

# Using Assessment for Learning Mathematics with Mobile Tablet Based Solutions

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**Abstract**—This article discusses assessment for learning in mathematics subjects. Teachers of large classes face the challenge of regularly assessing students' ongoing mathematical learning achievements. Taking the complexity of assessment and feedback for learning as a background, we have developed a new approach to the assessment for learning mathematics at university level. We devised mobile tablet technology supported assessment processes, and we carried out user studies in both Rwanda and Norway. Results of our study indicated that students found it fruitful to be involved in assessing other students' mathematics work, i.e. assessing fellow students' answers to mathematical tasks. By being involved in the assessment process, the students expected mathematical learning gains. Their providing and obtaining of feedback to/from their fellow students using technology supported tools were highly appreciated as regards their own mathematical learning process.

**Index Terms**—Mathematics assessment, mobile tablet technology, feedback for learning.

## I. INTRODUCTION

Assessment is one of the salient features of learning. However, assessment may serve various purposes. One purpose of assessment includes measuring and providing of feedback regarding students' achievements at the end of a mathematics teaching unit or a mathematics course. Additionally, assessment may support the identification of students' needs and competences in the learning process as well as monitoring the students' metacognitive competence. Considering the potentials of assessment as regards providing information of students' achievements, competence, and learning needs, taking advance of this information may support the students to improve their mathematical learning.

The research work presented here addresses issues of how assessment can be done for learning mathematics. The aim is to contribute towards the use of new technology solutions for assessing mathematics within large classes. This article presents an overview of assessment practices and discusses user studies that involved students assessing mathematics with tablet technology based solutions.

## II. ASSESSMENT FOR LEARNING

In the research literature regarding assessment one main issue is assessment for the purpose of learning, i.e. assessment that is used to empower the students in their learning process. Black and Wiliam [1], based on a thorough review of literature focusing on assessment and

classroom learning, conclude that regular and appropriate feedback to students regarding their learning process may effectuate significant learning gains. In their study, these authors discuss the rich amount of research literature devoted to the purposes of assessment. When talking of assessment meant to guide and motivate the students, they talk about *formative assessment*.

The concept of formative assessment comprises assessment that is regularly conducted during the course of study. Formative assessment thus has as its main purpose to inform the students about the progress of their learning as well as to provide the students with opportunities to address and improve the plausible shortages in reaching their learning goals. Teachers are often involved in formative assessment. However, students also play a key role in formative assessment since it is the students who know how to take advantage of the outcomes of the assessment. This is particularly the case if shortcomings are addressed.

In their study, Black and Wiliam [1] suggest to emphasize learning goals rather than performance goals, if to avoid underachievement as plausible results of formative assessment. Learning goals aim at making students develop know-how and know-why whereas performance goals rather aim at making students perform and complete given tasks successfully, disregarding students' possible understanding. Adopting a learning goal approach yields, according to Black and Wiliam, higher motivation and achievement compared with adopting a performance goal approach.

Formative assessment emphasise the learning process (the means) of the student rather than the final result (the product) of that learning process [2]. The purpose of formative assessment is to show the student where she falls short of the given expectations. Additionally, formative assessment also emphasizes how to possibly meet the expected standards or learning goals. It is thus important in formative assessment to highlight both the type and the quality of the feedback given to the student(s). Formative assessment adapts to the different situation and thus has as a goal to motivate the low-achieving students and to encourage the more high-achieving students to achieve even higher.

Sadler [3] reports that assessments with grades are most likely to have negative effects. The author suggests that one plausible reason for this is that students may then focus more on scoring higher grades than focus on getting to know the subject or learning unit as well as being able to explain the subject to fellow students. Sadler [p. 127] [4] claims that "*strictly speaking, all methods of grading which emphasize rankings or comparisons among stu-*

*dents are irrelevant for formative purposes*". Moreover, Sadler argues that formative assessment and summative assessment have to be clearly separated. He argues that formative assessment concerns how to improve students' competences by communicating judgments regarding the quality of the students' responses to tasks. Summative assessment, on the other hand, is concerned with how to summarize students' achievements for the purpose of reporting after finishing a course of study. Among others, summative assessment can be used for certification. Formative and summative assessments adopt different methods. These two do not only differ by timing. The main difference concerns the purpose of assessment and the expected effects of the assessment [1]. When conducting formative assessment one emphasizes how to support students in improving their achievements. This is done through giving the students regular, valid, and reliable feedback with respect to the quality of the students work as well as their progress. However, Sadler highlights that formative assessment does not automatically guarantee improvements in the students' learning. To increase the possibility that the formative assessment has the expected value, students have to possess skills so that they are able to appreciate what is work of high quality. This is needed in order to be able to compare their own work with high quality work, for then in the next step to be able to make appropriate adjustments to their own work.

