Taylor & Francis
Taylor & Francis Group

Implementation and student perceptions of e-assessment in a Chemical Engineering module

Eva Sorensen*

Department of Chemical Engineering, University College London, London, UK

This paper describes work carried out at the Department of Chemical Engineering at UCL into the use of e-assessment in a second year module and, in particular, the student perceptions of this mode of assessment. Three quizzes were implemented in Moodle, the first two as formative assessment and the final quiz as summative assessment. The results were very encouraging and practically all students engaged with the process. An online survey was delivered to all students after the module, which showed that the students felt that e-assessment added value to their learning and they would like to see it implemented in other modules. The quizzes were intended to be mainly beneficial to the weaker students as it gave them an opportunity to go over key aspects of the material in their own time. Interestingly, the stronger students were even more in favour of e-learning than the weaker students, for whom the quizzes were originally designed.

Keywords: E-assessment; student perception; course experience questionnaire; chemical engineering; Moodle

1. Introduction

The current rapid development in information technology provides both opportunities and serious challenges to engineering and engineering education. As the ability of technology to provide interactive multi-media instruction continues to improve, this rich mixture of visual and verbal information, self-assessment of knowledge and understanding, practice in problem-solving and immediate individual feedback can provide deep learning far better than traditional lecturing approaches can possibly do. Richard Felder pointed out a decade ago that the role of technology in engineering education delivery is one of the main critical issues facing the future of engineering education and that 'the potential impact on traditional campuses that fail to meet the challenge is not pleasant to contemplate' (Shuman et al. 2002). Together with colleagues, he contributed a series of articles to chemical engineering education on 'The Future of Engineering Education'. The first four parts addressed a vision for a new century (Rugarcia et al. 2000), teaching methods that work (Felder et al. 2000a), developing critical skills (Woods et al. 2000) and learning how to teach (Stice et al. 2000). The last two focused on assessing teaching effectiveness (Felder, Rugarcia, and Stice 2000b) and making reform happen (Felder, Stice, and Rugarcia 2000c). The authors provided a comprehensive synthesis of the available literature on effective practice in engineering education that could help faculty meet the challenges facing them. Although these

---

*Email: e.sorensen@ucl.ac.uk

thoughts are now over a decade old, they are nevertheless still highly relevant and advocate for a curriculum that is engaging and stimulating in both content and delivery and that helps develop the required problem-solving skills of tomorrow's engineers (Woods et al. 2001, 2002).

1.1. *Assessment and e-assessment*

Key to any teaching and learning is assessment. Assessment is a process of measuring a person's knowledge, understanding, capability or skill (Quality Assurance Agency for Higher Education 2004, 2006). Equally important, assessment is a way of promoting student learning by providing the student with feedback, normally to help improve his or her performance. An assessment therefore contains evaluation and feedback that has a profound influence on both teacher and learner. If assessment, and in particular feedback, can be applied properly, it can make a great contribution to effective learning (Nicol 2007). Online assessment, or e-assessment, is able to improve the procedure and method of assessment as it has the advantages of time saving, immediate feedback, better use of resources, assessment records saving and more convenience (Morris 2008; Chen, Wei, and Huang 2009). As discussed by Morris (2008), economies of scale are often the main driver for the deployment of e-learning, but e-learning is also viewed variously as having the potential to improve the quality of learning, to improve access to education and training and to improve the cost-effectiveness of education (Alexander 2001). One of the main benefits of e-assessment is that it enables feedback to be delivered instantaneously. This provides an opportunity for students to take immediate action to 'close the gap' between their current level of knowledge and a reference point and thus for the feedback to be effective (Jordan and Mitchell 2009). It should be noted, however, that concern has been expressed that conventional e-assessment tasks can encourage a surface approach to learning (Gibbs 2006) and any implementation of e-learning must keep this in mind.

Although e-learning is now used routinely in some disciplines, engineering has been particularly slow to take this up (McKenna and Yalvac 2007). There may be several reasons for this, but for the Department of Chemical Engineering at UCL it is not because e-learning is not perceived as being important, but unfortunately because of staff time constraints due to high student numbers. There has been a doubling in the number of students within the department over the past five years but with a much slower increase in the number of academic staff. Nevertheless, the department is committed to the implementation of e-learning and started using Moodle as a course management system in 2008–2009 and all course modules now have a Moodle presence. The main aim of this study was to evaluate how e-assessment through Moodle may be implemented in traditional lecture modules, particularly in year 1 and year 2, where the student numbers are currently between 80 and 130 students per cohort.

Assessment is an essential element of a learning process and it is therefore not surprising that almost all online course management systems offer support for assessment, e.g. for the creation, execution and evaluation of multiple choice tests. A number of authors have considered the use of e-assessment using such systems. Aravinthan and Aravinthan (2010) considered the effectiveness of self-assessment quizzes as a learning tool in two engineering courses, where the quizzes were made available through an e-learning system. They found a strong correlation between students who attempt the quizzes and their overall student performance assessed by final grades. Swan (2004) found that an online quizzing environment created for a first year physics course resulted in high student satisfaction and participation rates. The students felt that the quizzes helped them study more consistently over the semester as the quizzes provided them with regular problem-solving practice and immediate detailed feedback. Swan also argued that the quizzes could help identify weak students for early intervention. Jordan (2011) reported on a survey of distance learners and found that students engaged more with the online questions when they carried some weighting and most students felt that their marks should count towards their overall course score.

