across multiple contexts within a particular tool consumer instance as being maintained properly by the consumer.

In order to select which provider domain credentials are used for a particular LTI link, the consumer examines the domain name in the launch URL for the LTI link. The provider domain credentials are looked up after scanning the domain name of the launch URL.

Credentials associated with a tool provider URL - These credentials authorize access to a particular provider URL from the consumer. These are typically used when the administrator is enabling a remote tool within the tool consumer with a preset configuration which can be added to a context by the teacher with little or no further configuration.

Credentials associated with a particular link - These credentials authorize access to the resource at the URL specified by the link. These credentials are typically entered by the instructor at the moment that the link is created in the context.

The overview of IMS Basic LTI usage for the communication between tool provider and tool consumer using the Basic LTI services can be illustrated as shown in Figure D.1.

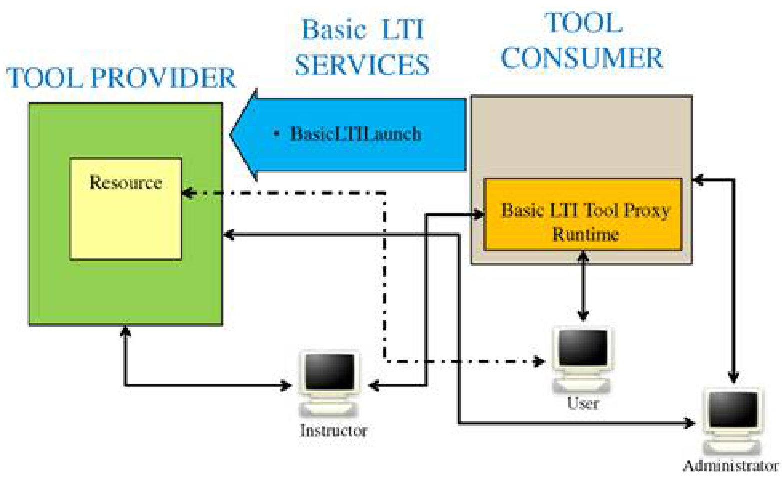


Figure D.1: Overview of IMS Basic LTI (IMS GLC, 2013d)

IMS Basic LTI Message Signing

IMS Basic LTI uses OAuth protocol to communicate between the tool provider and consumer. Therefore it is needed to look at the way the message signing is carried-out using OAuth and Basic LTI.

OAuth is a security mechanism designed to protect request and response between tool provider and consumer. For this purpose two commonly used methods GET and

POST is used. Generally, GET is used to requests data from a specified resource and POST is used to submit data to a specified resource for processing. This section only applies to protecting launch and other LTI messages that are being serialized and sent using POST (IMS GLC, 2013d).

OAuth website (OAuth, 2013) contains the specification for OAuth 1.0 and sample source code for implementing OAuth security. OAuth 1.0 specifies how to construct a base message string and then sign that string using the secret. The signature is then sent as part of the POST request and is validated by the tool provider using OAuth.

For the OAuth specification, the signing process produces a number of values that are to be added to the launch request (IMS GLC, 2013d).

```
oauth_consumer_key=b289378-f88d-2929-lmsng.school.edu
oauth_signature_method=HMAC-SHA1
oauth_timestamp=1244834250
oauth_nonce=1244834250435893000
oauth_version=1.0
oauth_signature=Xddn2A%2BjzwjgBIVYkvigaKxCdcc%3D
```

The important values and attributes for signing a message using OAuth are the *oauth_consumer_key* and *oauth_consumer_secret*.

The *oauth_consumer_key* is passed in the message as plain text and identifies which consumer is sending the message allowing the provider to look up the appropriate secret for validation. The *oauth_consumer_secret* is used to sign the message.

Consumer and provider must support and use the HMAC-SHA1 signing method with OAuth fields coming from POST parameters.

Upon receipt of the POST, the tool provider will perform the OAuth validation utilizing the shared secret it has stored for the *oauth_consumer_key*. The timestamp should also be validated to be within a specific time interval. This time interval can be tool provider defined, but should be small.

The tool provider should keep a record of the *oauth_nonce* parameter which is a unique token that tool provider application should generate for each unique request. For example: Twitter service will use this value to determine whether a request has been submitted multiple times. The tool provider should only allow the use of any *oauth_nonce* parameter a single time combined with the timestamp. This means that they only have to keep track of *oauth_nonce* for a period of time equal to their acceptable time interval.

One of the considerations is that this security profile requires the tool consumer and tool provider to have synchronized clocks. The use of a configurable time interval can adjust for slightly-off clocks, but setting the interval too large is discouraged.

D.2 Communication between the UOC LMS and the TEA System

To make a communication link between the UOC LMS and the TEA system, the URL associated with the particular course of the TEA system was obtained. This URL is known as the "Launch URL" as is it used in the UOC LMS to launch a connection and move to the TEA system. After the establishment of this connection, students who were logged into the LMS could automatically login to the TEA system through the single sign-on facility. The steps followed for this communication can be explained as follows:

- In the course of the system, it is needed to select "LTI Provider" under the "Navigation" menu.

- Then after clicking on the "Add" button, it will prompt a screen as shown in Figure D.2.

- Under *"Tools to be provided"*, select *"Course"*. Then under that select *"Send grades back"* and *"Force course or activity navigation"*. Then select the course roles for instructors and learners as *"Teacher"* and *"Student"* respectively. After that enter the *"shared secret"* of the remote system. In this case, it is the secret key of the UOC LMS Logic course. Then enter the encoding type and save the data. And then it will display a screen as shown below in Figure D.3.