### III. FEEDBACK FOR LEARNING

In control engineering the term feedback is used about signals or values that are taken from the system or process output and then re-injected into the input of the system/process aiming at allowing the system/process to generate a wanted outcome. Analogic reasoning may be used concerning the educational system. Feedback in the education system comprises any kind of information provided to students in order to raise their awareness regarding their ongoing learning achievements to possibly enhance their learning. Feedback thus may effectuate support for the students to come farther in their process of learning in order to reach the desired achievement goals [5]. Feedback for learning is an essential component within formative assessment. The success or failure of formative assessment hence is heavily dependent on how the students are provided with the feedback, but also how students utilize the feedback given [6].

Feedback regarding the learning process may be of different types; feedback only by grades, feedback by grades together with comments and feedback solely by comments. Studies of the learning gains of feedback have shown that it is feedback solely by comments which is the type of feedback that yields the highest level of improvement in learning. Secondly, it is the type feedback by grades together with comments which yields medium improvement in learning. However, feedback only by grades may actually cause a decline in students' achievements [1]. Interaction between the students and the provider of the feedback is required in order for the feedback to have formative purposes. By way of this interaction, shared understanding of the process of assessment may be reached and the outcomes may be negotiated. In order for the students to make substantial use of the feedback, perceived usefulness of the feedback is very important. Poulos and Mahony claimed that students' perceptions regarding the usefulness of feedback are informed by three fac-

tors; the credibility associated with the feedback provider, the timeliness of the feedback, and the type of delivery of the feedback [7]. In case of our studies, students have the teacher's solution to the questions at their disposal for them to check with the "correct" solution(s). During one of our studies, a participant mentioned that "getting quick feedback felt good". This can confirm that it is very important to provide feedback in time [8].

In order for the feedback to be *effective*[9], students have to be convinced that they are likely to succeed if they utilize the received feedback. For the students it is essential to realize the difference between their current achievement level and the desired achievement level, and to consider this information as feedback only if the information may be utilized to remove that difference [10]. In the environment of large classes, it would take the teacher a long time both to assess all students' work in a formative manner and to communicate the feedback to every one of the students. Thus, formative assessment runs a risk of not being able to provide the students with purposeful feedback in time.

### IV. STUDENTS AS ASSESSORS

#### A. Self-assessment

Student self-assessment labels a process in which each student may detect her/his own mistakes in solutions to tasks on a subject of study. The very nature of self-assessment is that each student has to assess her/his own individual work or group work. Studies of student self-assessment show that this type of assessment may be used to increase the students' own confidence regarding their ability to accomplish learning tasks. Additionally, self-assessment may help students to become more independent learners as well as more reflective regarding their own understanding of the subject [11].

Brookhart et al. [12], in their research on student self-assessment, studied third grade students who were about to learn multiplication facts. The authors asked the children to regularly predict their results on tests and plot these predictions as graphs. The aim of the study was to investigate whether student self-assessment had additional benefits, on top of learning mathematics. Brookhart et al. adopted an action research methodology, and their anticipation was "that the higher order thinking and metacognitive processes required for self-assessment" [p. 213] would make the students able to learn how to learn rather than supporting a mere memorization of the multiplication tables amongst the students. In participating in the study, students were encouraged to reflect on their learning progress and achievements every week. The authors detected differences between the student self-predicted scores on test and their actual scores. However, the study showed that the accuracy of the students' self-predictions improved over time. These findings support that it is important for students to be involved in assessing their own learning progress. Brookhart et al. maintain that the students in general took a positive attitude towards self-assessment. Moreover, the students liked to observe that they made progress in their learning process. The students became more interested in learning new mathematical skills and to improve their ability to solve the mathematical tasks rather than accomplishing a better score on the tests. In addition, we assert that students could learn a lot from assessing others' work. They may get opportunities

to acquire more skills such as analytical and critical thinking skills as they get involved into the assessment process.