Jordan also argued that student perception is very important and that it is important to monitor the use of e-assessment and to make changes (to individual questions, the structure of an assignment or to the underlying e-assessment system) as and when appropriate as, frequently, a very minor change in wording can lead to a considerable improvement in the performance of a question.

The use of online quizzes is not just limited to higher education, however. In fact, resources for primary and secondary schools are way ahead of universities in many fields. Wang (2008), for instance, reported on work in an elementary school in Taiwan and found that the children actively participated in web-based formative assessment.

1.2. *Adaptive educational systems*

More recent work goes beyond just providing online assessment or quizzes. Adaptive educational systems attempt to maintain a learning style profile for each student and to use this profile to adapt the presentation and navigation of instructional content to each student. In other words, the learning process is adapted on the basis of the student's learning preferences, knowledge and availability (Markovic, Jovanovic, and Popovic 2011). Most of the adaptive learning systems, however, tailor presentation content and navigational support according to students' prior knowledge. Some research suggests that cognitive styles significantly affect student learning because they refer to how learners process and organise information and that adaptive learning systems should also be tailored to students' cognitive styles and that this, in turn, will improve learning (Mampadi et al. 2011). Although such personalisation of learning is clearly of benefit to the learners, it is, however, considered beyond the scope of this work.

1.3. *The student experience*

It has been widely recognised that e-assessment can contribute to improving the quality of the student learning experience and much research has been carried out into the attitudes towards e-assessment on the part of academic staff. However, much of the literature on e-learning is merely a description of what the teacher could do or has done online, while the student experience of those activities goes largely undocumented (Alexander 2001). Some authors have nevertheless considered student feedback on e-assessment. Dermo (2009) conducted a survey of a cohort of 130 students at the University of Bradford, who had taken part in online assessment, either formative or summative, during the academic year 2007–2008. The students came from several disciplines but the majority were from management, informatics and engineering with life sciences, social sciences and education making up the remainder. The aim was not only to gauge student opinion but also to identify possible risks in planning e-assessment. His results showed that the most positive aspect of e-assessment in the eyes of the students was the benefits it can bring to learning and teaching. The results, however, highlighted concerns about fairness in the use of random questions from a question bank.

Ferrao (2009) presented a study of the implementation of e-assessment as a resource for learning assessment and student evaluation at the University of Beira Interior in Portugal. She surveyed the opinions of 425 students on a statistics and mathematics module, however, only reported the results for one cohort of 71 students from a specific department. The e-assessment was in the form of multiple-choice questions (MCQs) and each student had three e-assessments as well as other forms of assessment. Her study focused mainly on a very detailed statistical analysis of the student questionnaires. In general, Ferrao found that the students were in favour of adopting e-assessment more often, not only in statistics, but also in other disciplines. She did, however, find that failing students tended to be more conservative about the use of e-assessment method than students who passed.

Gilbert, Morton, and Rowley (2007) evaluated in-depth qualitative comments from student evaluation of an e-learning module on an MSc in Information Technologies and Management to develop a picture of their perspective on the experience. The authors found that the aspects of the student learning experience that should inform the development of e-learning included: each student engages differently; printing means that students use the integrated learning environment as a menu; discussion threads and interaction are appreciated, but students are unsure in making contributions; expectations about the tutor's role in e-learning are unformed.

2. E-assessment at Chemical Engineering, UCL

The main objectives of this study can be formulated:

(1) To introduce e-assessment into a departmental lecture module in the form of Moodle quizzes.
(2) To evaluate the outcomes of the formative and summative assessment quizzes.
(3) To solicit the students' views on the use of e-assessment in their modules and to attempt to explore the potential advantages and drawbacks from the students' point of view.
(4) To estimate the time and effort required by the lecturer for the implementation.
(5) To provide recommendations of how e-assessment can be applied efficiently.

It was decided to explore the possibility of using Moodle quizzes to replace parts of traditional course work for one assignment in a second year module on Particulate Systems and Separation Processes. This module is a compulsory BEng/MEng level module, which is taken by around 80–130 students every year. This module was chosen mainly because the course work component compared to the exam component is low compared to other modules (20% course work-80% exam compared to normally 30 or 40% course work). The module is shared between four lecturers, of which two set course work. The focus of this work was on a 10 hour section of the module, which focuses primarily on membrane and chromatographic separations. These are novel separation processes on the chemical engineering arena but are becoming increasingly important within the chemical and biochemical industries.

In the past, one course work assignment was set for this section, which was worth 10% of the total module mark and which consisted of around 15–20% theoretical questions followed by a mini-design project, where the students were required to design a membrane process and estimate its energy consumption and operational constraints. The theoretical questions, on the other hand, covered all aspects of the section, i.e. including chromatography.