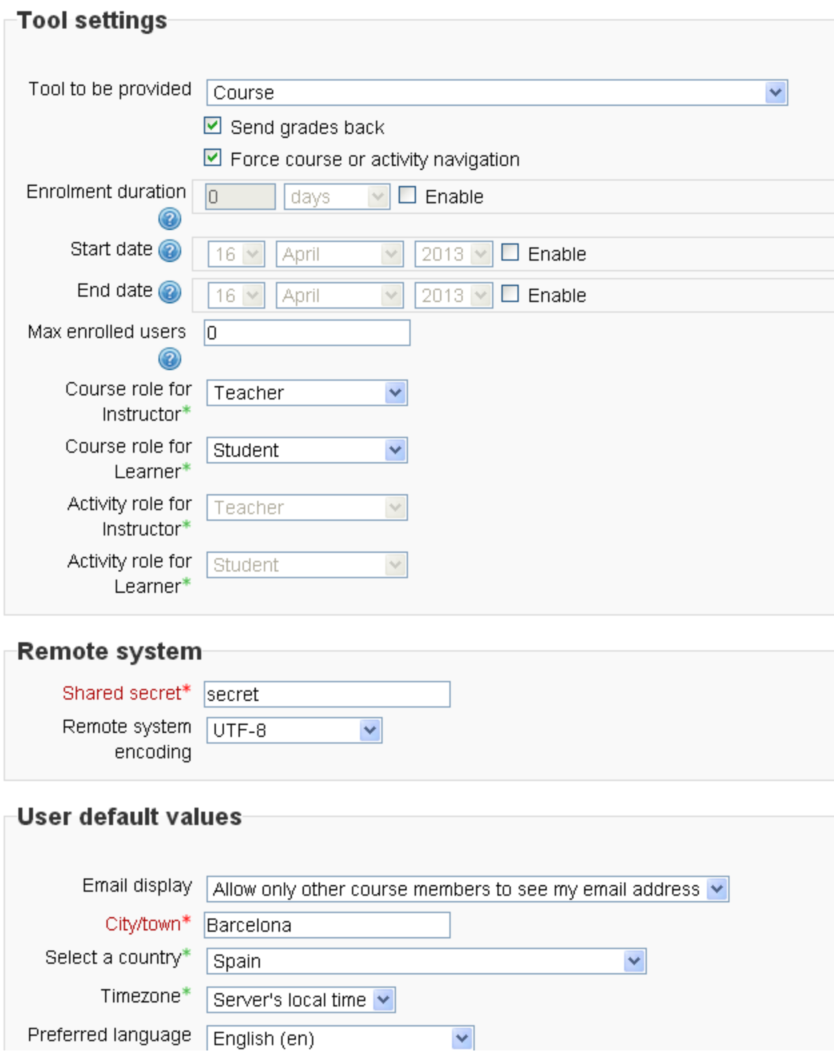
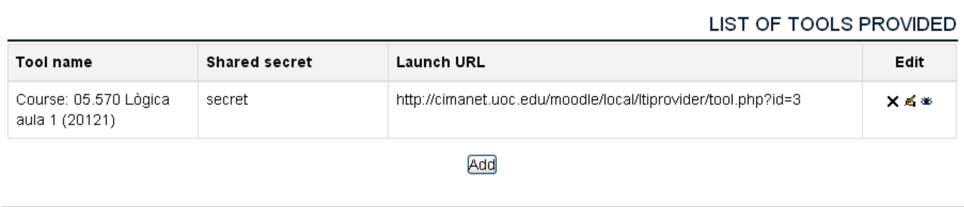


Figure D.2: Tool settings for LTI provider



LIST OF TOOLS PROVIDED

Tool name	Shared secret	Launch URL	Edit
Course: 05.570 Lògica aula 1 (20121)	secret	http://cimanet.uoc.edu/moodle/local/ltiprovider/tool.php?id=3	

Add

Figure D.3: List of tools provided with the Launch URL

- Then in the UOC LMS, under the particular course, enter links to other modules through a widget. In this widget, the "Launch URL" has to be pasted and this enables students who are logged into the UOC LMS course to automatically move to the technology-enhanced assessment system without any problems.

D.3 Communication between the Basic TEA System and the ITS

To communicate between the TEA system and the ITS tool, "external tool", a service provided by the TEA system was used. The "external tool" has to be configured as below.

From the main site of the system, move to the "settings" section. From there, select "Site Administration" → "Plugins" → "Activity modules" → "External Tool". From there, select "Add external tool configuration" and enter the configuration data as shown in Figure D.4.

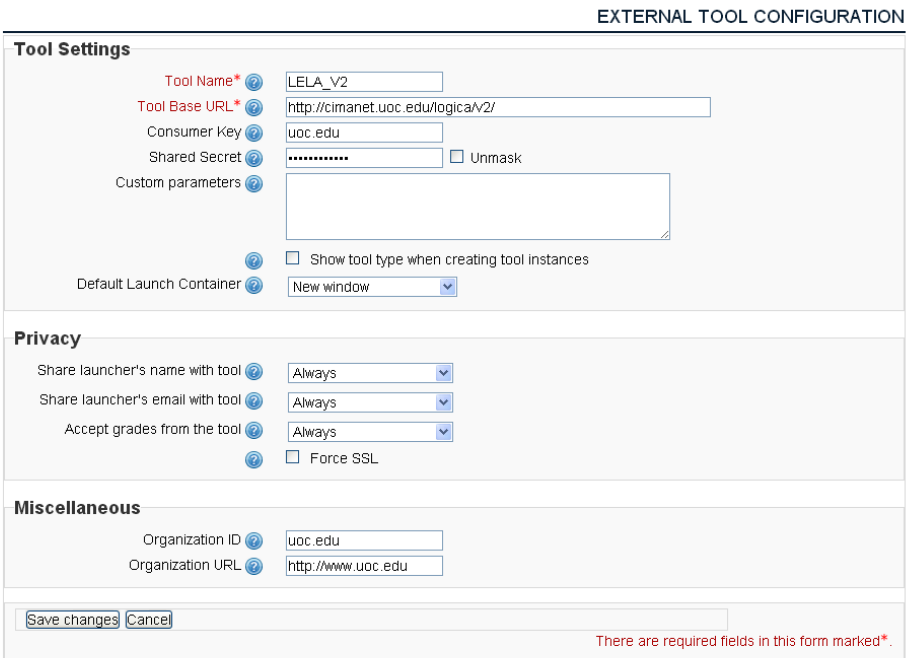


Figure D.4: External Tool Configuration details

After adding those data, it will appear under external tool types as shown in Figure D.5.

