

Skill and Knowledge E-Assessment: A Review of the State of the Art

Enosha Hettiarachchi (khettiarachchi@uoc.edu)

PhD Candidate, Internet Interdisciplinary Institute (IN3), Universitat Oberta de Catalunya (UOC)

Dr. M. Antonia Huertas, Dr. Enric Mor (mhuertass@uoc.edu, emor@uoc.edu)

Department of Computer Science, Multimedia and Telecommunication, Universitat Oberta de Catalunya (UOC)

Doctoral Working Paper

Doctoral Working Paper Series DWP13-002

The Information and Knowledge Society Doctoral Programme

Submitted in: October 2013

Accepted in: November 2013

Published in: December 2013



Internet Interdisciplinary Institute (IN3)

<http://www.in3.uoc.edu>
Edifici MediaTIC
c/ Roc Boronat, 117
08018 Barcelona
Espanya
Tel. 93 4505200

Universitat Oberta de Catalunya (UOC)

<http://www.uoc.edu/>
Av. Tibidabo, 39-43
08035 Barcelona
Espanya
Tel. 93 253 23 00



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Dr. M. Antonia Huertas, Dr. Enric Mor
(mhuertass@uoc.edu, emor@uoc.edu)

Department of Computer Science, Multimedia and Telecommunication, Universitat Oberta de Catalunya (UOC)

Recommended citation:

HETTIARACHCHI, Enosha; HUERTAS, M. Antonia; MOR, Enric (2013). "Skill and Knowledge E-Assessment: A Review of the State of the Art" [online working paper]. (Doctoral Working Paper Series; DWP13-002). IN3 Working Paper Series. IN3 (UOC). [Accessed: dd/mm/yy].
<<http://journals.uoc.edu/ojs/index.php/in3-working-paper-series/article/view/n13-hettiarachchi-huertas-mor/n13-hettiarachchi-huertas-mor-en>>

Abstract

E-Assessment, which is also known as technology-enhanced assessment or online assessment, is the continuous electronic assessment process where information and communication technology is used for the presentation of assessment activity, and the recording of responses. E-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 is an emerging concept and it has become increasingly attractive in Higher Education. This paper presents a literature review of the e-assessment along the dimensions of its key elements, systems, tools, and approaches, with special emphasis on the assessment of both skills and knowledge. These dimensions can provide the theory and technology, which are useful for designing and developing an e-assessment system for skill and knowledge acquisition in an online course.

Keywords

e-assessment; skill and knowledge assessment; online education, formative assessment; intelligent tutoring systems

Introduction

E-Assessment, which is also known as online assessment or technology-enhanced assessment, is the continuous electronic assessment process where information and communication technology 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 and 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). The aim of this paper is to present a comprehensive literature review addressing the general areas of e-assessment related to skill and knowledge acquisition. Therefore, this paper will specifically address aspects such as the advantages and disadvantages associated with e-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 e-assessment; and previous research based on skill and knowledge assessments.

The paper starts with an introduction to assessment, including skill and knowledge assessment. A brief introduction to e-assessment is also given. The elements of formative e-assessment are described along with its effects on students' learning process. Furthermore, this paper explains the e-learning systems, standards & specifications, e-assessment tools that are currently in use, and defined e-assessment models. Finally, the approaches to skill and knowledge assessment are explained.

1. Assessment

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 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 for both students and teachers. Therefore, it is interesting to have a look at the relationship between assessment and learning.

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).

1.2. Skill and Knowledge Assessment

Assessment tasks can be divided broadly into two types such as convergent assessment and divergent assessment (Crisp, 2009). 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-order 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 (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 modelling (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. E-Assessment

E-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 (Crisp, 2009). Alternative modes of presenting assessment tasks are now possible, ones that are more adapted to the diversity in learning styles displayed by students. E-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).

E-Assessment can be categorized as diagnostic, formative and summative based on, at which stage of the learning the assessment is carried-out (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 depicting the relationship between diagnostic, formative, summative assessment tasks linked to learning activities can be shown as in Figure 1.

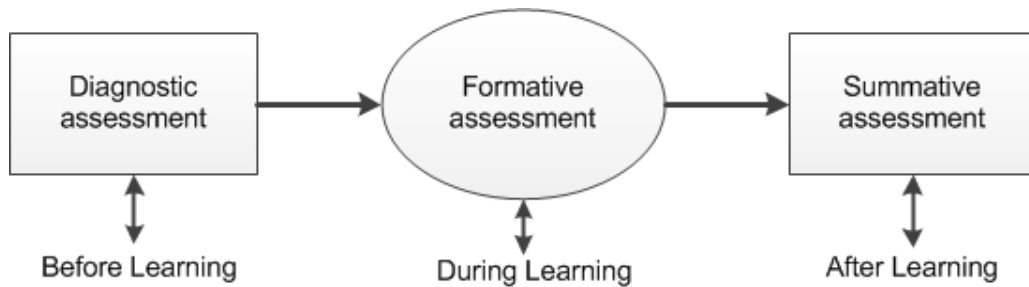


Fig 1. Relationship between diagnostic, formative, summative assessment and learning

The formative e-assessment process explained in JISC (2007) with respect to e-assessment and effective learning are 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 in Figure 2.