Industrial design is an eminently practical subject, but it includes a number of very basic concepts that are not always easy to understand (Rubio et al. 2007). Design is an activity that does not lend itself easily to multiple-choice type questions as a number of design decisions must be made based on complex mathematical calculations. It was therefore decided to keep the design project component of the course work unchanged. Moodle would therefore be used to develop an item of e-assessment in the form of an online quiz, which would replace only the theoretical questions in the course work and which would focus on the underlying theoretical concepts of the section. In the following, only the theoretical part of the course work will be considered, i.e. not the design project.

The specified learning outcomes of the module are the following:
On completion, students should:

- know, understand and be able to apply methods to analyse the characteristics and performance of particulate systems;
- be able to design equipment for fluid and solid–liquid separation processes.

The questions developed for the quizzes were therefore targeted mainly around the knowledge and understanding of membrane and chromatographic systems, not only in terms of their characteristics but also in terms of their performance. The level of difficulty was deliberately set fairly low and approximately equal to a pass mark level for a final module examination. By successfully completing the quizzes, a student should therefore have reached the minimum required learning outcome in terms of the theory. As mentioned previously, the analysis and design components of the module are still being assessed based on a traditional design project, but having reached the first learning outcome prior to the start of the project, it is believed that a student will be more likely to also successfully achieve the remaining learning outcomes.

Given the current high student:staff ratio within the department, the marking of course work assignments is a very time-consuming, and therefore also costly, task. The assignments are generally set by the lecturer, but are then marked by a post-graduate student before being double-checked by the lecturer. Each post-graduate student contributes between 50 and 100 hours per academic year, either marking course work assignments or by demonstrating in the laboratories and marking lab reports. The turn-around time for course work is typically 2–3 weeks, although 4–6 weeks is not unusual. The department, however, aims to reduce this to maximum two weeks, which is well within UCL's guidelines of one month.

The main aims of the implementation of e-assessment in this study are therefore:

- to improve student learning by providing an online learning resource that gives them immediate feedback (for the students);
- to provide more opportunities to go over fundamental concepts (for the students);
- to save time (for the teacher).

It is hoped that e-assessment may be used to replace some of the traditional course work in most of the lecture modules. This will hopefully free up more demonstrator time, which will reduce costs but, more importantly, will also allow a greater focus in the remaining course work component on more design-type questions or projects that are notoriously time-consuming to mark but that are much more effective in terms of developing and testing engineering skills. The combination of e-assessment and traditional design problems will hopefully also ensure that a surface approach to learning is avoided (Gibbs 2006).

There is, of course, an initial set-up time to develop e-assessment components, which is not insignificant; however, it was hoped that the pay-back period should be 1–3 years at the most.

In the following, it will be discussed how the e-assessment component was implemented in the module through Moodle quizzes and the motivations for why it was done this way. An analysis will be given of the results of the quizzes. After the completion of the module, a survey of all students was conducted and the results of this will also be presented. Based on student feedback, changes to some of the aspects of the e-assessment will be considered for the next academic year and these will be discussed. Also, recommendations for how e-assessment can be implemented will be given.

3.　E-assessment implementation

At UCL, the chosen course management system is Moodle (Moodle 2012). The software is open source and free to use and it is used all over the world by universities, schools, companies and independent teachers. The quiz activity module allows the teacher to design and set quizzes consisting of a large variety of question types including multiple choice, true–false and short answer questions. These questions are kept in a question bank and can be re-used in multiple

quizzes. Quizzes can be configured to allow multiple attempts. Each attempt is automatically marked and the teacher can choose whether to give feedback and/or show the correct answers.

The e-assessment developed for the Particulate Systems and Separation Processes module was based on Moodle quizzes and consisted of three parts. The first two quizzes replaced two classroom tests, which earlier took place in class after each of the two sections, i.e. one test on membrane separations (covering six hours of lectures) and one on chromatographic separations (covering four hours). The main purpose of the class tests was to encourage, or rather force, the students to go through their notes after class as the majority of them would not look at their notes again until they had to either complete course work or before the exam.

The old paper class tests covered basic concepts only and consisted of around 10 questions, some multiple choice and some open-ended questions, of maximum two sides of A4. The tests took place in the normal lecture theatre, either at the start of the first lecture of the next part (for membranes at the start of lecture 7) or at the end of the last lecture for the final part (for chromatography at the end of lecture 10). The students were familiar with the assessment style as they also do class tests in a different module taught by the same lecturer. Although the class tests were short and only took 5–10 minutes to complete, they took up at least 20 minutes of lecture time as the answers were discussed in class immediately after collection of the scripts. Although this was probably very helpful for the weaker students, it was time wasted for many of the students as the questions were very simple and covered basic concepts only. The paper class tests took around three hours each to mark and process.

