TOWARDS INTEGRATING TECHNOLOGY SUPPORTED PEER-TO-PEER ASSESSMENTS INTO MATHEMATICS EDUCATION

Experiences with iPad Mobile Tablet Technology

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Abstract: This paper addresses technology supported formative assessment in university mathematics education. The challenges of formative assessment are the requirements for regular feedback and more student engagement in the learning process. This paper suggests integrating peer-to-peer assessment in mathematics education, using mobile tablet technology. The students are engaged in providing feedback to each other and the technology allows for fast and regular feedback provision. The paper presents the results of experiments with undergraduate engineering students, using iPad tablets and a learning management system. It is shown that mobile tablet technology can greatly contribute to the integration of peer-to-peer assessment into mathematics education; and providing peer-feedback is a practical approach to formative assessment.

1 INTRODUCTION

The new media technologies have not only extended learning opportunities, but they are also reshaping the university education as a whole. The ever increasing number of students and the quest for excellence in education, are also driving research efforts into new pedagogical models, which would be appropriate in this media-rich world. For instance, all undergraduate engineering students must study mathematics courses; and they may be grouped into larger classes with a minimum of teacher-to-student interaction (this is a real concern at the University of Agder and other universities around the globe). Technologies such as real-time video streaming are being used for teaching, but there is still a challenge to assess the students' progress as they learn (formative assessment).

The main purpose of this study is to investigate the students' attitudes towards technology enabled peer-to-peer assessment (P2PASS) using iPad tablet computers. P2PASS is a form of formative assessment, expected to have a positive impact on the students' learning performance as well as their reflective skills. Peer assessment encourages active learning and collaboration among students, as they assess each other's work and provide constructive feedback. On the other hand, this study will provide empirical data on the usability of the adopted mobile technology and the feasibility of P2PASS in a mathematics course.

The study will address the following research questions:

- What are the benefits that students can get from involvement into a P2PASS in mathematics education at university level?
- What are the challenges and opportunities for integrating mobile technology enabled P2PASS in mathematics education at university level?

The authors argue that mobile tablet technology offers many advantages for learning: students can experience a natural feel with finger writing or stylus in the same way as pen and paper; this would foster a faster technology adoption. Once the students get used to this technology, it can also be time saving compared to using alternative equation editor tools such as MathML (Mathematics Markup Language), which requires a substantial amount of time to input mathematical symbols. There is also a lack of flexibility in automated systems for the student to show his own approach to problem solving. Grading systems rely mostly on multiple choice questions (MCQ) type, hence missing the possibility to assess the student's

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understanding, strategies, reasoning, procedures and communication because those aspects cannot simply be reflected in the final answer. Moreover, peer-assessment on tablet technology adds a great advantage to be able to provide feedback on the same sheet as the assignment itself (student's work). The remainder of this paper is organised into 4 sections. In Section 2, this paper provides a brief overview of peer-assessment, including technology supported peer-assessment systems. In Section 3, the methods for this study are presented and in Section 4, the results of the experimental work are presented together with analysis. The final part, Section 5, summarizes our conclusions and future directions.

2 RELATED WORK

Peer-to-peer assessment stems from the practice of active learning. Falchikov (2003) emphasised the importance of students' involvement in the assessment process not only as the "testees" but also as the assessors. The author suggested that students could be involved more productively in their assessment by peer assessment. In peer assessment, students rate the performance of their peers through a four-stage process comprising the preparation, the implementation, the follow-up and evaluation as well as the replication. Despite peer-assessment being an "excellent way of enhancing the learning process", it may have some issues such as the students' lack of confidence and capacity to assess fairly and accurately, and their unwillingness to do the teacher's job among other things.

