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Linking E-Assessment to Student's Use of Online Learning Content

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INTRODUCTION

This article will examine the development and implementation of two information and communications technology (ICT) e-assessment tools—a diagnostic assessment system and an intelligent content assessment marking system—for the teaching of secondary science. An e-learning management system (ELMS, see Figure 1) was used with second-year secondary students in science which provided both content and online assessment tools for teachers. By using this system, teachers had the opportunity to modify how they assessed their students by shifting the skills and knowledge being tested and also when and at which stage of the learning they are tested. The use of the ELMS had also assisted teachers to move away from the narrow confines of standardised tests with their discrete and decontextualized 'items' towards more complex, holistic, contextualised, and authentic forms of assessment (e.g., Pellegrino, Chudowski, & Glaser, 2001).

Using these diagnostic tools for assessment teachers could better help students gain mastery in specific content areas, in particular, the more abstract concepts in science education. The ELMS was used to collate the data from the two assessment tools and provided an additional online diagnostic profiling system (DPS). This profiling tool was then used by teachers to detect the extent and nature of each individual student's knowledge and competence within topics of study in order to help that learner progress ahead in developing independent mastery and lifelong learning skills.

CAPTURING THE POTENTIAL OF E-LEARNING AND E-ASSESSMENT

In schools where traditional assessment modes prevail, teachers are often swamped with setting and marking different forms of assessment, usually aimed at preparing students for high-stake examinations. In order for them to adequately assess which difficulties confronted by students impact learning most strongly, they need effective tools to develop ways and means to collect and analyse data in class. With the help of ICT tools, teachers can locate timely information about student learning which allows them to set meaningful and measurable goals for future learning. Assessment whether online or not can be used as one of the most powerful ways of improving learning. By simply changing the assessment of the subject, teachers can in turn affect the way students engage with the subject content (Black & Wiliam, 1998). New pedagogy is also needed to effectively leverage the use of technology. E-assessment cannot simply invent new technologies which recycle current ineffective practices (QCA, 2004).

As Conole (2004, p.3) pointed out, one of the affordances of ICT is the potential for multimodal and nonlinear approaches to navigating through information. She highlights the fact that the nonlinearity of the Web (epitomised by hypertext and the use of powerful search engines) leads to the potential for different routes through, and forms of, learning. Yet many research studies have concluded that much of the current online training materials still appear to follow a linear, assembly line mode of learning. Many 'e-learning' packages are built on behaviourist principles of atomised experiences that need to be completed in a specified order before the individual is positively reinforced and permitted to move on—a form of electronic page-turning (Conole, 2004).

When designing online learning systems, the structure of how learning content is incorporated is vital to its success. According to Boettcher (2003), course content—the material to be learned or studied—is only one of the four key core components of the learning experience. The other three are the *teaching*, the *learner*, and the *environmental* components. In her research, she emphasized that online learning based on well-structured content can impact the identification, selection, and development of course content in three ways:

- Content must be semantically well-structured for instruction; this corresponds to the *teaching* component of the learning experience.
- Content must be a good fit or well-structured for a particular student; this corresponds to the *learner* component of the learning experience.
- Content must be technologically well structured; this corresponds to the *environmental* component of the learning experience.

Boettcher extends this notion well beyond the dictionary meaning of well-structured content. It includes the nuances of interaction with the other three components of the learning experience—teaching, learner, and environmental.

Therefore, in practice, when researchers work with teachers and students in schools, how can course content be sufficiently well-structured to be really meaningful to the students? Just as being an expert in teaching science is not by itself a guarantee of good pedagogy, any ICT technology tools might miss the mark if they are not fine-tuned to the content the teacher wishes to present. It is well established that how the tools are being used is more important than whether the students and teachers like them. Therefore, when designing content for online delivery, teachers, instructional designers, and other stakeholders need to actively investigate and formulate their own strategies on e-learning as well as how to apply ICT tools to e-assess students.

With the emergence of online technologies as a new space for instruction, a lot of research has been conducted on the effectiveness of the teaching and learning process rather than on what students are doing within the learning experience. The organization of what is being taught and how content is being taught and assessed online—the structure of the course content and associated tools used to evaluate learning gain—have received much less attention.