### B. Peer-assessment

Several studies report that it has many advantages to involve students in assessment for learning [13][14-16]. When students are involved in assessing their own work as well as their fellow students' work, these studies argue that the students may come farther in their learning process, students may increase their abilities to reflect on their learning process and to think critically about their learning, and the students may increase their engagement. From our study at Kigali Institute of Science and Technology (KIST), one of the participating students confirmed that peer-assessment was important for her in order to develop her reflective thinking skills. Particularly, she reported that her assessment of her work made her reflect on various methods of solving tasks, different ways of reasoning, and various ways of providing answers. Stiggins et al. [17] argue students are likely to achieve improved performance when they spend efforts in analyzing the quality of other's work and to criticize the key elements of the work. These authors claim that "*when students learn to apply these standards so thoroughly that they can confidently and competently evaluate their own and each other's work, they are well on the road to becoming better performers in their own right*" [p. 20] [17].

The characteristics of what is to be assessed have to be considered in assessment of mathematics. This has to be done in order to define how the activities of assessment may be carried out. Niss [18] has described a set of traditional tasks which are specific in mathematics education: *questionnaires, exercises and problems*. With respect to the various tasks, students are likely to be questioned about formulae, definitions, results of computations or properties. In addition, students may be urged to provide answers to tasks which comprise routine operations or they are to solve problems that comprise reasoning regarding strategies and multiple computational procedures multiple computational procedures. There is also a variety of mathematical questions expressed through the questions' formulations. This may vary from a category comprising straight, single answers till a category involving open response answers. For example, mathematical questions may be stated employing imperative expressions, i.e. *define, state, calculate, find etc.* Such imperatives may indicate the possibility that only one specific method leads to the correct answer.

However, there are also mathematical questions where students, in order to answer them, have to interpret what methods and/or procedures to use. For instance "A ball of ice melts so that its radius decreases from 5 cm to 4.92 cm. By approximately how much does the volume of the ball decrease?" [p. 267] [19]. Being able to competently assess responses to such a question requires the student to understand the task at hand. She also has to understand possible selections and uses of different strategies and procedures. Furthermore, the student has to make sense of the ways mathematical expressions may be presented in the answer(s). In the user studies that we conducted, the students assessed the work of fellow students by writing on media tablets. The writing was done using a stylus or a finger in a pen-an-paper like manner. Such kind of writing afforded feedback and assessment on several steps of the answer.

In order for students to appraise all components of the answer, we are of the view that the assessment criteria have to be explained to the students. Previous studies have remarked important issues regarding students' capabilities to assess fellow students' work and related responsibility [20]. First of all, students are in general non-experts in the subject of study. Secondly, students are generally novices in criteria referenced judgment with respect to the quality of work. Sadler [4] suggests that students may acquire evaluative knowledge through tutelage by a person who knows how to conduct criteria based assessment. Building experience amongst students with respect to evaluation should, according to Sadler, be organized into an instructional system. That would support the students in improving their self-assessment skills. Moreover, the students' strategies for closing gaps in their learning achievement may be expanded. Following these advices, we sought to clarify the meaning of each assessment criterion for the students. Additionally, a reference (correct) answer sheet was provided to the students in advance of their peer-assessment.

Both teachers and students may be challenged by the complexity of assessment practices. Watson [21] questioned the judgments of some teachers when they were to assess their students' mathematics learning during regular classroom experience. Disregarding the observed teachers' professional training in assessment, Watson concluded that the teachers' assessment practices were marred with interrelated issues such as *observation, interpretation, perspective, and expectation*. One teacher's interpretation of a student's work may differ from another teacher's interpretation due to the fact that teachers' views regarding quality of work may differ. Teachers may emphasize interactions outside the classroom differently, and they may have differing expectations to individual students. Furthermore, mathematics is most often expressed through symbols; symbols which represent what students know or are able to do. Challenges then occur when the same meaning of a mathematical thought has to be communicated to different people without having the opportunity to use language.