3.1. *Test quizzes*

The main purpose of the first two quizzes was not only to familiarise the students with Moodle quizzes, but also to encourage them to revise their lecture notes, i.e. the main purpose was formative assessment. Two Moodle quizzes were developed based on the earlier class tests. The quizzes consisted of 15 questions each, some multiple choice with only one correct answer, some multiple choice with more than one correct answer and some matching questions. All students had the same questions and in the same order although the order of the choices for MCQs was randomised by Moodle. Brief feedback was provided for all incorrect answers. Examples of questions are given in Figure 1 and an example of question feedback in Figure 2.

The students had 30 minutes to complete each quiz. For the first quiz, there was no limit to the number of attempts, but for the second quiz only three attempts were permitted. The quizzes were open from Tuesday 13.00 hours, when the last lecture of that part finished, until Thursday 09.00 hours when the next part started. The students were informed about the quizzes at the start of the first lecture, reminders were given during the lectures and reminder emails were sent out via Moodle a few days before each quiz, informing the students of the terms and conditions of the quiz.

The results on the first two quizzes were very good, with most students achieving very high or perfect scores. The overall average was 14.0 out of 15 for the membrane quiz and 14.66 out of 15 for the chromatography quiz. The easy level was intentional to make the quizzes seem fun, easy and worth while doing. Although the students had 30 minutes to complete the quizzes, some of the stronger students completed them, with perfect scores, in under two minutes. Several students nevertheless ran out of time on their first attempts and had to try again. These were some of the weaker students in terms of overall grade-point average and confirmed that the quizzes were of main benefit to these students as it allowed them more time to go through the basic concepts.

3.2. *Course work quiz*

The third and final quiz formed part of the formal course work, i.e. summative assessment, and consisted of 25 questions from both parts of the module section. For this quiz, six new numerical

Figure 1.   Examples of theoretical quiz questions.

Figure 2.   Example of question feedback.

questions were included, as well as five new questions on membranes and five new questions on chromatography. An example of a numerical question is given in Figure 3. In addition, four questions from the previous membrane quiz and five questions from the previous chromatography quiz were included. These old questions were selected randomly by Moodle from the question banks of 15 questions per part. The order of the questions was random as was the order of choices

Preview Calculation - water flux

Quiz: Coursework quiz - due 21 March 2010

1
Marks: --/1

An experiment is performed to determine the pure water flux of a membrane. The membrane area is 38 cm^2 and the module is operated at 5 bar and 25C. 160 ml of water was collected in 36 min. What is the value of the water flux (with units in l/(m^2,hr)) to 2 decimals accuracy?

Answer: [   ]

[Submit]

[Submit page] [Submit all and finish]

[Fill with correct] [Start again] [Close preview]

ⓘ Moodle Docs for this page

You are logged in as Eva Sorensen (Logout)

UCL Moodle usage policy and guidelines | Staff help | Student help

Figure 3. Example of numerical question.

within MCQs. The students had 60 minutes to complete the quiz and the quiz was open for five days, which included the weekend. The students only had one attempt this time; however, within this attempt they were able to repeat a question if they had answered it incorrectly but this incurred a penalty of 0.5 out of 1 point, in other words, only two attempts carried points. (The Moodle settings for this quiz were therefore: shuffle questions: Yes; shuffle within questions: Yes; attempts allowed: 1; adaptive mode: Yes; grading method: last attempt; apply penalties: Yes.)

The numerical questions were intended to be more difficult than the questions that were testing basic concepts. Nevertheless, they were mainly based on examples that had been covered in the lectures. The numerical values used in these questions were randomised to some extent as ranges were given for all values and Moodle would generate 10 alternatives of each question and would randomly assign one of these alternatives to each student. Each student would thus have a personalised quiz with different values for the numerical questions and some questions that were different to those of other students.

The overall results from the final summative quiz were not as high as for the first two formative test quizzes but were nevertheless very good, with an overall score of 21.77 out of 25. Out of a total of 91 students who took the test, 15 students achieved a perfect score and 30 students achieved over 24 points. The lowest score was 10.15. Six students did not attempt the quiz but did submit a design project.

The quickest completion time was just under six minutes but this was one of the strongest students, with one of the highest overall grade-point averages in the class, who also achieved a perfect score. A total of 38 students nevertheless needed over 50 minutes to complete the quiz and seven of these were timed out after 60 minutes, which shows that this quiz was not as easy as the previous two.