Meanwhile, content development has certainly not been neglected. Large amounts of funds have been spent on developing digital libraries, learning objects, and online learning systems. These are all efforts that foster the evolution of learning management systems and tools for easy mounting of content and access to such content resources. There is clearly a trend for governments worldwide to continue further development of knowledge repositories at all levels of education. However, putting content online or packaging them as learning objects does not in itself guarantee the quality of teaching and learning. It may help students access learning opportunities, but it is unlikely to prove acceptable unless online learning is carefully and appropriately designed and structured to assess learning outcomes. Online learning materials cannot be stand-alone units; they have to blend in with teaching, learning, and assessment strategies.

Within the context described above, the main purpose of the article is to present the framework used for content creation when developing the online learning system which incorporated technology tools to facilitate a better understanding of profiles of student learning and the effective use of e-assessment. The framework established from this implementation guides us to understand how to utilize ICT tools and capabilities to enhance online learners' abilities to acquire knowledge through experiencing the process of guided e-assessment.

One critical factor for designing appropriate student-centered e-learning is to understand how students actually interact with the content and the ELMS. Another critical factor is: how can the ELMS develop and provide a profile of each student's learning which in turn allows teachers to attend to student learning deficiencies? The diagnostic assessment and content marking tools integrated in the ELMS presented in this article help to raise fundamental questions about the whole learning and teaching process. This is a process which needs continual research if we are to achieve the desired goal of maximizing the potential technologies offer to improve learning, teaching, and assessment.

EMBEDDING E-ASSESSMENT WITHIN THE ELMS

According to Bransford, Brown, and Cocking (2000, p. 12), active learning is where students take control of their learning by recognizing when they understand and when they need more information. To achieve this metacognition, new approaches to creating classroom environments must be employed and one key aspect of this change involves assessment. Pachler and Byrom (1999) stated that:

The nature of assessment of and through ICT sits ill-at-ease with traditional educational paradigms of testing the retention, recall and understanding of knowledge by individual learners compared with the more skill- and application-based collaborative modes supported by and intrinsic to working with ICT. ...it seems therefore, that assessment paradigms will need to evolve in the light of emerging technologies and the learning objectives they predicate. (p. 127)

Black and Wiliam (1998a) have presented rather convincing evidence that formative assessment can lead to improvement in student learning. Yet, Black and Wiliam (1998b) also noted that such practice is rarely found in classroom teaching.

In a review of literature from 1994–2002, Webb and Cox (2004) concluded that ICT in secondary science, particularly in the form of simulations or animations of processes, provides a range of affordances for learning science. However, they went on to say that 'teachers do need to understand the affordances provided by the various types of ICT so that they can select ICT to meet their teaching objectives' (p. 258). They contended that 'much more significant changes in teachers' pedagogical practices would be needed to support a curriculum that was to take full advantage of the range of affordances provided by ICT and where more opportunities for student collaboration and student control of the learning are available' (p. 258).

High stakes assessment systems have perpetuated mainly because they have defined what is rewarded by a culture for many years. Current practice in schools means that teachers are swamped with setting and marking different forms of assessment which do not necessarily lead to better learning. To effectively integrate ICT in schools, teachers must consider integration issues into both the curriculum and assessment. Teachers need to reconsider the assessment approaches as there may be a greater role for formative assessment when ICT was integrated with the assessment process.