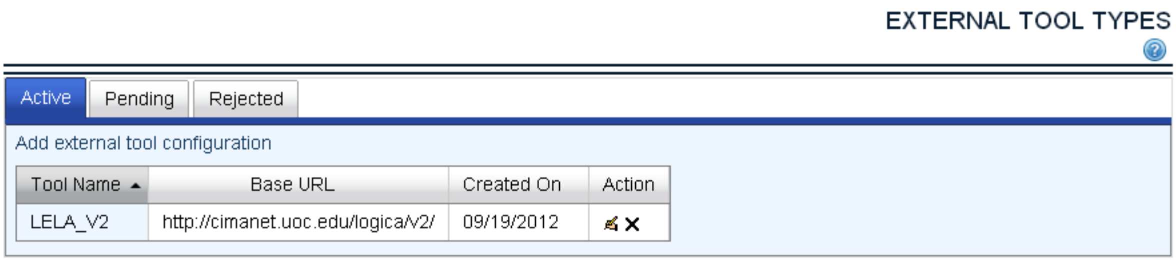


Figure D.5: External Tool Types

Then from the course page, it is needed to make a link to the ITS tool. This communication has to be carried-out in a way that students do not have to login again to the ITS tool. Therefore it was not possible to use the "URL" module of the system as it is.

This raised the need to create a special plug-in and it entitled "ITS URL" where the LELA parameters required to make a proper connection such as *session_campus_id*, *domain_campus_id*, *language_campus_id* and *username_campus* were added. This plug-in can be reused for any other tool instead of ITS as shown in Figure D.6 by making necessary modifications to the required parameters.

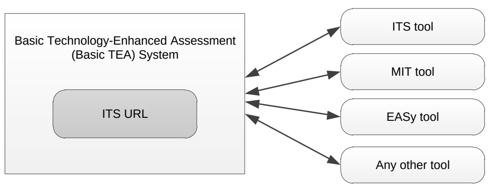


Figure D.6: Communication between TEA system and any other tool through "ITS URL" plug-in

Only the main changes done to the view.php page of the ITS URL is listed as below.

```
//Adding the ITS required parameters
$session_campus_id = $SESSION->session_campus_id;
$domain_campus_id = $SESSION->domain_campus_id;
$language_campus_id = $SESSION->language_campus_id;
$username_campus = $SESSION->username_campus;
$lelaurl->externallelaurl .= 'j='.$session_campus_id.'&e='
.$domain_campus_id.'&g='.$language_campus_id.'&h='.$username_campus;
```

```
//Check if has ``?''  is in the url
if (strpos($lelaurl->externallelaurl, `?')===FALSE) {
$lelaurl->externallelaurl .= `?';
} else {
$lelaurl->externallelaurl .= '&';
}
```

The "ITS URL" was created as a plug-in for the technology-enhanced assessment system; therefore it was needed to install it into the system to incorporate with other modules.

It was needed to add parameters to the session in the LTI provider. Therefore it was needed to add the following code segment to the *tool.php* page available in the local/ltiprovider folder of the TEA system. Add the code segments under line 44 of the 'tool.php" code.

```
//Correct launch request
if ($context->valid) {
//20120605 added to get ITS parameters
$SESSION->session_campus_id = $_POST['custom_sessionid'];
$SESSION->domain_campus_id = $_POST['custom_domain_code'];
$lang_lti_locale = $_POST['launch_presentation_locale'];
$lang_id = 'c'; //english
switch ($lang_lti_locale) {
case 'ca-ES':
$lang_id = 'a';
break;
case 'es-ES':
$lang_id = 'b';
break;
case 'fr-FR':
$lang_id = 'd';
break;
}
$SESSION->language_campus_id = $lang_id;
```

```
$SESSION->username_campus = $_POST['custom_username'];
//20120605 END: added to get ITS parameters
```

The ITS parameters which correspond to the above can be listed as:

- j = *custom-sessionid*
- h = *custom-username*
- g = *launch-presentation-locale*
- e = *custom-domain-code*

It was needed to analyse the ITS tool to understand the changes that are need to be done in order to carry-out a proper communication between the two systems. The developments done to the ITS can be listed as below:

- **The most essential tables used for the communication between Basic TEA system and the ITS Tool**

```
create table `sell_ltiprovider` (
`id` bigint auto_increment not null,
`domaincode` varchar(255) not null,
`number_pec` varchar(50) not null,
`service_url` varchar(255),
`instanceid` varchar(255),
`consumerkey` varchar(255),
`consumersecret` varchar(255),
`sendgrades` bit,
`disabled` bit,
`lastsync` datetime not null,
`extrahash` varchar(255),
primary key (id)
) ENGINE = MYISAM ;
```

```
create table `sell_ltiprovider_user` (
`id` bigint auto_increment not null,
`lti_id` bigint not null,
`user_id` bigint not null,
`user_source_id` bigint not null,
`lastgrade` float not null,
`lastsync` datetime not null,
primary key (`id` )
) ENGINE = MYISAM ;
```

- Then a new file called "config_lti.php" was created as follows to add the configuration details for the LTI. This file should be included under the "lib" folder of lela tool as "lela/lib/config_lti.php".
- Changes were done to the "check_login.php" of in the "lela" folder.
- Created a new file which was directly included in the "lela" folder called "sync_grades.php". This was created to call the cron service. Cron service was used to automatically pass grades periodically at certain times (for example : every 1 hour) from the LELA system to the TEA system.
- Created a class to manage the communication using the OAuth protocol called "cLTI_Helper.php" which was placed under the "lib" folder. (lela/lib/cLTI_Helper.php).
- Created the required files for the BasicLTI and OAuth communications and include them in a folder called "ims-blti" under "lib" folder. (Due to space limitations, all the codes are not included here
  This folder mainly consists of:
  - blti.php
  - blti_util.php
  - OAuth.php
  - OAuthBody.php
  - TrivialOAuthDataStore.php

- **Then define a cron job every 5 minutes to sync_grades to the TEA system, example:**

  `*/5 * * * * /usr/bin/wget -q -O /dev/null`

  `http://cinmanet.uoc.edu/logica/lela/sync_grades.php`

After carrying-out all the necessary changes, it was needed to add the new plug-in, “ITS URL” for each activity to automatically direct students to the appropriate skill assessment test in the ITS tool.

Then configure the “ITS URL” by adding the “number_pec” parameter (this is the ID designated for each Continuous Assessment Test(CAT) of the ITS) Example : http://cimanet.uoc.edu/logica/lela/index.php?number_pec=1

The configuration of the “ITS URL” can be displayed as shown in Figure D.7.