In recent studies on technology-supported peer assessment systems (Wen et al., 2008; Al-Smadi et al.,2010; Chen, 2010; de-Marcos et al., 2010), several advantages were reported, from the savings in time and costs to improved students' performance. Web-based peer-assessment systems allow the assessors (students and teachers) to enter grades and feedback. The systems described may be efficient for subjects such as history, language studies and other studies for which students are assessed on oral presentations or plain text answers. The authors have not reported on any tools for writing mathematical symbols and equations. In addition to that, there are no indications of how the assessors could clearly indicate on the same sheet any missing points and provide easy access to feedback. It is noted that mobile technology has also been considered for peer-assessment (Chen, 2010; de-Marcos et al., 2010), but in both studies there was no consideration for a touch input interface. A separate study at the University of Southern Queensland (Brodie et al., 2009) considered the courses where standardized answers and feedback could not be generated, thus requiring a marker's feedback on the individual level. Such courses involve a lot of mathematical or technical drawings, which proved to be time consuming for students to produce feedback. In that work, they studied the online marking with typed comments (there were text boxes used for adding comments on each assessment criteria) and a second option to provide hand written annotations on the students' assignments using a Tablet PC (Toshiba Portege M750). At the end, the marker in this experiment was "supportive of the use of the Tablet PC". The analysis done thereafter showed no significant difference in the quantity and the quality of feedback, but still the handwritten feedback provided more details. Besides special tools that are needed for assessing mathematics, there is also a need for appropriate mathematics assessment rubric to help students objectively assess their peers' work. Egodawatte (2010) proposed a comprehensive rubric for assessing mathematical problem solving tasks.

3 METHODS

Subsequent to a literature review, an experimentalist approach was adopted for conducting user studies and technology evaluation. The investigations consisted of experiments, observations and a survey which was completed at the end of the experiments. To study the integration of P2PASS into mathematics education, the researcher obtained consent from the teaching staff of first year and second year engineering mathematics to use the exercises from their respective courses. This has allowed the study on the assessment of learning while it is happening. The teachers provided both the question papers as well as the correct answers, the latter being needed for the students to provide correct and meaningful feedback to each other.

3.1 Research Intentions

The practice of peer assessment has been around for several years and in different fields of study. However, to the best of our knowledge, still a lot has to be done in the area of mathematics peer-assessment based on mobile tablet technology. Therefore, this study intends to help understand this topic from a practical point of view:

1. Can students perform the peer assessment in mathematics using mobile technology tools and the LMS?

2. How do students actually perform the involved tasks (solving mathematics problems, providing and receiving feedback)? Which usability problems that the students may find?
3. How is the student peer-feedback? Questions related to the quantity, quality and clarity of the peer-feedback

3.2 Participants Sample

The participants in this study are engineering students in: mechatronics, as well as civil, computing, electrical and electronics engineering. All participants were taking a mathematics course at the time of experiments and, they had basic computer literacy without prior experience of using iPad tablets. There were 96% (23)male and 4% (1) female students. 63% of the participants were between 20-25 years old, whereas 17% (4) were below 20 years and the remaininng were above 25 years old including 13% (3) older than 30 years. With a total of 24 respondents, the study would uncover usability problems to a great extent. In fact, previous studies (Nielsen and Landauer, 1993) (Nielsen, 1994) suggest that as few as 5 users are good enough for simple user testing (qualitative studies) and 20 users can typically provide a reasonable confidence interval in quantitative studies.

The experiments were conducted during the autumn semester 2011. This paper reports on the researchers' observations, the participants' opinions collected through a think-aloud technique and the results of a survey instrument.

3.3 Systems and Technologies

This study was based on the use of Apple iPad tablet computers with a selection of mobile applications for the iOS operating system. The iPad was chosen as a mobile platform to take advantage of the mobility, portability, wireless connectivity, relatively high processing power as well as a large memory. Additionally, the iPad has a good support for multimodal user interfaces including the support for hand-writing. The iPad touch screen is of a great interest because it is possible to directly write on it, especially the mathematics which involve a lot of symbol characters in equations and formulas. In this work, we used a mobile application to annotate, delete, and input text on top of PDF documents, using either a finger or a stylus pen.