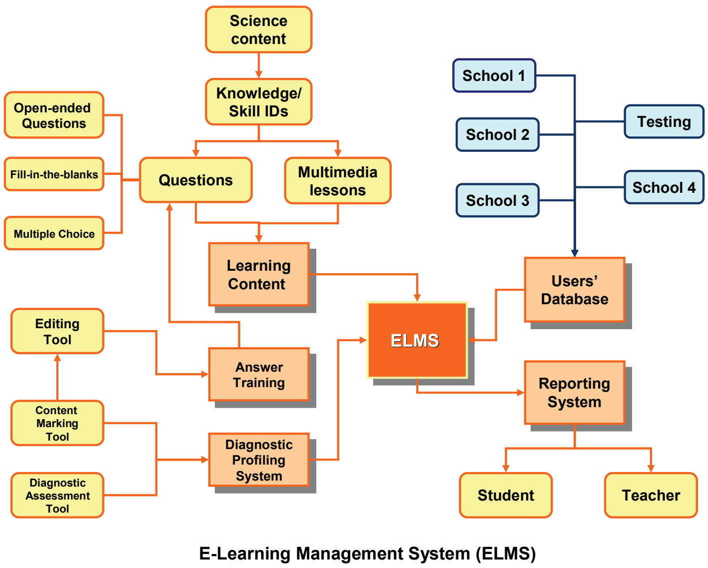
THE ELMS AND ASSOCIATED TOOLS

Within the ELMS (Figure 1), e-assessment methods were used to deliver much needed benefits to learners and alleviated the problem of lack of teacher time. The system provided immediate feedback for on-demand tests and quizzes. Simultaneous diagnostic feedback was also given to guide students to areas of weakness which needed remediation. Tests and other formative assessment items were delivered to students on a needs basis and completed as appropriate. Within the system, teachers could modify how they assessed their students by shifting the skills and knowledge being tested and also decide when and at which stage of the learning they were tested.

Throughout the preparation phase of the ELMS, consultations were held with all the stakeholders (teachers, principals, education authorities). This resulted in a radical redesign of the content and assessment tasks incorporated in the ELMS with the aim to stimulating student interest. Scenarios and game-based environments were used throughout. Both formative and summative assessment modes were facilitated by the diagnostic and content marking tools. These tools provided immediate feedback to both students and teachers on the students' abilities to grasp the concepts, and actually produced a profile (via the DPS) on a student's weak knowledge areas. The ELMS would then automatically customize a set of activities which were subsequently presented to students to improve the weak areas identified.

For students, the ELMS offered many benefits over traditional assessment modes. These benefits included attention to a greater range of important learning outcomes, opportunity for contextualized and authentic assessment, integration of formative feedback for improvement, and generation of an achievement profile over time rather than on a single occasion. Teachers gained valuable experience from ongoing professional discourse where they compared their assessments of students and moderated their judgments against common benchmarks of learning outcomes. This provided an excellent opportunity for improving and modifying

Figure 1. E-learning management system (ELMS)



their own practice purely based on professional motivation and not on any official sanctions.

THE E-ASSESSMENT TOOLS WITHIN THE ELMS

Teachers were asked to explicitly identify the type of science problems that a student found difficult to solve. Based on this information, high-quality, interactive component lessons were developed which comprised a suite of teaching and learning content based on the diagnostic capabilities of the diagnostic and content marking systems which would allow students to engage in learning in new ways. Great care was taken when designing the interactive materials to ensure that students could achieve a deeper mental interaction with the content. Through simulations, students would need to grapple with ideas, make decisions, and choose directions when given options to consider.

In order to alleviate the problem of time, substantial resources were produced which comprised usable learning objects that could be used to strengthen teaching and learning activities. Appropriate content was integrated into curricula so teachers had more time to monitor and assess actual student learning. In no way was the ELMS meant to comprise isolated pieces of specialized software that allowed teachers to 'teach' science per se. It was a complete learning environment that facilitated meaningful professional thinking and working. Through this tool, teachers could use the reusable learning objects and the environment to engage their students in critical thinking and to help further their own professional development concerning aspects of assessment. The online curriculum content provided teachers with interactive learning activities which included text, graphics, audio, and animation which were linked to the specified science skills framework. Such materials were purposefully designed to exploit the use of online tools to enhance students' learning experiences. These learning objects existed as either one or more files or 'chunks' of learning material which may be used in multiple contexts for multiple purposes. The learning objects could also be used as components of a topic or unit of work alongside other digital and nondigital resources and tools. To provide meaningful data for teacher analysis, each of the specified science skills as portrayed in official curriculum documents were explicitly identified and coded and accessed by their metadata descriptors.

The Diagnostic Tool

Within the ELMS, teachers had use of two major assessment and diagnostics tools, which fed data into the diagnostic profiling system. When data was collected by the diagnostic and content marking systems, teachers could then access the DPS to obtain a continuous profile of students' abilities on the specific subjects or topics. Teachers could easily monitor students over a period of time and keep historical records, thus enabling them to see areas of strength and weakness of individual students or classes at any time of the year for each subject topic. With this information, they could plan future lessons or carry out revision accordingly. This successfully eliminated the current practice where teachers were only able to know pupils strengths and weaknesses after several months or after each manual test or exam.