The numerical questions, in particular, caused problems for many of the students. The average marks for most of the theoretical questions were between 0.8 and 1 (out of 1), with the majority between 0.9 and 1. For the six numerical questions, however, the averages were 0.41, 0.5, 0.78, 0.79, 0.8 and 0.83, respectively, which showed that these questions were considerably more
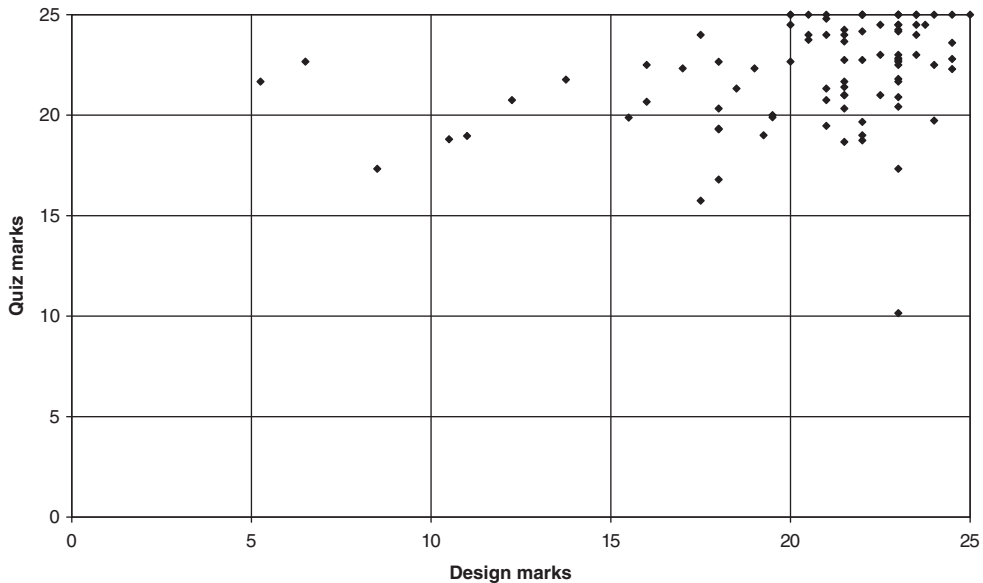
Figure 4.　Comparison between quiz marks and design project marks.

challenging. As it is quite difficult to give online feedback on randomised numerical questions, complete solutions to these questions were emailed to all students after the quiz had closed.

It is also interesting to compare the marks on the final quiz with those obtained on the design project (see Figure 4). It is clear from the figure that the marks on the quiz are generally higher than on the design project, which may indicate that the quiz might, in fact, still have been too easy. The average mark for the design project was 20.5/25 versus 21.77/25 for the quiz.

Overall, the results from the three quizzes were very encouraging. The students revised their notes prior to each quiz as intended, which most of them would not have done otherwise. An analysis of the quiz results shows that the weaker students, in terms of overall grade-point average, particularly benefitted as the quizzes gave them a structured opportunity to go over the material in their own time and to focus on the fundamental aspects of the module.

4.　Student feedback

One of the main objectives of this work was to investigate the students' views of e-assessment and this was done using an online questionnaire. The development of a suitable questionnaire requires considerable thought and questions need to be posed carefully to allow attitudes and feelings to be converted into numbers. Dermo (2009) used adapted Likert scale-type questions for his survey and a similar approach was applied in this study. An online course experience questionnaire was developed using Opinio (Opinio 2012). The questionnaire had questions in three parts. First, a few demographic questions were asked, such as gender (male–female), fee status (home–EU–overseas), year 1 accumulated class of degree (First–Upper second–Lower second–Third) and previous experience with e-assessment (yes–no for secondary school/college and other UCL modules). The main part of the questionnaire consisted of a series of Likert-type questions based on a 5-point scale ranging from strongly disagree (1) to strongly agree (5). Finally, a comment box was included to allow for open-ended responses as closed questions alone may not suffice in capturing all the students' views.

4.1. *Survey results*

The quiz results will be considered in two parts. First, the questions related to the students' general views on e-assessment (Table 1) and second on their views on the Moodle quizzes implemented in this module (Table 2). Altogether, 54 out of a cohort of 100 students completed the survey, i.e. the response rate was 54% of the class total or 59% of those who did the course work e-assignment (91 students). The students' responses to the general questions can be found in Table 1. As the scale used is from strongly disagree (1) to strongly agree (5), an average of 3.0 would indicate that the students have no strong feelings about that particular question and an average above 3.0 would indicate agreement etc.

From the general views in Table 1, one can see that the students feel that e-assessment does have a role to play in higher education (Q1, 3.87/5) and that it is applicable to chemical engineering (Q2, 3.74/5). They also feel that e-assessment adds value to their learning (Q4, 3.82/5) and goes hand-in-hand with e-learning (Q6, 3.85/5). They particularly like being able to choose when and where to do the assessment (Q12, 4.18/5).

From the module specific views in Table 2, it can be seen that the students found the immediate Moodle quiz feedback very helpful (Q16, 4.38/5) and that they would like to see more e-assessment in other modules (Q19, 3.97/4). They did not seem particularly concerned about the random choice of questions from the item bank (Q17, 3.28/5), nor did they feel that they could obtain the correct answers by guessing (Q15, 2.88/5). Dermo's (2009) study indicated concerns about fairness in the use of random questions from a question bank but the UCL students do not seem to share this concern.

Some indication of a gender bias was found unlike in Dermo's (2009) study. For Q2, 'E-assessment is appropriate for chemical engineering modules', 62% of male students and 47%

Table 1. General student survey responses.