It is argued that for a formative assessment to be effective, the feedback should be timely accessible to the intended receiver (a student). On the other hand, however, peer-to-peer assessment also requires

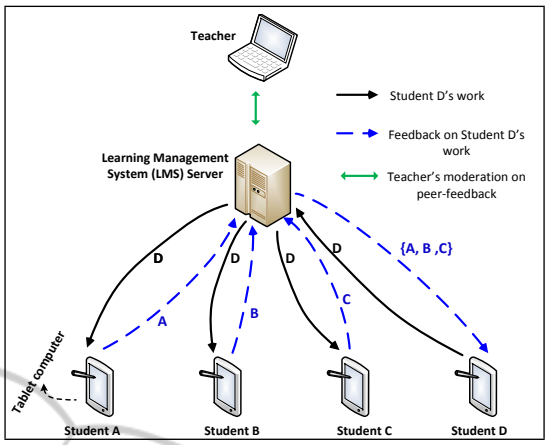


Figure 1: Peer-to-peer assessment experimental model.

equal active participation of all students, both as feedback providers and feedback receivers. Therefore, there is a need for a system to allow submission of the work to be assessed and subsequent access to the same work for the assessors (feedback providers); especially in case of a synchronous assessment process. This was achieved using a Learning management System (LMS) called 'Fronter' (Pearson, 2011) and an iPad web browser application 'iCabMobile' (Clauss, 2011) which supports downloading and uploading of files to the LMS. Each participant can have read and write access rights to documents owned by three other students so that he/she could assess their work as illustrated in Figure 1. In this way, everyone was able to provide feedback to up to three other students, and likewise receive up to three feedback from different colleagues. It is argued that this can help students to learn from different perspectives.

3.4 Experiment Design

This study was conducted in a controlled environment, a laboratory setting as shown in Figure 2. Before the experiments begin, the researcher uploaded to the LMS a set of mathematics exercises provided by the teacher. At the start, each student was given an iPAD, and the researcher explained the peer-to-peer assessment process for 10 minutes, with a brief demo of the tools on the iPad. Then students were grouped according to their performance in the last mathematics exams, in such a way that each group of 3 students would have at least one member with either an "A" or "B" grade where possible. Collaboration was encouraged among group members. Upon completion of the given exercises, the correct answers were uploaded to the LMS, and the research explained the mathematics assessment rubric, which consisted of five crite-

ria: the Understanding, Strategies, Reasoning, Procedures and Communication. The assessors (students) were required to rate their peers' performance (High, Medium, Low) and provide a feedback. Once all the papers are marked and uploaded back to the LMS, each participant should be able to see his/her initially submitted work along with the feedback.

Figure 2: Peer-to-peer assessment session.

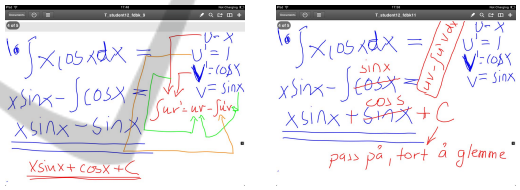
Subsequent to students' grouping, each participant solved the given questions using the iPad and submitted the work to the LMS. Once everyone has submitted, the correct answer sheet was made accessible to all, and every participant was assigned 2-3 papers to assess with reference to the assessment rubric. The next step was to submit the marked papers with feedback to the LMS so that each participant could have access to 2 or 3 feedback provided by his/her colleagues (peers).

A survey instrument was used to collect students' opinions on peer-to-peer assessment in general, their experience with mobile technology supported peer-to-peer assessment system and the way forward (potential improvements).