## V. TECHNOLOGY SUPPORTED PEER-ASSESSMENT IN MATHEMATICS EDUCATION

### A. Tablet technology based solution concept

Assessment of mathematics tasks requires consideration of the characteristics of mathematics as a subject. This approach of assessing mathematics tasks is based on qualitative judgments as defined by Sadler [22]. Qualitative judgment is done by a person and cannot be done automatically by a formula such as using a computer program. It goes beyond the correct/non-correct judgment of an answer or a piece of work, to provide judgment on the quality of performance using multiple criteria. Using a small and easy to understand sample of possible assessment criteria, more than two persons judge the quality of work, each one of them assigning a level of achievement for every assessment criteria. It is noted that the chosen criteria are fuzzy (not considering only two states of either 1 or 0, true/false but considering also intermediary states) rather than sharp as discussed in [4]. Students can assess whether answers are correct, whether the student has understood the methods/procedures, whether the solution is easy to read and understandable, and finally rate the solu-

tion as low, medium or high. In our previous work on assessment [23, 24], we studied the possibilities of involving students in their own formative assessment, with students judging each other's quality of work. The research studies were conducted in Norway and Rwanda: in both countries, we worked with engineering students and university mathematics teachers to organize peer assessment sessions concurrently with the teaching. We adopted a new approach of using media (mobile) tablet technology to support peer assessment in mathematics. The iPad mobile tablet was chosen as a technology platform that can support natural writing based on the touch sensitive screen. By using a portable document format (PDF) editing and annotation software (PDF Expert), students answered mathematical tasks on the tablet. Then the answers were submitted to a Virtual Learning Environment (Frontier by Pearson International) for assessment purposes. Thereafter, each student was assigned three answer sheets to assess and in return get feedback from three other students.

Using similar techniques at two institutions of higher learning, students carried out peer assessment in mathematics, while we observed them working together and interacting with the media tablet based peer assessment system. Mathematical tasks at University of Agder (UiA) consisted of Calculus exercises (functions, derivatives and integrals) whereas students at Kigali Institute of Science and Technology (KIST) worked on Fourier series.

Based on experience with the peer-to-peer assessment processes in [23, 24], this work suggests to effectively embed peer assessment into university mathematics education using tablet technology based solutions. Data collected through observations, interviews and questionnaires indicate that students are positive about the concept of peer-assessment in mathematics. Using an online survey questionnaire, 23 students at UiA ( $N_{UiA}$ ) and 22 students at KIST ( $N_{KIST}$ ) provided their opinions on peer assessment for learning mathematics. Students expressed themselves with statements such as "I really like the idea of multiple feedbacks"; "I realize that it is one of the best way to feel responsible in serious tasks"; "Easy to get a copy to evaluate"; "I did not have to get the written copy, since everything was in PDF (portable document format)

on the Fronter Learning Management System" (LMS); "It helped me, because I am very happy to be corrected or to be advised by my classmate rather than by the teacher"; "I believe this is a great way of sharing knowledge and collective learning and reflection"; "It is helpful because I want to compare my level of course understanding with that of my peers".

Despite the difficulties due to using new media technology and dependency on the wireless network connectivity, students expressed the benefits of having a mobile tablet technology supported system, with one of them stating: "it enabled us write using pens like we do on papers resolving maths problems". The facility to digitalize students' work has several direct and indirect advantages, because "you can save your work for a long time", "the iPad is portable, that means wherever you are you can apply for peer assessment" and "multi-modality: that machine has many programs which can be used when you are doing your assessment". It is indeed helpful to be able to revise the learning material/ resources while answering or assessing the given work; a fact that was observed on several occasions during the user studies (from time to time, students were browsing the web looking for mathematics notes and formulae).

By comparing the attitudes of students at UiA and those at KIST shown in Table 1 we can see that students in Rwanda scored higher on the Likert scale. It is also observed that in KIST, the standard deviations (SD) are smaller for all attitudes' measurements, which indicates that the sample students have more closely related attitudes towards peer assessment. Cultural differences have influences on technology enhanced learning [25, 26], which can impact on how students in general interact with computer mediated learning environments. Based on personal observations, we think, in Rwanda for example, people with education enjoy a much higher status in society. Improving ones' ICT skills and using ICT tools can help to achieve this much needed status. On the other hand however, in Norway, the majority of university students have access to latest ICT tools; hence using them does not significantly contribute to their status in society. This can be one of the reasons why students at KIST were more positive about the new technology supported pedagogy.