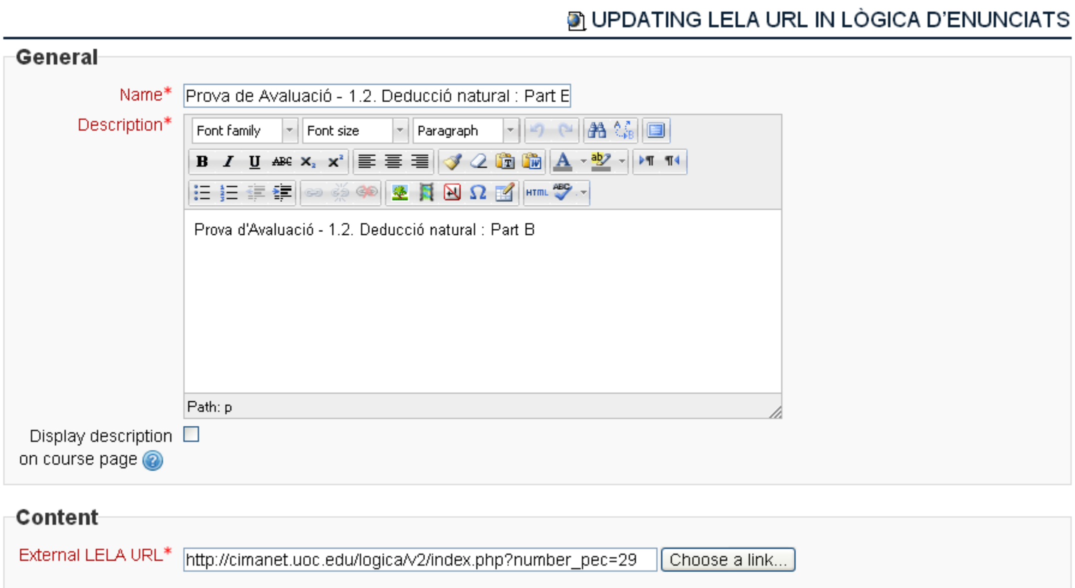


Figure D.7: Configuration details of the LELA URL

Then updated the ‘sell_ltiprovider’ table with the extrahash according to the appropriate ‘instanceid’ as shown below.

```
UPDATE 'logica'.'sell_ltiprovider' SET 'instanceid' = '7',
'sendgrades' = b '1', 'extrahash' = '5018b3bf2e7951.47174925' WHERE 'sell_ltiprovider'.'id'
=4;
```

To transfer and store grades and relevant data, the "External Tool" service of the TEA system can be used.

Therefore select, "External tool" from the activity drop-down list and add the configuration details as shown in Figure D.8. Here, it is important to provide the Launch URL, Consumer key and the shared secret. These were done to maintain the security with respect to the communication among tools. It is also needed to accept the privacy data to accept the share launcher's name with the tool, share launcher's email with the tool and accept grades from the tool.

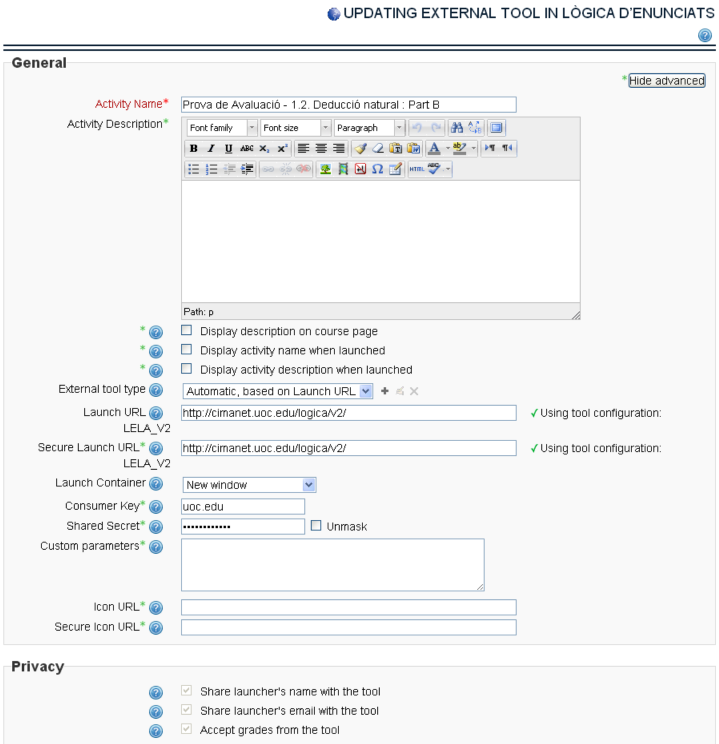


Figure D.8: External tool configuration details

After setting the above configuration details, students had the possibility to access the ITS tool for skill assessment.

Appendix E

Test Plan

Test plan ensures that a product or system meets its design specifications and other requirements. Test plan includes items to be tested, features to be tested, approach, and item pass/fail criteria. For testing these features, test cases are used. Test cases are a set of actions executed to verify that a particular feature or functionality of the system works correctly as expected.

Main test items were derived from the five main modules of the TEA system. Therefore, knowledge assessment module, skill assessment module, progress bar, competencies module and gradebook were selected as main test items. In addition to that single sign-on facility was selected as it played a major role in the communications between the LMS and the TEA system as well as between the Basic TEA system and the skill assessment module. Through this facility, students who were logged into the LMS could easily move to the TEA system and then to the skill assessment module

E.1 Test Plan : Features to be Tested

After identifying the test items, the important features to be tested under each item were selected as follows.