4 RESULTS AND ANALYSIS

4.1 Summary of the Researcher's Observations

At the beginning of all experiments, students appeared very interested in the process and as expected some of them started exploring the iPad as soon as they were handed to them. There was a mixture of curiosity and a great interest in the new experience. As the researcher explained about the process, students were engaged in finding out the available tools on iPad and within 5-10 min, about 40% of them had already managed to download the mathematics question paper. It was also observed that around 25 % of the students had a tendency to first solve the problems on paper then write down the answers on the iPad. Despite the guidance of the researcher for the students to work on the touch interface straight away, still some of them resisted and kept on using both methods (pen and paper as well as iPad touch interface). 60 to 70 % of the students used the pen at least on one occasion for solving the math problems, and one of the respondents just solved all the problems on paper and the researcher helped to scan the paper (using the iPad camera) and uploaded the paper as a PDF document on Fronter. On the other hand, all students were very enthousiastic in providing peer-feedback using the touch interface. Figure 3(a) and figure 3(b) illustrate an example of how two students provided feedback on the same work but in a different way, with one marker providing an indication of what was missing and the right formula that should have been used.



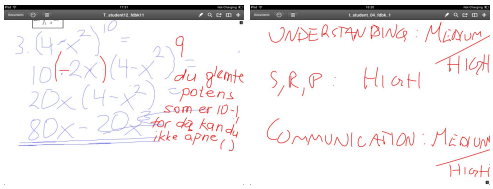
(a) Student 'A' receives feedback from student 'Y'.

(b) Student 'A' receives feedback from student 'Z'.

Figure 3: Example of 2 feedback received by one student.

Peer-feedback comprised of both free text as well as typed text. Even tough an assessment rubric was given, many students also gave a feedback in their own words and indicated the errors on the answer sheet as shown in Figure 4(a). On the other hand, however, there were also students who used keywords for the performance levels (Low, Medium, High) to rate their peers' work as shown in Figure 4(b). Annotations were observed on a majority of marked paper; which indicates the willingness of students to provide a more personalized feedback rather than strictly conforming to the assessment rubric. This study showed indications of promoting student responsibility and high level of engagement in learning.

Collaboration among students was also stressed in this study, and students were often seen seeking help from the peers in their group as well as those in the neighbouring group. Timely help was offered as the researcher observed the students explaining the math principles and referring their peers to the rele-



(a) Detailed feedback. (b) Summary feedback.

Figure 4: Peer-feedback provision.

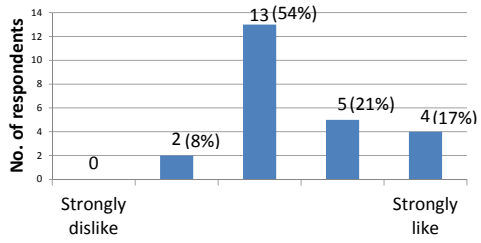
vant course materials from their mathematics books.

From the usability perspective, all participants were generally challenged by the new tools and needed assistance from the researcher, in addition to the instructions sheet that was handed to them at the beginning. The user interfaces were not very intuitive, therefore there was a higher necessity to recall rather than recognise, which usually minimise memory loading on behalf of the user. System message boxes such as "Open In" or "Save in Downloads" don't tell much the user unless he/she is quite familiar with the interface. The learnability of the tools proved difficult. The affordance of the PDF Expert application was liked by the majority of users because they could easily manage to choose the tools needed for opening a file, writing and saving; but scrolling and clicking was not obvious since the system responsiveness was not always the same. Students adopted a trial and error approach to achieve their goals. The students appeared to have the pleasure with the iPad, and the portability of the device was well appreciated with some users sitting in a very relaxing way while working on the given task.