The diagnostic assessment system is an innovative tool that intelligently identifies the specific strengths and weaknesses of individual students throughout each topic's relevant lesson and automatically prompts component lessons for remediation in weak areas. It is Web-based and aims to add value to the teaching and learning process of students and make learning more effective and efficient. Access via the Internet also enables students to access the resources outside their classrooms (e.g., homes). This tool instigates a complete learning cycle (Figure 2) by replicating the teaching and learning process while automating the performance feedback mechanism. It does so by empowering the learner to engage in self-learning through the Web on any subject, for example, science (as is the case for this project).

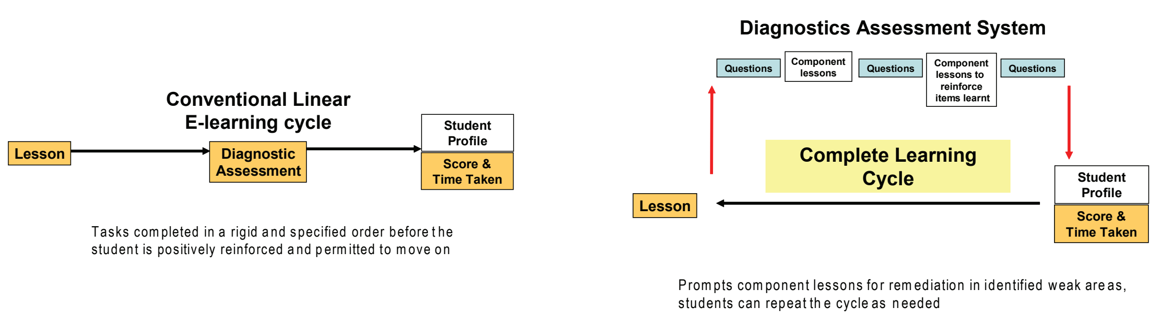
The predict–observe–explain learning cycle was employed for each topic where students had to engage in three tasks. First, they *predict* the outcome, and then they *observe* the event (simulated experiment online) and describe what they see and finally they *explain* any conflict between their initial prediction and final observation. Using this process, the students' thinking processes were made explicit and, at the same time, documented by the ELMS for later analysis by the teacher.

The ELMS could be used in class to supplement face-to-face teaching. It could also be used by students for individual self-learning through repetition without the presence of the teacher, as the system can be accessed from home. On the one hand, it provided opportunities for students to be independent learners. On the other hand, it offered an opportunity for schools to embark on and create an e-learning culture through learning and teaching via the Internet. Through this approach, students were exposed not only to quality content but also given the chance to experience knowledge acquisition in a different mode, an important process in the overall objective of the current education reform agenda.

The Content Marking Tool

The content marking tool is able to mark open-ended content like short and paragraph answers for subjects like science where the content that does not require writing style as a criterion for performance. This system is

Figure 2. Conventional linear vs. complete learning cycle



also able to classify and group various students' answers, especially nonstandard, creative answers. With the use of this tool, online learning is no longer constrained to conventional inputs such as multiple-choice and fill-in-the-blank questions. This tool can mark thousands of open-ended answers instantaneously and provide feedback to students as they learn.

The Diagnostic Profiling System: Tools for Formative and Summative Assessment of Individual Students

The diagnostic and content marking tools engage students in a complete learning cycle comprising multimedia lessons, diagnostic tests, component lessons, and remediation activities. Data collected with these tools are then combined to reveal each student's degree of learning through the diagnostic profiling system (DPS). At the system level, teachers are provided with:

- Instantaneous and meaningful feedback to students;
- Removal of time lag for teacher feedback to students;
- Significant reduction in marking load for teachers, freeing up time for them to focus on diagnostic and assessment strategies;
- Provide historical records of student diagnostics—individual, class, or level;

Once the answers have been marked, the system can automatically tabulate all the marks of each student after the new marking scheme (after step 4 has been completed) has been set and saved. In this manner, the teacher does not have to mark every script. All the teacher has to do is sieve out all the creative or unacceptable answers and allocate the marks that need to be rewarded for correct or partially correct answers.

Advantages of the Student Profiling System

The student profiling system (DPS) collates each student's answer and allows the teachers to monitor the performance of each student. In addition to the teacher, coordinators or subject committees can gather real-time statistics of all students' performance. Since each skill is tagged, specific skills and subskills attached to the questions within topics can assist the teacher to more closely evaluate and assess the students on their literal, interpretive, or applied skills. As and when needed, reports can be generated to provide a profile with clear diagnostics of areas of weakness or strength as depicted in the boxes in the righthand column (Figure 3).