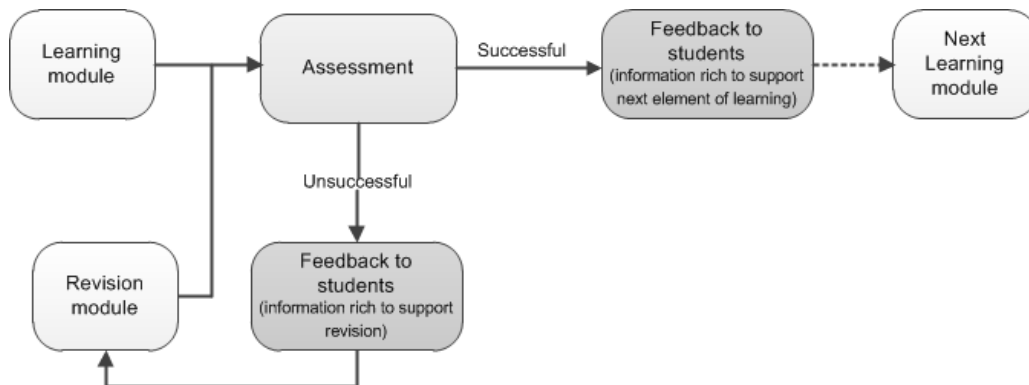


Fig 2. The relationship between e-assessment and effective learning (JISC, 2007)

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 given feedback and improve their learning process. Therefore, this is an important aspect which has to be considered when designing and developing an e-assessment system.

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

2.1. Advantages of using E-Assessment

As several authors (Dermo, 2009; Hettiarachchi & Huertas, 2012; Whitelock, 2007, 2009; Whitelock & Watt, 2008) have suggested, main drivers for using e-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 today's higher education, which ensures that e-assessment will play an increasingly important part in higher educational practice (Whitelock & Watt, 2008).

2.2. Disadvantages of using E-Assessment

As with advantages, there are some limitations and risks that need to be considered when introducing e-assessment in the online educational context. There are many barriers that need 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 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 (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).

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 (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 e-assessment.

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 therefore 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 (de Bruyn et al., 2011).

According to 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 channelling 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 student 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).

4. E-Assessment Systems and Tools

In this section, the e-assessment systems and tools that are currently in use are discussed. 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.

4.1. 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; 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, 2013a), 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, 2013) 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 developer 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, 2013b).

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 LTSC, 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, 2013d).

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

The basic use behind the development of the 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 realizes 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.

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 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.

4.1.1. 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. The selection of the formats to be analysed are based on the 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, 2013b), 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 state the problem, predicted responses which are matched with student responses, feedback and full explanation which are 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, 2013) 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 1.

Table 1: Key features in assessment formats (Gutierrez et al., 2010)

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

Table 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 an 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.

Table 2: Question types of assessment formats (Gutierrez et al., 2010)

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

According to Table 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 1 and 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 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, 2013b) and IMS QTI (IMS GLC, 2013c) can be considered.

Moodle is an open source e-learning system that includes e-assessment facility (Moodle, 2013a). 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. Even though, through QTI it was needed to adopt portability, it does not specify a QTI compliant player which also means that player features such as the use of tools, journaling and reply are not covered. QTI also lacks the flexibility and adaptive test modes (Beevers, et al, 2010).

As a summary, because of the simple type of questions offered by the Moodle XML, it can be used to support knowledge assessment but not the skill assessment.

4.2. 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 (Crisp, 2009).

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 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.

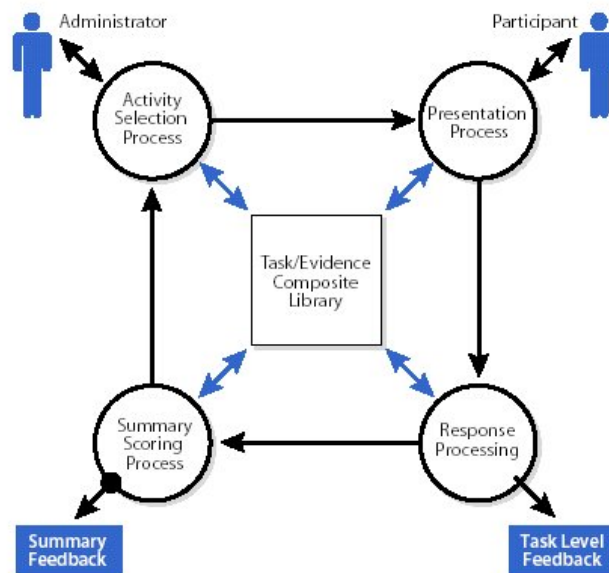


Fig 3. A Four-process architecture for assessment (Almond et al., 2002)

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) (Figure 4). 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. As well as, new systems can be composed of 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).