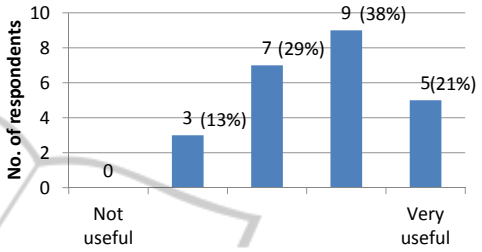
4.2 Survey Results

4.2.1 Students' Opinions on P2PASS

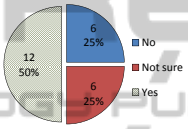
In a previous study related to student peer-assessment (Isabwe et al., 2011), we have found that students would be interested in getting feedback from their peers. The survey results in this study confirmed a positive attitude towards peer-assessment, with only 8% of the participants below the average on the Likert scale as shown in Figure 5(a). The majority of the respondents (67%) believe that their colleagues can provide them with a meaningful and fair feedback. In addition to that, 50% of the respondents felt confident to make a fair and responsible assessment of their peers' work and 25% were not sure, whereas 25% of the respondents said 'no'. Upon completion of the peer to peer assessment exercise, 21% and 38% found the peer feedback 'very useful' and 'useful' respectively.



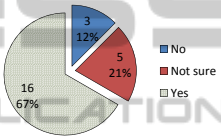
(a) P2PA rating scale.



(b) Usefulness of P2PA.



(c) Confident to provide feedback.



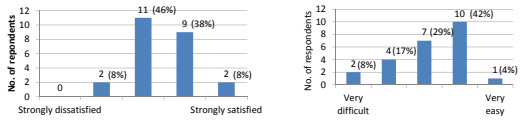
(d) Trust to receive fair feedback.

Figure 5: Students' opinions on P2PASS process.

The participants also mentioned the usefulness of peer-feedback provision, with statements such as "it could help me understand if i did see what other people do", "getting to see common errors would be useful for me too" and "when I have to explain something to another person I do understand it better myself". Peer-feedback provision also helps in reflective skills development as one student pointed out: "Helping others to understand is an easy way of forcing myself to reflect on my own competence". Other students were interested in peer-feedback because they believe that peer-feedback on assignments greatly helps a student's progress in his/ her learning process. The study suggests that 20-40 minutes could be spent on feedback provision regularly (at least once every two weeks).

On the other hand however, solving the mathematics problems on iPad appeared time consuming for the participants since it was their first time using this tool. The user interfaces were not user friendly, and one of the student expressed his frustration saying that 'A lot of time was wasted due to problems with the interface, and way too much time spent trying to solve the math problems compared to giving feedback'. Giving feedback was a lot easier, at first much of the time was spent on navigating the iPad rather than providing feedback, but this trend decreased as students got

used to the interface.



(a) Satisfaction with the setting for P2PA.

(b) Difficulty to provide peer-feedback.

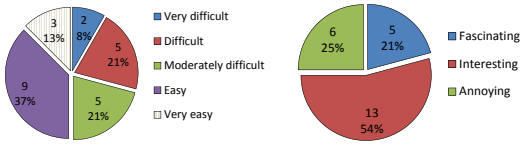
Figure 6: Opinions on P2PA model.

The students expressed mixed opinions on the mathematic assessment rubric that was given to them. Some thought it was good and well defined, but others could not well understand the criteria. It was suggested that 'the main focus should be on giving a written comment instead of giving a mark for each separate criteria'. There is a clear indication that students need more skills to act as assessors. The peer-feedback was found helpful by 66.6% (16) of the participants, the reasons being the opportunity to understand and correct their own mistakes, in addition to increasing their confidence to perform the given tasks. Some of the students (high-performer) noted that they could recognise their mistakes themselves by seeing the correct answersheet, but others didn't read the feedback because they were exhausted by the end of the experiment. P2PASS has also a motivational factor among other things. The students mentioned that the idea of peer-feedback made them spend more time on their studies and work harder. There is also a 'feel good and positive competition' element because students can help others and see "how well others have done and then compare them to oneself".