No.	Question	Average	SD
1	E-assessment has an important role to play in higher education	3.87	0.92
2	E-assessment is appropriate for chemical engineering modules	3.74	0.88
3	Chemical engineering is too complex to be dealt with by online multiple-choice questions	3.05	1.21
4	E-assessment can add value to my learning	3.82	1.02
5	E-assessment is just a gimmick that does not really benefit learning	2.13	1.08
6	E-assessment goes hand-in-hand with e-learning (i.e. the use of Moodle)	3.85	1.09
7	Technical problems can make e-assessment impractical	3.26	1.19
8	E-assessment uses less paper, which is important to me	3.79	1.38
9	E-assessment is just as secure as paper-based assessment	3.61	1.31
10	E-assessment marking is more accurate because computers do not suffer from human errors	3.33	1.28
11	I would rather do course work using a computer than on paper	3.28	1.39
12	I would rather do e-assessment where I choose to, than in a scheduled cluster room exam	4.18	1.02
13	The Moodle quiz system is vulnerable to hackers	2.81	1.19

Table 2. Moodle quiz student survey responses.

No.	Question	Average	SD
14	The Moodle quiz questions were mostly about memorising the content being assessed	3.08	1.12
15	In many questions it was possible to get a correct answer by guessing	2.88	1.18
16	The immediate feedback on the Moodle quiz questions helped me learn	4.38	0.93
17	Randomised questions from an item bank means that sometimes you get easier questions	3.28	0.96
18	Sufficient time was allowed for the course work quiz	4.53	0.80
19	I would like to see e-assessment implemented further in departmental modules	3.97	1.09

of female students responded agree (4) or strongly agree (5). For Q4, 'E-assessment can add value to my learning', 69% of male students and 53% of female students chose the same responses. It therefore seems that the male students in this cohort are more in favour of e-learning in chemical engineering. However, the responses in terms of gender need to be considered in parallel with those in terms of the relative academic strength of the students as there was a considerably higher proportion of high-achieving male students responding to the survey as compared to high-achieving female students.

When considering Q4 'E-assessment can add value to my learning', 44% of those with a year 1 First class degree accumulated average (i.e. the strongest students) responded strongly agree (5) versus only 17% and 10% of those with an Upper second and Lower second, respectively. This is quite striking as the quizzes were primarily intended for the weaker students, however, not altogether surprising as the stronger, i.e. First class students, will have a stronger interest in their own studies and will generally show more commitment to independent learning. This result is also consistent with the findings of Ferrao (2009) and do, it is believed, explain the gender bias that was found.

Only a few students added written comments, which stated:

> Student 1: The time/resources saved far outweigh any drawbacks to this system.
> Student 2: The idea of e-assessments is brilliant because we are forced to study through out the year and the fact that you get feedback immediately instead of picking it up from the personal tutor is convenient.
> Student 3: Online quiz is quite interesting.
> Student 4: The quizzes were very useful; it forces students to keep on top of it.
> Student 5: The lecturer puts a lot of effort in ensuring that we know our stuff well, through the homework questions as well as online quizzes after she covers a topic.
> Student 6: Definitely e-assessment should be implemented in other modules, it's just a really, really good way of learning.
> Student 7: E-assessment for other departmental modules will be excellent as a form of continual assessment for ourselves. They don't have to count for much of the percentage, just a check for those who bother with their work!
> Student 8: Should allow more time if calculation is involved. In one way, it is good that we can't achieve perfect score in the first trial. We will then have to repeat doing the same question which then strengthen our knowledge. But in general, time allocated for calculation is not much.

These comments are in agreement with the intentions and the findings of this study.

5. Discussion and recommendations

5.1. *Required resources*

One of the main drivers for the introduction of e-assessment is often the claim that it has the advantages of time saving and better use of resources (Morris 2008; Chen, Wei, and Huang 2009). For the work presented here, three question banks of Moodle quiz questions were developed; two covering theoretical aspects consisting of in total 20 questions each (one for membranes and one for chromatography); and one consisting of seven numerical questions. Three quizzes were then developed based on these question banks, as reported earlier.

The development of the Moodle quizzes was time-consuming, with around six hours spent for each of the theoretical question banks and around four hours for the numerical question bank.

It should be noted that two class tests of around 10 questions each were already available as a starting point and a development from scratch would therefore have taken longer.

The use of Moodle itself was very straightforward and the questions were developed directly within the software. The main time spent in the development was in terms of the questions themselves, in particular, coming up with good 'wrong' answers. For MCQs, the incorrect alternatives need to be realistic as the question otherwise becomes trivial. The questions were also varied to have some standard MCQs with only one correct answer, some MCQs where several answers were correct as well as some questions where the students had to match items, e.g. membrane compound names to chemical structures.

The numerical questions were based on examples shown in class; hence, time was saved for this development as well. The main challenge, however, was the randomisation of the questions, i.e. the use of ranges for each numerical value. As Moodle creates the alternatives, as the name indicates, randomly, it is possible that combinations of values are chosen that do not make sense physically, for instance, one particular combination of parameter values for a question ended up with negative concentrations, which is not physically possible; however, is correct mathematically with the numerical values chosen. The ranges therefore had to be narrowed and all the alternatives had to be checked manually. Only 10 alternatives were therefore considered for each numerical question although Moodle can generate as many as 100.