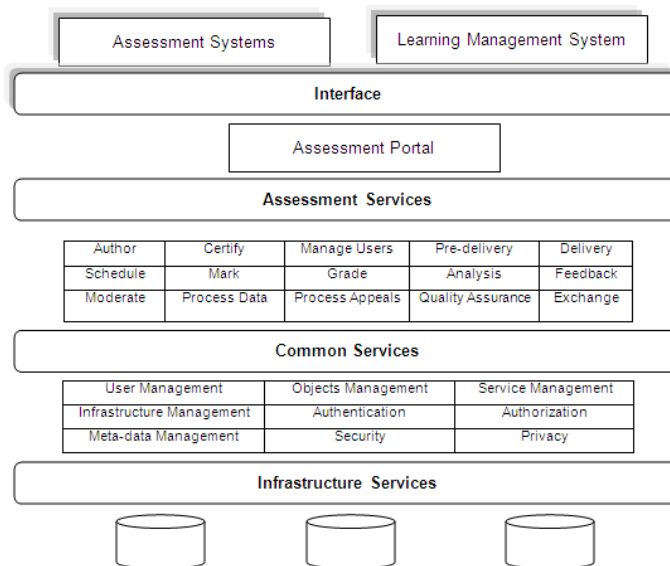


Fig 4. Abstract Framework for Assessment (AL-Smadi et al., 2009)

The "Assessment Services" in AFA have been identified based on FREMA process concept map (AL-Smadi et al., 2009; Millard et al., 2005). These 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.

4.3. E-Assessment Systems

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 (Bull & McKenna, 2004; Sitthiworachart et al., 2008; Tselonis & Sargeant, 2007).

There are some interesting systems 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, 2013a), Moodle Assignments (Moodle, 2013a), 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, for e-assessment of skills, 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.

At the same time, e-assessment tools that are based on skill assessment depend 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. Therefore, as an example, in this paper we have considered the logic subject which requires a higher-level of skill acquisition in order to qualify in the subject. Under that we have studied some e-assessments tools that can be used 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 tools. Therefore, it is important to discuss about the main characteristics of both ITS and e-assessment tools.

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), OpenMark (The Open University, 2013) and ACME (Prados et al., 2011; Soler et al., 2002); 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 an e-assessment system 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 provides full support for questions that are designed to allow multiple tries with stepped feedback. Also the system allows the 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. However, OpenMark does not provide question authoring facilities and assessment, building tools for use by module users. 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. 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 facts that they are developed particularly for this system, sharing of question banks with other tools are not possible.

ACME is a web based e-learning tool developed by the University of Girona specially targeted towards continuous assessment of the student's skills in an initial mathematics course (Soler et al., 2002; Prados et al., 2011). Its main features of this tool are communication through the internet and use of a computer algebra system (mathematics) to achieve a high degree of interactivity. The assessment is made through a personal exercise book generated by the system for each student at the beginning of the course. According to Soler et al. (2002), the system should be serviceable at any level

of mathematics and should be adaptable to subjects other than mathematics. However, ACME is not an open source tool.

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 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 fulfil 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 facilities 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 3, outlines a comparison of the above tools with respect to the expected characteristics of an e-assessment system for logic.

Table 3: Characteristics found in some of the tools for logic

Characteristics	Math e-assessment tools				ITS tools for logic		
	EASy	AiM	OpenMark	ACME	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	*	*	*	*	*	*	*
Open Source		*	*		*		

Thus, by comparing the representative tools that can be used for learning and assessing logic or most related math subjects, as in Table 3, it was not possible to find a general open source 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 acquisition, unfortunately these tools do not support most of the e-assessment characteristics as shown in table 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.

5. Approaches to Knowledge and Skill Assessment

Under this section general trend and positions associated with e-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.

5.1. General Trends and Positions

Even though with the evolution of online education, the e-assessment 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, e-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 the 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. E-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.

5.2. Skill and Knowledge Assessment Tools

Introduction to research work carried-out based on 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 had 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 earned 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 delivers 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 Politècnica 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 adapted 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.

ACME is another interesting web based e-learning tool developed by the University of Girona specially targeted towards continuous assessment of the student's skills in an initial mathematics course (Soler et al., 2002; Prados et al., 2011). According to Soler et al. (2002), the system can be adapted to subjects other than mathematics, but is not an open source tool.