TABLE I.  
COMPARATIVE TABLE OF USERS' ATTITUDES IN KIST AND UIA

Users' attitudes measurement parameters	Mean		Mode		SD		Variance	
	<i>KIST*</i>	<i>UiA**</i>	<i>KIST</i>	<i>UiA</i>	<i>KIST</i>	<i>UiA</i>	<i>KIST</i>	<i>UiA</i>
Rating of peer-assessment on 1 to 5 Likert Scale (5- Strongly Like)	4.74	3.46	5	3	0.45	0.88	0.20	0.81
Difficulty to provide peer-feedback (5- Very Easy)	3.65	3.17	3	4	0.71	1.05	0.51	1.15
Difficulty to use the media tablet supported system (5- Very Easy)	3.43	3.25	4	4	0.79	1.19	0.62	1.45
Usefulness of peer-feedback (5- Very Useful)	4.70	3.67	5	4	0.70	0.96	0.49	0.95

\*KIST-Kigali Institute of Science and Technology (Rwanda); \*\*UiA- Universitetet i Agder (Norway)

The higher values of SD at UiA could be resulting from the fact that students had varied experiences with technology supported learning, some of them already using media tablets and personal computers in learning, whereas all students at KIST had experience neither with the LMS nor with media tablets. The Mode values in Table 1 indicate that more students at KIST perceive peer assessment to be very useful as compared to those at UiA.

The graphs in Figure 1 and Figure 2 also show differences on students' perceptions about student generated feedback. Students at KIST show a higher tendency to believe in the validity of the peer feedback, whereas at UiA there is a non-negligible number of students who are not sure about it. The results obtained in this work may not be generalised due to a relatively small sample size ( $N_{KIST}=22$  and  $N_{UiA}=23$ ). However, they provide a good indication on learning opportunities of technology supported peer assessment in mathematics education.

The above user studies have contributed towards conceptual validation of mathematics peer-assessment with tablet technology based solutions. Additionally, technical usability was evaluated and we found that there was a need to enhance the ease of use, ease of learning and the ability to recover from errors. Since the studies used of-the-shelf tools, it would be difficult to achieve the usability goals; therefore a new solution was built based on user centered design principles.

A. New solution architecture and technology

The new solution, called Agder Peer Assessment System (A-PASS) hereafter, is a web application developed for mobile devices. This approach was chosen over a native mobile application in order to avoid dependency on a specific mobile platform. However this choice comes at a cost in terms of user experience. A web application depends much more on computer network speed and server performance, which can negatively affect the application responsiveness.

From a student perspective, A-PASS modules and user interfaces are built to support functions shown in Figure 3.

The user centred design of A-PASS endeavours to provide a user experience nearing to that of a native mobile application. The A-PASS user interfaces offer a tabbed navigation making the information easy to find [27] and faster navigation between pages on a limited screen size of the mobile tablet computer. The user interfaces consist of webpages rendered to the browser using hypertext mark up language (HTML). The latest HTML version (HTML5) offers new elements such as the *canvas* which allow for structuring and presenting graphical content on the web. Using the canvas element and JavaScript code, it is possible to implement a drawable region in order to enable handwriting of mathematical symbols on a tablet computer touch interface. From the interaction point of view, the feature to draw or write with a finger or stylus pen offers an intuitive natural feel for users. The additional option to provide text based reviews in A-PASS allows for flexibility in feedback provision.