Student collaboration was another aspect of study in this paper. Students worked in groups of 3 students, and at the end of the experiment, it became clear that it was important for them to work together. A student stated that "Collaboration makes participants work as a team and discuss ideas. This in turn increases the knowledge of participants". The results here obtained, emphasise the need to foster collaboration among students since it helps them not only for knowledge acquisition but also for developing their social skills.

4.2.2 Students' Opinions on the Usability of Technology-supported P2PASS

Generally, the system suitability for learning scored low. Users found difficult to learn the system functionalities, hence conformity with user expectation was also low. Since the learnability was low for the majority of users, the effectiveness was greatly affected as the experiments took longer than expected (average duration was 3 hours). Participants ex-



(a) Difficulty to use the tools.

(b) Appearance & responsiveness.

Figure 7: Opinion on P2PA tools.

pressed usability problems related to the system responsiveness and interaction, the user interface was not very intuitive and iOS "apps dependent" file management system is not user friendly. The user guidance of the mobile applications that were used was also poor : there were no detailed error messages and some of the actions were not confirmed upon execution; hence prompting the users to repeat the same action several times. On the other hand, however, there are also indications of improvements in suitability for the task as users get used to the system.

Despite some difficulties to use iPad, the concept was much appreciated; with statements such as "Portability is important. The touch feature of the iPad is also better than a mouse, since you can draw and write uncommon sign without a lot of hassle. The size, weight and battery power is also important" and "It might help in the sense that you'd be able to check out feedback and such at any time, any place".

4.3 Challenges and Potential Improvements

This study encountered the challenges concerning the students' involvement, conceptual understanding of peer-assessment as well as technology adoption. Students did not respond well to the invitations to participate in this study. As a recruitment strategy, participants were rewarded with the university bookstore gift cards, and in some cases their participation was considered instead of a compulsory coursework. Further on, peer-assessment concept was new to the students and there were concerns regarding the quality of feedback they might receive from their peers, the additional workload involved and the potential impact on their final grades. As it was mentioned earlier, participants were concerned about their lack of necessary skills in mathematics assessment; hence we suggest that a system should be put in place to enhance the students' judgment capacity and foster the active role of students as assessors. Peer-feedback is one of the good approaches to formative assessment, especially in large classes because it would be very difficult for a

teacher and very costly to provide regular individual feedback. It is also suggested that students work in groups in order to foster collaborative learning since it proved beneficial in this study.

The participants also expressed issues related to the technology tools used in this study, not only because they were not familiar with the tools, but also because the tools were not necessarily designed for mathematics peer-assessment purposes. The problems range from file management to finding the right tools such as the pen colors and sizes. The user control was limited as well, and in some cases participants could not easily find their way to perform a desired task or go back from an unwanted function. It was challenging for participants to recognise and recover from errors, since the users were not timely informed on the system status (success or failure). Improvements can focus on training the students on the available tools while working towards a development of an integrated tool.

5 CONCLUSIONS

This paper presented results of iPad mobile tablet technology-supported P2PASS experiments for two mathematics courses. The study confirmed that peer-assessment can foster student engagement and responsibility in their learning. In addition to portability, connectivity and mobility features of the iPad, this study has proved the advantages of tablet technology in writing mathematics expressions, and this can be time saving especially in providing an elaborate (step by step) feedback. However, this study found no clear evidence of the benefits to use iPAD in solving math problems. The technology acceptance was found greatly dependent on how well the peer-assessment could be planned especially in regards to students' training on how to use the tools. Future research is required to find the effectiveness of the P2PASS carried out over a period of time. This would be necessary to exclude the effects of learnability issues and to enable the measurement of the potential impact on students' performance. It is also desirable to carry out the same experiments with students of a different social and ethnographic background since collaborative learning could be affected by such parameters. The iPad is easy to use in general but the current set of available applications and LMS solutions are not well integrated and prevent an efficient use for P2PASS. This may change once iPad-like devices are cheaper, more widely spread, and when more integrated solutions have evolved.

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