As mentioned under "4.3. E-Assessment Systems", some e-assessment tools and intelligent tutoring systems for mathematics and logic such as EASy, AiM, OpenMark, ACME, Pandora, Organon and AELL were studied. From the analysis, it was understood that when it comes to the case of logic, mostly 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 open source system which was able to support both skill and knowledge e-assessment in a convincing way.

6. Conclusions

This paper presented a literature review of the research on e-assessment of skill and knowledge acquisition. Under this, skill and knowledge assessment, e-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 an e-assessment system for skill and knowledge acquisition. According to literature discussed, most of the organizations use knowledge assessment rather than skill assessment. 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 assess both skill and knowledge acquisition, 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 open source solution, which supports both skill and knowledge assessment. At the same time, these tools depend on a particular subject, therefore, it is not easy to apply or adapt it into another context.

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Resumen

E-Assessment, también conocido como technology-enhanced assessment o evaluación en línea es el proceso continuo de evaluación electrónica donde se utiliza la tecnología de la información y la comunicación para la presentación de las actividades de evaluación, y el registro de las respuestas. E-Assessment ofrece a profesores y alumnos nuevas posibilidades para la interacción en un entorno educativo inmersivo y receptivo, yendo más allá del entorno estático del tradicional enfoque del “lápiz y papel”. E-Assessment es un concepto emergente y se ha vuelto más y más atractivo en la Educación Superior. Este trabajo presenta una revisión de la literatura del e-assessment a lo largo de las dimensiones de sus elementos clave, sistemas, herramientas y enfoques, con especial énfasis en la evaluación tanto de habilidades como conocimientos. Estas dimensiones pueden proveer la teoría y la tecnología que son útiles para el diseño y desarrollo de un sistema de e-assessment para adquisición de habilidades y de conocimientos en un curso online.

Palabras clave

e-assessment, evaluación de habilidades y conocimientos, educación en línea, evaluación formativa

Resum

E-Assessment, també conegut com technology-enhanced assessment o avaluació en línia és el procés continu d'avaluació electrònica on s'utilitza la tecnologia de la informació i la comunicació per a la presentació de les activitats d'avaluació, i el registre de les respostes. E-Assessment ofereix a professors i alumnes noves possibilitats per a la interacció en un entorn educatiu immersiu i receptiu, anant més enllà de l'entorn estàtic del tradicional enfocament del "llapis i paper". E-Assessment és un concepte emergent i s'ha tornat més i més atractiu en l'Educació Superior. Aquest treball presenta una revisió de la literatura de l'e-assessment al llarg de les dimensions dels seus elements claus, sistemes, eines i enfocaments, amb especial èmfasi en l'avaluació tant d'habilitats com coneixements. Aquestes dimensions poden proveir la teoria i la tecnologia que són útils per al disseny i desenvolupament d'un sistema d'e-assessment per a adquisició d'habilitats i de coneixements en un curs en línia.

Paraules clau

e-assessment, avaluació d'habilitats i coneixements, educació en línia, avaluació formativa

Enosha Hettiarachchi

khettiarachchi@uoc.edu

Internet Interdisciplinary Institute (IN3), Universitat Oberta de Catalunya (UOC)

Enosha Hettiarachchi is a PhD Student at the IN3 of Universitat Oberta de Catalunya (UOC). She obtained both her Bachelors and Masters Degrees in the field of Computer Science from University of Colombo School of Computing (UCSC) in Sri Lanka. Currently she is following her PhD in the Network and Information Technologies Area. Her main research interests are technology-enhanced assessment, e-learning, technologies and tools for distance education and learning object repositories.

Dr. M. Antonia Huertas

mhuertass@uoc.edu

Department of Computer Science, Multimedia and Telecommunication, Universitat Oberta de Catalunya (UOC)

Dr. M. Antonia Huertas is an Associate Lecturer of Mathematics and Knowledge Representation in the Department of Computer Science, Multimedia and Telecommunication at the Universitat Oberta de Catalunya (UOC). She holds a Ph.D. in Mathematics (University of Barcelona), a Postgraduate in Information Systems and Communication (UOC), and Post doctorate studies in Logic and Artificial Intelligence (Institute for Logic, Language and Computation, University of Amsterdam). Her research interests include logics, knowledge representation, web-based teaching and learning and mathematical education.

Dr. Enric Mor

emor@uoc.edu

Department of Computer Science, Multimedia and Telecommunication, Universitat Oberta de Catalunya (UOC)

Dr. Enric Mor Pera graduated in Computer Science by the Universitat Politècnica de Catalunya (UPC) and obtained his PhD in Information and Knowledge Society by Universitat Oberta de Catalunya (UOC). Since 1998 he is a lecturer at the Computer Science, Multimedia and Telecommunication department of the UOC. His main research areas are human-computer interaction, accessibility and technology enhanced learning.