The time saving clearly came in terms of the marking. In the past, the two sets of class test quizzes would be marked by the lecturer and the course work quiz questions would be part of the course work marked by the demonstrator. For the class tests, typically around two hours would be spent marking each test and then around one hour logging and processing the marks, returning the sheets to tutors etc. With around 100 students, the time involved for the demonstrator would also be considerable and estimated to be around five hours, allowing five minutes per student script to mark the theoretical questions. With the question banks now available, the development of quizzes for subsequent cohorts has been considerably less time-consuming, and in the order of only 1–2 hours. The estimate of a pay-back time of 1–3 years was therefore quite reasonable.

5.2. *E-assessment implementation improvements*

The results presented above indicate that both targets, i.e. to provide the students with an online resource to help with their learning and to be more efficient in terms of marking time, were achieved. There are, however, some aspects of the implementation that could have been done differently. First, the two formative quizzes were too easy and should have contained some numerical questions in addition to the theoretical questions.

Second, more time should have been allowed for the question bank development, as most of the questions can be found directly from the lecture notes. It would have been beneficial if some material had been taken from the reference books instead as the students often do not consult textbooks and this is something they are strongly encouraged to do.

Third, it would also be useful to have general topic quizzes available on Moodle all the time to allow students to revise the material whenever they want. The three quizzes developed for this work were only open for a limited period of time although a revision quiz was also made available later before the exam for revision purposes and over 60 students completed this quiz at least once. To make more efficient use of the quizzes as a learning resource and for formative assessment, a much larger question bank would be required and this will be one of the main priorities for the next academic year. The feedback given to both correct and incorrect questions will then also be extended so that the quizzes can work better as a learning resource. This would also include references to text books, where the students can do further reading.

5.3. *E-assessment in general*

The implementation of e-assessment in the form of Moodle quizzes in other departmental modules will commence in the next academic year. The main challenge will be the development of good multiple choice and numerical questions as the implementation as quizzes in Moodle is trivial. The use of e-assessment will be of great benefit in any engineering module, whether there is a substantial theoretical component or not, as the weighting between the theoretical and numerical questions can easily be adjusted. Even design modules could benefit from e-assessment quizzes in terms of testing design fundamentals and design decisions, although probably not in terms of detailed design calculations.

UCL is committed to a strong implementation of e-learning, including e-assessment. Guidance in the use of Moodle as a virtual learning environment is available to all staff, including how to use Moodle quizzes for online examinations. Online activities should, however, be only one component of an undergraduate module. A large part of the students' learning takes place in the classroom and it is therefore essential that the two modes complement each other to ensure the disadvantages of one mode is outweighed by the other (Gibbs 2006).

The results from this study indicate that the weaker students were less in favour of e-assessment than those with high overall grade-point averages and this was assumed to be because stronger students generally have a greater dedication and commitment to own independent learning. This raises the very interesting question of how weaker students, typically constituting around 5–10% of the class, can be better motivated, both in the classroom and outside. This discussion is beyond the scope of this study; however, it has been considered in an interesting study by Heys (2011).

6.   Conclusion

This paper describes an implementation of e-assessment in a traditional lecture module through Moodle quizzes. The results were very encouraging and practically all students engaged with the process. It was found that the quizzes were mainly beneficial to the weaker students, i.e. those with lowest overall grade-point averages, as it gave them an opportunity to go over key aspects of the material in their own time. Student perceptions were investigated through an online questionnaire and the students were found to be in favour of e-assessment and they would like to see it implemented in other departmental modules. It was found that stronger students were more in favour of e-learning than weaker students. There also seemed to be some indication of a gender bias in preferences; however, this difference is assumed to be strongly correlated with the academic strength of the student.

References

Alexander, S. 2001. "E-learning Developments and Experiences." *Education & Training* 43 (4/5): 240–248.
Aravinthan, V., and T. Aravinthan. 2010. "Effectiveness of Self-assessment Quizzes as a Learning Tool." In *Engineering Education* 2010: Inspiring the Next Generation of Engineers (EE2010), Birmingham, UK, July 6–8.
Chen, N-S., C-W. Wei, and I-F. Huang. 2009. "Design and Implementation of Synchronous Cyber Assessment and its Potential Issues." In Proceedings of the 17th International Conference on Computers in Education, Hong Kong: Asia-Pacific Society for Computers in Education.
Dermo, J. 2009. "e-Assessment and the Student Learning Experience: A Survey of Student Perceptions of e-assessment." *British Journal of Educational Technology* 40 (2): 203–214.
Felder, R. M., A. Rugarcia, and J. E. Stice. 2000b. "The Future of Engineering Education V: Assessing Teaching Effectiveness and Educational Scholarship." *Chemical Engineering Education* 34 (3): 198–207.
Felder, R. M., J. E. Stice, and A. Rugarcia. 2000c. "The Future of Engineering Education VI: Making Reform Happen." *Chemical Engineering Education* 34 (3): 208–215.
Felder, R. M., D. R. Woods, J. E. Stice, and A. Rugarcia. 2000a. "The Future of Engineering Education II: Teaching Methods that Work." *Chemical Engineering Education* 34 (1): 26–39.