Our design was specifically customized for 10 inch mobile tablet, with iPad2 as a test platform. iPad2 is considered because it had some of the best tablet technical specifications at the time of A-PASS development. The built-in "Safari" browser mostly supports HTML5 and the touch sensitive screen supports handwriting/drawing neces-

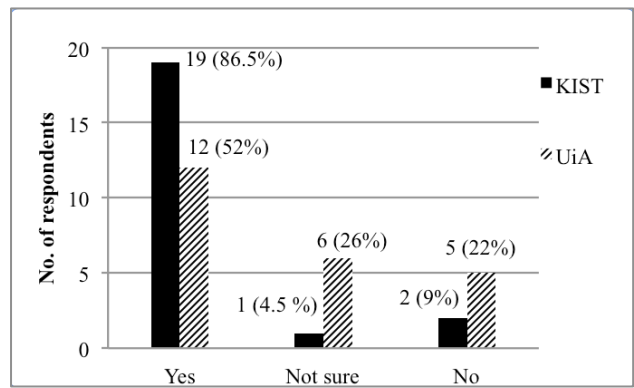


Figure 1. Students' confidence to provide fair and responsible feedback

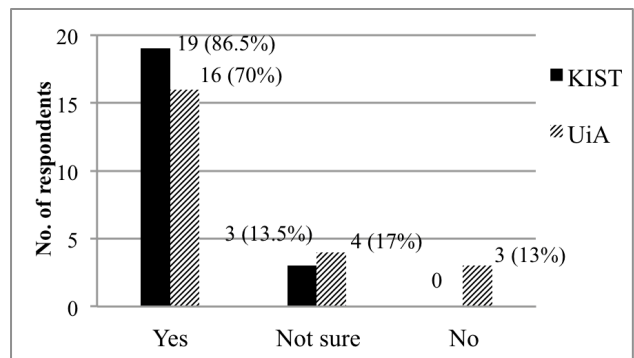


Figure 2. Students' trust to receive fair and meaningful feedback from peers

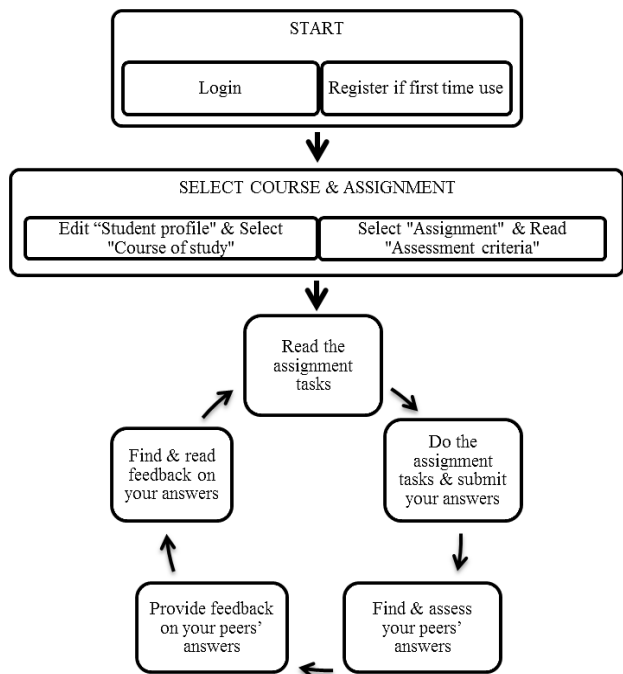


Figure 3. A-PASS functional architecture

ssary for presenting mathematical expressions. The A5 dual core 1Ghz processor provides a user experience while drawing on iPad approaching that of writing with pen and paper. This indicates that users are likely to be more satisfied and adopt the likes of A-PASS solutions in the near future as tablet technology evolves.

A-PASS development follows three-tier architecture:

- presentation tier based on HTML5, CSS3 and JavaScript
- application tier built with Microsoft .Net architecture using C# and
- back-end database using MSSQL accessed by LINQ (language integrated query) over SQL (structured query language).

From a conceptual point of view, it is important that an assessor can write feedback reviews directly on top of the submission. At the same time it is important not to delete a student's initial submission so that it can be compared with review suggestions from the peers (assessors). This would help the student to see where an error was committed and how to make necessary corrections as shown in Figure 4.

To achieve this functionality, we designed a solution such that the assignment mathematical tasks are directly solved by writing/ drawing on a canvas within the website allowed for by the HTML5 standard. A student could create several pages as part of the answer. Upon finishing all mathematical tasks, the answer pages are merged into one long answersheet and submitted as a single file.

For the review phase, the submission file is displayed in the background with a transparent canvas on top. This allows a peer student to perform assessment and provide feedback directly on-top of the submitted answersheet as shown in Figure 5.