1. Single sign-on facility
   (a) Automatic login and transfer of data from the UOC LMS to the TEA System
   (b) Automatic login to the appropriate classroom of the ITS
2. Knowledge assessment module

(a) Answers given for each question consisted of feedback
(b) Overall test consisted of detailed feedback with links to learning materials and practice tests
(c) Provided only a limited number of attempts (eg: 3 attempts) to obtain the required pass mark
(d) An attempt had to be completed within a given time limit
(e) Questions within each attempt were provided in a randomized manner
(f) Marks were stored for each attempt
(g) Highest mark was considered as the final mark
(h) Needed to obtain a given mark (eg: 50%) to qualify in the test
(i) If the final mark is less than the given mark, students were directed back to the practice tests

3. Skill assessment module

(a) Answer given for each question consisted of feedback
(b) Provided only a limited number of attempts (eg: 3 attempts) to obtain the required pass mark
(c) An attempt had to be completed within a given time limit
(d) Questions within each attempt were provided in a randomized manner
(e) Marks were stored for each attempt
(f) Highest mark was considered as the final mark
(g) Needed to obtain a final mark of 50% or more to qualify in the test
(h) Highest mark obtained was transferred to the TEA System (to the particular activity and the gradebook)

4. Progress Bar

(a) The color policy expected : green = tests completed on time, red = tests not completed on time, white = tests to be completed
(b) All tests including the tests given using the ITS tool appeared and counted in the progress bar

   (c) "Now" button appeared on the correct position based on where the rest of the class was at that particular moment
   (d) Overall progress was showed to each student as a percentage
   (e) Mouse over each test block showed the name and the overall status of that test such as; graded or not and the expected date with time
   (f) Summary of all students were displayed only to administrators and teachers

5. Competencies module
   (a) Allowed only administrators and teachers to upload the subjects and related competencies through an XML file
   (b) Then, teachers were allowed to select the appropriate subjects and topics
   (c) Based on the activities given, teachers were allowed to select the appropriate competencies
   (d) Teachers were allowed to select the competencies for each student based on the marks obtained
   (e) The competencies obtained were displayed to the students as a list and as a percentage

6. Gradebook
   (a) The highest marks obtained for each test was displayed
   (b) Highest marks were transferred from the ITSto the gradebook through the communication link
   (c) Overall grade qualifications of students were displayed to the teachers
   (d) Teachers were allowed to select appropriate outcomes based on the grades obtained by students
   (e) Students were displayed with their own qualifications as a user report including grades and outcomes for each activity, total grade obtained for the course along with the final outcome.

Then the test cases identified were tested based on a given input and testing whether they satisfied the expected result. If test cases failed, the respective modifications were done and tested again.

E.2 Test Plan : Test Cases

Based on the features to be tested, the test cases were identified. These were tested based on a given input and testing whether they satisfied the expected result. If test cases failed, the respective modifications were done and tested again.

Test cases used can be displayed as shown in Table E.1,E.2, E.3,E.4 and E.5.

Table E.1: Test cases used for testing the features of the TEA system

Test Cases	**Procedure / Inputs**	**Expected Results**	**Pass/Fail**
1. Automatic login and transfer of data from the UOC LMS to the TEA System	Login to UOC LMS, move to appropriate course and then access the TEA system through the given link	Login to TEA system without any problems or errors	Passed
2. Automatic login to the appropriate classroom of the ITS	Click on the link to access the ITS	Direct students to the correct classroom	Failed
2.1. User was directed to the wrong classroom	Fixed “DomainID” and “EpcMenuID” in the UOC classroom		Passed
3. Answer given for each question consisted of feedback	Select an answer for a question and submit	Feedback based on the answer	Passed
4. Overall test consisted of detailed feedback with links to learning materials and practice tests	Attempt the questions within a test and submit	Overall detailed feedback with links to tests (based on marks) and learning materials	Passed

Table E.2: Test cases used for testing the features of the TEA system *"(cont.)"*

Test Cases	**Procedure / Inputs**	**Expected Results**	**Pass/Fail**
5. Provided a given number of attempts	Attempt the test several times	For each attempt load a new test	Passed
6. An attempt had to be completed within a given time limit	Attempt the test	Display of a countdown timer from the first access to the test	Passed
7. Questions within each attempt were provided in a randomized manner	Attempt the test several times	Different questions for each attempt	Passed
8. Marks were stored for each attempt	Attempt the test several times	Marks along with the attempt number	Passed
9. Highest mark was considered as the final mark	Attempt the test several times	Highest marks displayed as the final grade	Passed
10. obtain a final mark of 50% or more to qualify in the test	Attempt the test and check the feedback	If the mark obtained is higher than or equal to 50, an indication of passing the test is given and if not if not feedback and links to tests and learning materials are given	Passed
11. Highest marks obtained were transferred from the ITS to the TEA	Attempt the test and check the highest mark obtained	Highest mark to appear in the Gradebook	Failed

Table E.3: Test cases used for testing the features of the TEA system *"(cont.)"*

Test Cases	Procedure / Inputs	Expected Results	Pass/Fail
12. The color policy worked as expected in the progress bar	1. Complete a test within the deadline 2. Keep another test without attempting	Color should change to green = tests completed on time, red = tests not completed on time, white = test to be completed	Passed
13. All the tests were included in the progress bar	Check all the tests and also add new tests into the course	All tests to appear in the progress bar	Passed
14. "Now" button appeared on the correct position in the progress bar	Check the average progress to test where the rest of the class is at that particular moment	"Now" button to appear in the appropriate place	Passed
15. Overall progress was shown to each student as a percentage in the progress bar	Check the progress as a student	Percentage of progress to appear under the progress bar as "Percentage ..%"	Passed
16. Mouse over each test block showed the name and the overall status of the test in the progress bar	Mouse over each test block	Display overall status of that test such as graded or not and the expected date with time	Passed
17. Summary of the progress of all students were displayed only to administrators and teachers	Change login role to student, teacher, administrators and check what happens	For student role, there should not be an "Overview of Progress" button. For both teachers and administrators it should be. At the same time clicking on the button should give a detailed report	Passed

Table E.4: Test cases used for testing the features of the TEA system *"(cont.)"*

Test Cases	Procedure / Inputs	Expected Results	Pass/Fail
18. Allowed only administrators and teachers to upload the subjects and related competencies through an XML file into the competencies module	Change login role to student, teacher, administrators and check what happens	For students, only "assessment of competencies" should be displayed whereas others have the possibility to upload the XML file	Passed
19. Teachers were allowed to select the appropriate subjects and topics in the competencies module	Select the appropriate subjects and topics from the list available	Display the selected subjects and its topics	Passed
20. Teachers were allowed to select competencies for each student based on the marks obtained	Select the appropriate competency for each student based on the marks displayed	A tick mark for the students who have achieved the competency	Passed
21. The competencies obtained were displayed to students as a list and as a percentage	As a student click on the "assessment of competencies" link	Display of competencies achieved as a list along with a progress bar	Passed
22. The highest marks obtained for each test were displayed in the Gradebook	Check the highest marks obtained in the test and check whether it corresponds to the Gradebook mark	Same mark appears in both the test and the Gradebook	Passed