With regard to teaching and learning science, Linn (2004) found that 'students do not connect their views, they fail to generalize their ideas to new problems, and they often cannot recognise problems that closely resemble those they have studied' (p. 345). They maintained that 'too often assessments tend to reinforce piecemeal science learning' (p. 345). In order to avoid this, the ELMS was designed to give students a low threat environment where they can be provided a second and third chance learning. In this study, students could work with the ELMS in three ways:

- The teacher teaches the topic in a face-to-face classroom situation, and students are then asked to complete the assessment tasks in class;
- After the topic has been covered in class, students can access the system at any time and work on the assessments tasks to further consolidate their skills and knowledge and be guided through the learning according to their level of ability; and
- Students can attempt the topics, questions, and component lessons totally on their own or for revision purposes.

Table 1. Actions taken by teachers to train the answers in the ELMS

Steps	Action by Teachers
1	Teachers input model answers for each topic and allocate marking scheme
2	Students complete the topics and input individual answers
3	Teachers go over the answers from students and decide on marking scheme for those answers not already in the system
4	All answers consolidated back into the system for future use

Figure 3. Strengths and weaknesses of each skill diagnosed for individual students to facilitate remediation

Strength of Each Skill Diagnosed

Topic	Skill	Score	No. of questions	Ability
Making Use of Electricity	Understand current is measured using Ammeters	7/9	9	Excellent
Making Use of Electricity	Investigate how a current flows through a closed circuit, with the presence of a source of electrical energy	7/9	9	Excellent
Making Use of Electricity	Investigate how a current flow in a closed circuit to light up a bulb.	6/12	12	Weak
Making Use of Electricity	Classify objects into electrical insulators and conductors	5/9	9	Average
Making Use of Electricity	Explain what is meant by the term current	7/9	9	Excellent
Making Use of Electricity	State the unit and symbol of current	3/3	3	Excellent

[Back]

As discussed earlier, the diagnostic and content marking tools can track iterative improvements using embedded assessments. This degree of flexibility afforded to students means that the ELMS can play a crucial role in assessment, and at the same time, teachers can continually redesign instruction to better cater for students' differing learning styles.

The ELMS provided an assessment system that integrated formative feedback and adaptive learning programmes. Given the administrative overload that many teachers are experiencing, it is providing teachers with the tools needed to intelligently automate assessment (Davitt, 2005). Using the ELMS, teacher can obtain a personalized learning profile for each student by tracking progress in each area against learning targets. As Figure 4 indicates, at any stage, students and teachers can review their learning progress in each area.

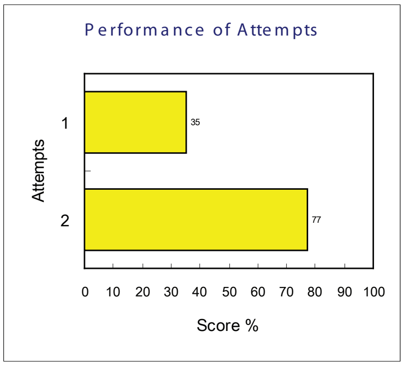
Students completing the tasks were guided by the system to e-learning applications which were personalized and provided instantaneous feedback to the students at appropriate times. Depending on the level of students' abilities in completing the tasks, the ELMS was able to provide individual users with a navigational path that guided their learning. Results from the trials show that when students make more attempts at learning by repeating the learning cycle several times, they actually improved. For some topics, after five attempts, students were able to score 100%. Figure 4 shows how students were able to improve their score after several attempts.