This approach allows for combining answersheets with or without the review on top on the client side without the need for a server post-back after the initial post-back.

For drawing and saving canvas on iPad a problem arose as the iPad did not support any form of JavaScript file saving and retrieval in a simple fashion. To work around this, the canvas content is turned into a PNG file which was stored in a base64 encoded string. This "base64 encoded string" is then sent back to the server and built into a PNG image file on the server. This technique allows rendering the picture on the client from a base64 encoded string delivered by the server. Since the file is handled between the server and client as a base 64 encoded image, it can be buffered on the client. The amount of client-server connections is considerably reduced, hence improving the mobile user experience.

**B. Peer-assessment student grouping**

A-PASS functional requirements comprise of students grouping among other things. A-PASS design embraces the social constructivist learning whereby learning is achieved as a social collaborative activity. We assert that students can have more learning opportunities if they assess multiple answersheets from their peers. Having access to various approaches of problem solving is likely to enhance the learning experience and the development of critical thinking skills.

A-PASS handles multiple students in one course, divided into groups of three students. There are also cases where the integer division of the total number of students by three has a fractional part. Hence four students make a group. In each case, every student assesses and provides feedback to three other students (peers). Since A-PASS

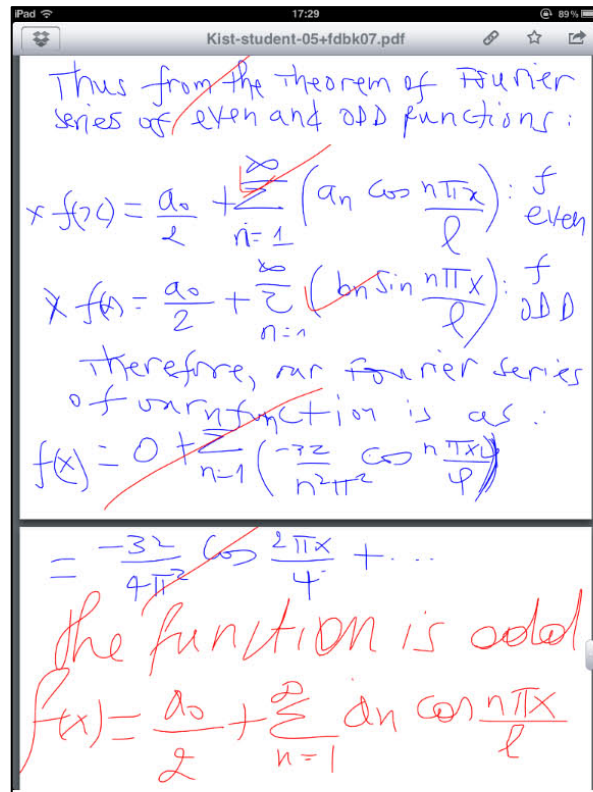


Figure 4. Assessment and feedback on mathematical task

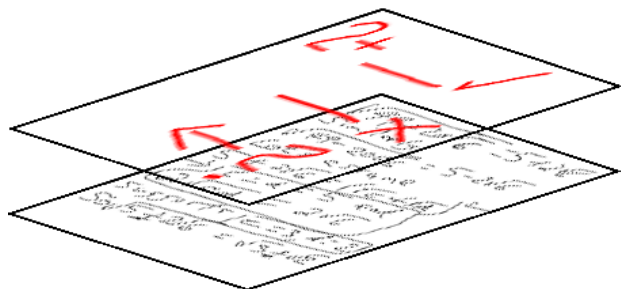


Figure 5. HTML5 Canvas overlay for mathematics assessment

caters for large student numbers, an algorithm is designed to automatically create student groups according to certain rules:

- Groups are created according to individual learning performance levels
- Students in the same group cannot assess each other's submission
- Each student should assess peers from all three different performance levels

This was achieved by using a combination of Fisher-Yates shuffle[28] and round-robin approach as follows:

1. Make 3 lists of all students based on their performance levels ("High", "Medium" and "Low").
  - a. Create as many groups as the number of students on a list in one category of performance level (say "High")
  - b. Remove performance level group already assessed.
  - c. Remove all students from own group in all performance level groups.

- d. Remove all students from groups already assessed in all performance level groups.
2. Pick a random remaining student from a random remaining performance level.