Ferrao, M. 2010. "E-assessment within the Bologna Paradigm: Evidence from Portugal." *Assessment & Evaluation in Higher Education* 35 (7): 819–830.

Gibbs, G. 2006. "Why Assessment is Changing." In *Innovative Assessment in Higher Education*, edited by C. Bryan, and K. V. Clegg. London: Routledge.

Gilbert, J., S. Morton, and J. Rowley. 2007. "e-Learning: The Student Experience." *British Journal of Educational Technology* 38 (4): 560–573.

Heys, J. 2011. "Chemical Engineering Problem Solving: How Important is Persistence?" In American Society for Engineering Education SEE Annual Conference and Exposition, Vancouver, BC, June 26–29.

Jordan, S. 2011. "Using Interactive Computer-based Assessment to Support Beginning Distance Learners of Science." *Open Learning: The Journal of Open, Distance and e-Learning* 26 (2): 147–164.

Jordan, S., and T. Mitchell. 2009. "e-Assessment for Learning? The Potential of Short-answer Free-text Questions with Tailored Feedback." *British Journal of Educational Technology* 40 (2): 371–385.

Mampadi, F., S. Y. Chen, G. Ghinea, and M.-P. Chen. 2011. "Design of Adaptive Hypermedia Learning Systems: A Cognitive Style Approach." *Computers and Education* 56 (4): 1003–1011.

Markovic, S., N. Jovanovic, and R. Popovic. 2011. "Web-based Distance Learning System with Adaptive Testing Module." *International Journal of Engineering Education* 27 (1): 155–166.

McKenna, A. F., and B. Yalvac. 2007. "Characterizing Engineering Faculty's Teaching Approaches." *Teaching in Higher Education* 12 (3): 405–418.

Moodle. 2012. http://moodle.org/ (September 2012).

Morris, D. 2008. "Economics of Scale and Scope in e-learning." *Teaching in Higher Education* 33 (3): 331–343.

Nicol, D. 2007. "Laying a Foundation for Lifelong Learning: Case Studies of e-assessment in Large 1st-year Classes." *British Journal of Educational Technology* 38 (4): 668–678.

Opinio. 2012. http://objectplanet.com/opinio/ (September 2012).

Quality Assurance Agency for Higher Education. 2004. Code of practice for the assurance of academic quality and standards in higher education. Section 2: Collaborative provision and flexible and distributed learning (including e-learning).

Quality Assurance Agency for Higher Education. 2006. Code of practice for the assurance of academic quality and standards in higher education. Section 6: Assessment of students.

Rubio, R., J. Suarez, R. Gallego, and S. Martin. 2007. "Innovative Teaching Methods in the Industrial Design Class Room." *International Journal of Mechanical Engineering Education* 35 (1): 32–45.

Rugarcia, A., R. M. Felder, D. R. Woods, and J. E. Stice. 2000. "The Future of Engineering Education I: A Vision for a New Century." *Chemical Engineering Education* 34 (1): 16–25.

Shuman, L. J., Atman, C. J., Eschenbach, E. A., Evans, D., Felder, R. M., Imbrie, P. K., McGourty, J., Miller, R. L., Richards, L. G., Smith, K. A., Soulsby, E. P., Waller, A. A., and Yokomoto, C. F. 2002. "The Future of Engineering Education." In Proceedings – Frontiers in Education Conference, Boston, November 6–9, Volume 1, pages T4A1-15.

Stice, J. E., R. M. Felder, D. R. Woods, and A. Rugarcia. 2000. "The Future of Engineering Education IV: Learning How to Teach." *Chemical Engineering Education* 34 (2): 118–127.

Swan, G. 2004. "Online Assessment and Study." In Australasian Society for Computers in Learning in Tertiary Education Conference (ASCILITE), Perth, Western Australia, December 5–8.

Wang, T.-H. 2008. "Web-based Quiz-game-like Formative Assessment: Development and Evaluation." *Computers and Education* 51 (3): 1247–1263.

Woods, D. R., R. M. Felder, A. Rugarcia, and J. E. Stice. 2000. "The Future of Engineering Education III: Developing Critical Skills." *Chemical Engineering Education* 34 (2): 108–117.

Woods, D. R., T. Kourti, P. E. Wood, H. Sheardown, C. M. Crowe, and J. M. Dickson. 2001. "Assessing Problem-Solving Skills: Part 1. The Context for Assessment." *Chemical Engineering Education* 35 (4): 300–307.

Woods, D. R., T. Kourti, P. E. Wood, H. Sheardown, C. M. Crowe, and J. M. Dickson. 2002. "Assessing Problem-Solving Skills: Part 2. Assessing the Process of Problem Solving." *Chemical Engineering Education* 36 (1): 60–67.

About the author

Eva Sorensen is a Reader in Chemical Engineering. She mainly teaches mass transfer operations, separation processes and process modelling, design and control. In 2002, she was awarded the UCL Faculty of Engineering Excellence in Teaching Award.