Table E.5: Test cases used for testing the features of the TEA system *"(cont.)"*

Test Cases	**Procedure / Inputs**	**Expected Results**	**Pass/Fail**
23. Highest marks were transferred from the ITS to the Gradebook	Check the highest marks obtained in the ITS and check whether it corresponds to the Gradebook	Same marks appear in both the ITS and the Gradebook	Passed
24. Overall grade qualifications of all students were displayed to the teachers	As a teacher, check the grade qualifications provided through the Gradebook	Detailed overall grade qualifications of all students as a report	Passed
25. Teachers were allowed to select the appropriate outcome based on the marks	Select appropriate outcome from the dropdown list in the Gradebook	Display the grade and the corresponding outcome	Passed
26. Students were displayed with their grades and outcomes for each test and the final grade and outcome for the course	Check the qualifications section as a student	Display grade and outcome for each test as well as final grade and outcome for the course	Passed

The pass/fail criteria based on the above test cases is as below.

Pass/Fail Criteria

Initially all the test cases passed except "1b. Automatic login to the appropriate classroom of the ITS" and "6b. Highest marks were transferred from the ITS external tools to the gradebook through the communication link". The bugs identified for those few were corrected during the iterative development cycle and tested again.

The bugs which occurred were listed below:

- Single sign-on facility
  The UOC LMS and the TEA system were linked with each other using the IMS Basic LTI standard which provided single sign-on facility. For this purpose, an external tool with LTI provider facility within the TEA was used. Therefore from the TEA system, it was necessary to obtain the Launch URL and assign it to the required UOC Classroom. Even though this process was followed, students were directed to an old classroom in the ITS tool, if they had already taken that classroom in the previous semester. After considering all the possibilities, it was understood that the cause was due to having a fixed "*DomainID*" and "*EpcMenuID*" in the UOC classroom. After fixing this bug it was possible to login to the appropriate classroom in the ITS tool without any problems.

- Gradebook
  Even though students were able to do the tests using the ITS tool, it was not possible to transfer the marks from the ITS tool to the TEA system. Earlier it was thought, that it was because of the manual execution of the cron job. Therefore it was automated; even then it was not possible to transfer marks. After several iterations it was understood that the tables used in the MySQL query to extract the required data was wrong. At the same time, some modifications had to be done to the code regarding the data communications between the ITS tool and the TEA system. After making all the changes it was possible to transfer marks and data back and forth between the ITS tool and the TEA system.

After fixing the bugs mentioned above, three iterations of testing were carried-out to test whether the system worked as expected and it was possible for these two test cases to pass without any errors.

Appendix F

Analysis of Data for Practice Tests (PT)

F.1 Analysis of First Pilot Study Data for Practice Tests (PT)

This section presents the students attempts for the 8 practice tests in the first pilot study.

PT 1

No. of attempts	Final Mark
1	76
1	53,33
1	88
1	61,33
1	68
2	96
2	100
2	68
2	57,33
2	80
2	68
2	25,33
2	66,67
2	56
2	98
2	89,33
2	88
2	76
3	88
3	88
3	64
3	92
3	100
4	76
4	100
5	80
6	76
8	100
9	100

Attempts = 6
32
36
44
52
76
76

Attempts = 8
52
60
68
76
76
76
92
100

Attempts = 9
32
68
84
84
84
92
92
92
100

Mode =2

F. ANALYSIS OF DATA FOR PRACTICE TESTS (PT)

PT 2

No. of attempts	Final Mark
1	75
1	71,67
1	63,33
1	90
1	50
1	63,33
1	55
1	38,33
1	95
1	0
2	100
2	95
2	100
2	65
2	65
2	98,33
2	70
2	70
2	85
2	100
2	90
2	75
3	90
3	85
3	95
3	96,67
3	100
4	90
4	100

Attempts = 2
20
100

Attempts = 3
30
70
95

Attempts = 4
0
10
23,33
60
90

Mode =2

PT 3

No. of attempts	Final Mark
1	75
1	55
1	6,67
1	0
1	90
1	35
1	65
1	100
1	65
1	91,67
1	70
1	45
1	70
1	0
1	60
1	70
1	0
2	70
2	66,67
2	88,33
2	55
2	100
2	100
2	96,67
2	100
2	100
2	80
2	90
2	75

Attempts = 2
60
96,67

Mode =1

PT 4

No. of attempts	Final Mark
1	93,33
1	63,33
1	80
1	70
1	80
1	100
1	60
1	80
1	90
1	60
1	100
1	60
1	70
1	75
1	90
1	55
1	100
1	0
1	100
1	100
1	90
1	100
1	83,33
1	100
2	90
2	80
2	75
2	90
3	100

Attempts = 2
45
90

Attempts = 3
76,67
80
100

Mode =1

PT 5

No. of attempts	Final Mark
1	85
1	50
1	65
1	65
1	80
1	20
1	0
1	50
1	0
2	30
2	95
2	65
2	89
2	82,5
2	70
2	32,5
2	62,5
2	50
2	90
2	70
3	100
3	70
3	50
3	70
3	85
4	100
4	85
5	55
5	100

Attempts = 3
20
35
50

Attempts = 4
25
40
55
85

Mode = 2

F. ANALYSIS OF DATA FOR PRACTICE TESTS (PT)

PT 6

No. of attempts	Final Mark
1	80
1	100
1	90
1	100
1	58,33
1	63,33
1	60
1	0
1	20
1	76,67
1	100
1	60
2	70
2	100
2	100
2	80
2	50
2	90
2	80
2	100
2	60
2	100
2	100
2	80
2	87
2	76
2	58,33
3	100
3	100

Attempts = 2
40
100

Attempts = 3
15
35
100

Mode = 2

PT 7

No. of attempts	Final Mark
1	100
1	70
1	75
1	86,67
1	0
1	21,67
1	53,33
1	80
1	70
1	90
2	90
2	90
2	100
2	100
2	70
2	100
2	55
2	90
2	60
2	90
2	100
2	86,67
2	53,33
2	60
2	100
2	100
3	95
3	100
4	60