LIMITATIONS AND ISSUES

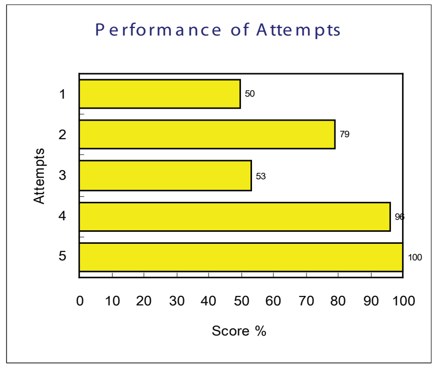
This article has provided an account of how a curriculum innovation project was conducted in secondary schools to establish a valid and reliable online measuring tool for knowledge components and problem-solving skills when learning science. Information is also provided on how the use of two online tools can assist students to engage with more cognitively demanding computer-based curricula to achieve enhanced learning outcomes. The experience from this project correlates with research findings which indicate that technology supported innovative classroom practices can help to change classroom teaching and learning (Kosma, 2003; Lee, 2002; Means, Penual, & Padilla, 2001; Schofield & Davidson, 2001). When teachers are stretched and required to collaborate with outside actors, they begin to see the potential use of technology well beyond their normal expectations. They begin to use technology differently and accept the fact that their students will also use technology differently. Both these changes in classroom practice demonstrate the possibilities of how curriculum can be delivered and how technology can be used in a more integrated ways to achieve desired learning outcomes.

However, in reality we found that students often found it difficult to meet the challenges and to engage in logical reasoning, particularly in the form of simulations or animations of processes specifically designed to measure the degree of learning. This is an area where students need a lot of teacher support. As Webb and

Figure 4. Student performance improved when more attempts at learning were made



Performance increased from 35% to 77% after two attempts



Performance increased for students: after five attempts students scored 100% on the assessment tasks

Cox (2004) had emphasized, ICT in secondary science does provide a range of affordances for learning science. However, they cautioned that teachers do need to understand the affordances provided so that they can select ICT to meet their teaching objectives (Webb & Cox, 2004, p.258). It is also very important for teachers to be aware of their students' beliefs in relation to their degree of control of their learning, and they need to understand the affordances for their particular students. It is only then that teachers will be able to plan activities that enable students to exercise control over their learning and to provide support or scaffolding when students need it (p. 274).

The experience gained from this implementation is in accord with a model for assessment presented in a NCR report, Knowing What Students Know: The Science and Design of Educational Assessments (Pelligrino, Chudowsky, & Glaser, 2001). In this report, it is argued that an improved educational assessment system ought to connect the three key elements of an assessment triangle: cognition, observation, and interpretation: The cognition leg of the assessment triangle is a 'model of student cognition and learning in the domain' (p. 296). Report authors contend further that 'assessments need to examine how well students engage in communicative practices appropriate to a domain of knowledge and skill, what they understand about those practices, and how well they use the tools appropriate to that domain' (p. 92).

There is, in any event, further scope for research that would need to identify innovation in teaching methodology prompted by the unique features of the diagnostic assessment and content marking tools particularly moving in the direction of more student-centered methods and how they impact student learning. For this implantation, the expectations of our research clashed somewhat with teacher beliefs because they had the tendency towards conservative teaching styles. Our expectations for the manner of engagement of students emphasized thinking and discussion, but this again did not match the student expectations as it was foreign to them.

The development of e-learning and e-assessment has provided an essential step forward for use of ICTs in schools. The outcomes from this implementation provide important insights into the use of these tools, and it can be concluded that there is a need to (1) provide a wider range of question formats; (2) encourage students to be more self-directed and control their own learning online; (3) encourage teachers to make significant changes to their pedagogical practices, and (4) continually refine and enhance the intelligence level of the marking system by achieving critical mass input of answers. Our view is that for the ELMS to be effective, all students and teachers need to experience it on an ongoing basis before they can fully appreciate its value and benefits.

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KEY TERMS

Content Marking Tool: A technology that is able to mark open-ended content like short and paragraph answers for subjects like science and any other content that does not require writing style as a criterion for performance. This system is also able to classify and group various students' answers especially nonstandard (creative answers) to facilitate immediate classroom discussions.

Diagnostic Profiling System: A tool that intelligently identifies the gaps in student understanding. Where required, the diagnostic process can automatically trigger appropriate learning resources to help the learner start to address any gaps that might have been identified. It is Web-based and facilitates self-paced learning via a complete learning cycle which replicates the teaching and learning process while automating the performance feedback mechanism.

E-Assessment: Refers to on-demand testing to cater for students who learn at different rates; assessment is provided in a timely manner and is adaptive in nature. It includes automating administrative procedures relating to assessment tasks and digitizing content for online testing which ranges from multiple choice tests to interactive assessments of problem-solving skills.

E-Learning Management System: An electronic environment that enables the delivery, management, and administration of a range of learning activities, services, content, and data to better cater for students' learning needs.