Figure 6 shows an example of student grouping, with each student from group “2” assessing a peer from each of the three levels of performance in the remaining three groups.

Using the new system, students at UiA provided each other with feedback based on a learning unit taken from a mathematics course in the spring semester 2012. Students suggested that the system can enhance their critical and reflective thinking, and also provide timely and encouraging feedback. The screenshot in Figure 7 shows an example of a student assessment on mathematical tasks in the right pane, and detailed feedback on the left side. The assessor advised to “check through the calculations in the first question. There are a couple of mistakes with the fractions”. And “In question 2 there are some errors, the answer isn’t far from correct. Just a couple of miscalculations which easily happen when finding determinants for bigger matrices”. The feedback in this example is based on “the correctness of calculations” assessment criteria. The assessor can also provide feedback on “the understanding of methods/procedures” as well as communication of the answer (whether the answer easy to read and understand). This tablet based solution allows providing quality feedback, with clear indications of what should be improved. The assessment is criteria based and the performance levels (High, Low, Medium) are indicated just for formative purposes.

The affordances of mobile tablet technology have an added value for learning mathematics. Students take advantages of mobility and flexibility to assess each other’s work. Our user studies indicated that students are willing to get involved in assessment for learning mathematics outside the normal fixed study hours. Mobile tablet based solutions enable collaborative learning as students use Internet connectivity to communicate, access, solve and assess mathematical tasks.

## VI. CONCLUSION

The purpose of this work was to provide modern insights into the practice of formative assessment. Our intention was to devise and test how this can be done in mathematics subjects at university level. This article supports the concept of involving students in assessment for learning. Several user studies were conducted in two countries and it was found that students are likely to adopt the new form of formative assessment. The study findings indicate possibilities of using mobile tablet technology to support peer assessment process. Students expressed a willingness to adopt the technology, but they also pointed out a need for an integrated tool with improved technical and pedagogical usability. A new mobile web application was designed based on the principles of user centred design. Students tested the new tool, and they suggested that mobile tablet technology can be useful in teaching and learning mathematics. Future work can consist of evolving the solution to enhance functionality and usability. Further user studies would provide extended knowledge on the integration of tablet technology supported peer assessment into mathematics education.

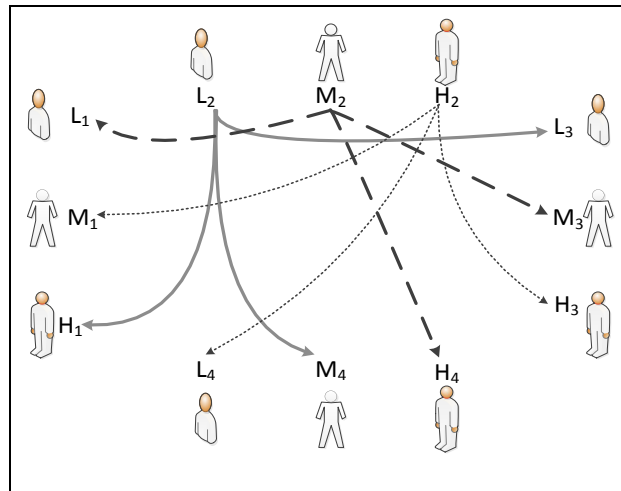


Figure 6. Student groups (L=low performance, M=medium performance, H=high performance)

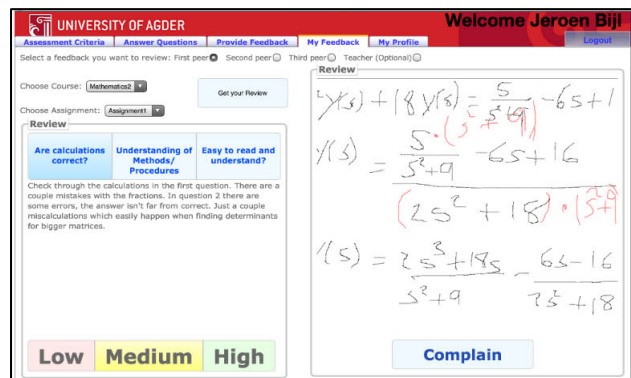


Figure 7. A-PASS interface for assessment and feedback provision

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