Attempts = 2
55
100

Attempts = 3
10
15
95

Attempts = 4
15
35
40
60

Mode = 2

PT8

No. of attempts	Final Mark	Attempts = 3	Attempts = 4	Attempts = 5
1	70	45	45	0
1	70	75	65	35
1	50	100	75	51,25
1	35		100	93,75
1	5			100
1	70			
1	56,25	Mode = 2		
2	70			
2	100			
2	100			
2	15			
2	100			
2	100			
2	95			
2	81,25			
2	100			
2	95			
2	80			
2	50			
2	67			
2	55			
3	76,25			
3	100			
3	95			
4	50			
4	50			
4	100			
5	100			
5	100			

F.2 Analysis of Second Pilot Study Data for Practice Tests (PT)

This section presents the students attempts for the 8 practice tests in the second pilot study.

PT1

No. of attempts	Final Mark	Attempts = 5	Attempts = 6	Attempts = 8
1	56	52	8	32
1	40	60	48	40
1	32	80	52	60
1	85,33	80	53,33	60
1	49,33	100	60	88
1	57,33		64	92
1	92			92
1	37,33			100
1	33,33			
2	72	Mode =2		
2	74			
2	78,67			
2	96			
2	48			
2	92			
2	72			
2	96			
2	96			
2	100			
2	92			
2	88			
3	92			
3	72			
3	100			
3	100			
3	76			
3	100			
3	96			
3	92			
4	89,33			
4	100			
4	100			
4	84			
5	100			
6	84			
6	64			
6	92			
8	100			

F. ANALYSIS OF DATA FOR PRACTICE TESTS (PT)

PT 2

No. of attempts	Final Mark
1	70
1	30
1	35,83
1	62,5
1	44,17
1	72,5
1	67,5
1	32,5
1	47,5
1	62,5
1	35
2	82,5
2	65
2	54,17
2	62,5
2	52,5
2	87,5
2	87,5
2	87,5
2	87,5
2	52,5
2	71,67
2	57,5
2	50
3	77,5
3	75
3	76,67
4	100
4	100
4	100
4	87,5
4	100
4	100
4	90
5	100
5	100
5	91,67
5	100

Attempts = 3
45
47,5
76,67

Attempts = 4
32,5
50
75
100

Attempts = 5
0
37,5
40
66,67

Mode = 2

PT 3

No of attempts	Final Mark
1	50
1	70
1	70
1	70
1	50
1	0
1	70
1	68,33
1	85
1	68,33
1	88,33
1	65
1	60
1	0
1	65
1	50
1	100
1	55
1	75
1	55
1	65
2	100
2	60
2	100
2	90
2	75
2	100
3	30
3	98,33
3	100
3	100
3	50
4	100
4	100
4	90
5	100
5	100
6	100

Attempts = 4
30
66,67
75
100

Attempts = 5
0
35
40
65
100

Attempts = 6
28,33
35
45
50
50
100

Mode =1

PT4

No. of attempts	Final Mark
1	50
1	66,67
1	45
1	45
1	100
1	50
1	0
1	50
1	0
1	66,67
1	40
1	40
1	45
2	75
2	75
2	75
2	70
2	50
2	100
2	100
2	45
2	70
2	70
2	50
2	100
2	75
2	50
3	75
3	100
3	91,67
3	100
3	100
3	75
3	75
3	70
4	100
4	100
5	100

Attempts = 3	Attempts = 4
36,67	50
66,67	50
100	50
	100

Mode = 2

PT5

No. of attempts	Final Mark
1	65
1	100
1	47,5
1	80
1	62,5
1	95
1	92,5
1	100
1	0
1	65
2	45
2	85
2	80
2	100
2	65
2	82,5
2	77,5
2	100
2	100
2	85
2	100
2	95
3	80
3	40
3	70
3	100
3	100
3	65
3	100
3	100
4	100
4	100
4	100
4	100
4	100
5	100
5	100
9	70

Attempts 4	Attempts 5	Attempts 9
17,5	25	2,5
45	32,5	32,5
65	35	40
100	55	45
	100	50
		55
		55
		70
		70

Mode = 2

PT6

No. of attempts	Final Mark
1	86,67
1	73,33
1	80
1	80
1	46,67
1	100
1	73,33
1	48,33
1	63,33
1	50
1	16,67
1	38,33
2	90
2	75
2	95
2	65
2	80
2	100
2	100
2	95
2	80
2	90
2	100
2	100
2	100
2	76,67
3	100
3	100
3	100
3	75
3	100
3	96,67
3	100
3	85
3	100
4	100
4	100
4	100

Attempts 2
0
76,67

Attempts 3
20
55
100

Attempts 4
50
75
80
100

Mode = 2

PT 7

No. of attempts	Final Mark
1	100
1	63,33
1	100
1	100
1	60
1	100
1	100
1	35
1	0
1	30
1	95
1	88,33
1	35
2	75
2	50
2	50
2	100
2	100
2	40
2	90
2	95
2	100
2	66,67
2	96,78
2	80
2	100
2	100
2	33,33
2	93,33
3	55
3	87
3	90
3	100
4	80
4	100
4	100
5	80
5	100

Attempts = 3
5
45
90

Attempts = 4
8,33
50
81,67
100

Attempts = 5
20
58,33
80
96,67
100

Mode = 2

PT 8

No. of attempts	Final Mark
1	70
1	82,5
1	55
1	45
1	42,5
1	82,5
1	55
1	85
2	65
2	62,5
2	100
2	92,5
2	100
2	70
2	100
2	82,5
2	100
2	65
2	100
2	55
2	67
2	45
2	100
2	90
3	70
3	100
3	70
3	100
4	100
4	100
4	100
4	100
5	70
5	100
5	55
7	100
8	100
9	100

Attempts = 7
17,5
22,5
70
85
92,5
85
100

Mode = 2

Attempts =8
22,5
25
30
35
40
40
70
100

Attempts =9
0
5
22,5
50
35
40
40
30
100

F. ANALYSIS OF DATA FOR PRACTICE TESTS (PT)

Appendix G

Questionnaires

G.1 Questionnaire of the First Pilot Study

This section presents the anonymous questionnaire which aims to gather information that can be used to improve PT and AT, which was proposed during the first pilot study. It is a short questionnaire with 20 questions that can be answered in less than 5 minutes.

Question # 1

Instructions of the questions were provided in a clear and concise manner

- Yes
- No, please specify....

Question # 2

Feedback provided by the system was satisfactory

- Yes
- No, what kind of feedback do you expect?

Question # 3

Do you need more practice questions (PT)?

- Yes
- No

Question # 4

Was the time provided in the assessment tests were enough to complete it?

- Yes
- No

Question # 5

Were there any errors in the assessment tests that you would like to point out?

- Yes, please specify....
- No

Question # 6

Overall, the grades for the tests performed were

- Very good
- Good
- Satisfactory
- Low
- Very Low

Question # 7

The grades given in the tests were fair

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Question # 8

During which period did you mostly use the system, to complete PT and AT?

- When the test was open
- Central part of the test
- When the test was about to close

Question # 9

Was it useful to do Practice Test (PT) before attempting Assessment Test (AT)?

- Yes, please specify why?
- No

Question # 10

Do you think, it is a good method to have a restriction with a pass mark for PT to move to AT ?

- Strongly Agree
- Agree
- Neutral

- Disagree
- Strongly Disagree

Question # 11

Both Practice Test (PT) and Assessment Test (AT) helped me to understand some of the topics covered in the learning materials

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Question # 12

Doing both PT and AT questions helped me to evaluate my strengths and weaknesses in order to do CAT

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Question # 13

Doing an Assessment Test (AT) contributed to weekly monitor the subject correctly

- Strongly Agree
- Agree

- Neutral
- Disagree
- Strongly Disagree

Question # 14

If you could choose, what would you proposed for the frequency of tests

- 1 week
- 2 weeks
- 3 weeks

Question # 15

Completion of Assessment Tests (AT) was useful to prepare for the final examination

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Question # 16

Doing Practice Test (PT) and Assessment Test (AT) in the system, helped me to perform better in the skill assessment module

- Strongly Agree
- Agree
- Neutral
- Disagree

- Strongly Disagree

Question # 17 The questions of the skill assessment module helped me to evaluate my performance of proofs

- Yes
- No. please specify why? ......

Question # 18

How many attempts, on average, did you use to achieve the minimum score on the Assessment Test (AT)?

- 1 attempt
- 2 attempts
- 3 attempts

Question # 19

Completion of the tests (PT and AT) using the system made me interested in the subject

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Question # 20 In general, what are your suggestions to improve the system?

G.2 Questionnaire of the Second Pilot Study

This section presents the questionnaire given for the students of the second pilot study. This questionnaire aims to collect anonymous information to improve the technology-enhanced assessment system consisting of PT and AT, which was used in the second pilot study. It is a short questionnaire with 28 questions that could be answered in less than 5 minutes.

Learner Information

Question # 1

Is this your first time in the Logic course?

- Yes
- No, how many times have you attended this course?

Student Satisfaction

Question # 2

The instructions of the questions were presented in a clear and concise manner

- Yes
- No, please describe why?

Question # 3

In general, grades offered through the system for all tests (PT, AT) were:

- Very good
- Good
- Satisfactory
- Low
- Very low

Question # 4

The questions given in the tests (PT, AT) were clear?

- Yes
- No

Question # 5

Doing tests (PT, AT) using the tool made me more interested in the subject

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Formative assessment

Question # 6

Was it helpful to practice (PT) before attempting the Assessment Test (AT)?

- Yes, please specify why?
- No

Question # 7

Do you need more questions to practice (PT)?

- Yes
- No

Question # 8

The comments received automatically by the tools about your performance were satisfactory

- Yes
- No, what kind of comments you would be helpful?

Question # 9

Do you think that the marks you got fit your knowledge and skills developed?

- Yes
- No, please explain why?

Question # 10

Both practice tests (PT) and assessment tests (AT) helped me to understand the topics covered in the materials

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Question # 11

Doing Practice Tests (PT) and Assessment Tests (AT) helped me to identify my strengths and weaknesses related to the course

- Strongly Agree
- Agree
- Neutral

- Disagree
- Strongly Disagree

Question # 12

Doing the Assessment Tests (AT) was helpful for learning of skills related to the course

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Question # 13

How many attempts, on average, you used to achieve the minimum score on the Assessment Tests (AT)?

- 1 attempt
- 2 attempts
- 3 attempts

Question # 14

If you passed the Assessment Tests (AT) in the second attempt or third attempt, were you able to identify the mistakes you made in the previous attempts?

- Yes
- No, please explain why?

Question # 15

Do you think that you will learn the same if you do not have Assessment Tests?

- Yes, please explain why?
- No

Assessment Model

Question # 16

Do you prefer to have standard CAT instead of PT and AT ?

- Yes, please explain why?
- No

Question # 17

The weight of the Continuous Assessment (CA) and the final examination (EX) is 35% for CA and 65% for EX. Do you think it is appropriate?

- Yes
- No, which weight would you prefer?

Question # 18

Do you think that having a minimum score (30%) on the Practice Test (PT) and then moving to Assessment Test (AT) is a good way to get better results later in AT?

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Question # 19

The schedule given for the assessment tests was sufficient enough to accomplish the test

- Yes
- No, please explain why?

Question # 20

When did you mostly answer the test?

- At the beginning (when the test has just been published)
- At the central part of the period
- At the end (when the test was about to close)

Question # 21

If you could choose, what could be the better time gap to offer both practice and assessment tests?

- 1 week
- 2 weeks
- 3 weeks

Question # 22

The time given for the completion of the assessment tests was enough

- Yes
- No

Question # 23

Did you pay attention to the progress presented in the progress bar?

- Yes
- No, please explain why?

Question # 24

Is it useful for you to see your competence progress in a graphical way?

- Yes
- No, please explain why?

Question # 25

Was the progress bar useful for evaluating your progress in doing the activities/tests?

- Yes
- No, please explain why?

Question # 26

Was the competency block useful for you?

- Yes
- No, please explain why?

Question # 27

The outcomes and grades displayed in the qualification section provided useful information

- Yes
- No, please explain why?

Question # 28

Comments and suggestions :

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