Early testing of eExams in Calculus at University level

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Abstract

The aim of this work is to show the results of early testing using eAssessments on the course Mathematics I MA-154, mathematics for bachelor and master students in engineering. This course has graded written examination and 5 approved written assessments throughout the course. This is lots of work to administer, approve and grade. Having worked for the past 10 years with projects in eLearning, I wanted to use some of my knowledge to make grading easier. I started searching for suitable tools that could do this work for me. I ended up using Pearson and their textbook Calculus: A Complete Course *by Adams and Essex. Students get access to a powerful online homework, tutorial, and assessment system called MyMathLab Global when they buy the book. My ultimate goal is to fully implement this assessment system so that exams are taken and graded electronically by the end of 2012. Autumn 2010 and 2011 were used to do the first testing of this system.*

1. Introduction

Having lectured on the MA-128 Calculus course (now MA-154 Mathematics I) at University of Agder [1] in 2009, it was clear to me that I would make big changes in relation to how the course was presented. In 2009 I took over the course at short notice and did not have any time to change course arrangements from previous years. The earlier scheme was not bad but it was taught in the traditional way (board education, compulsory exercises and assignments). After working with eLearning for more than 10 years through a former project called parAbel [2], I wanted to use and exploit the advantage of PC-tools in the best possible way. I also have good experience in applying computer technology to my teaching. With the election of MyMathLab Global [3] I have a tool that satisfies most requirements for eLearning. Here I can give students assignments, tests, quizzes and exams. Questions can be randomised, so that students can get a new question if they want to practise more. The test module allows me to give a test that immediately gives students feedback on their scores. I can allow them to take a test again and again with randomised questions, so they can

improve their score. Student feedback indicates that this is motivational. Students can also get step-by-step help to solve problems. All in all, I have many opportunities to control the programme so that my students get what I think is best for them. In this paper I will describe the work performed in MyMathLab. I will also comment on the results and whether MyMathLab is a suitable tool for electronic exams on computers, from now on referred to as eExams. Can MyMathLab set the right grade for the students? Will students get a grade on eExams that is appropriate in relation to what they have achieved?

Students get access to MyMathLab via an access code provided when purchasing the textbook *Calculus: A Complete Course* by Adams and Essex, Pearson [4].

MyMathLab works just like any other Learning Management System (LMS) (Figure 1). I set up the page in a way that gives my students all the important information they need to progress on the course.

Figure 1.Main page for MyMathLab.

By entering 'Homework and Tests' students get an overview of what to do. Assignments are either 'Homework' (marked H), 'Tests' (marked T) or 'Quiz' (marked Q) (Figure 2). If they choose 'Homework' they will get questions picked from a large database (Figure 3). I can choose to randomise these questions so that each student will get the same type of questions with different values. I can also choose different aids allowed to help students solve the problems.
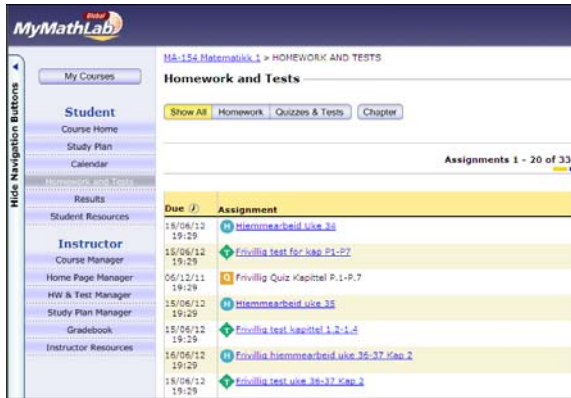
Figure 2. List of assignments.

Figure 3. 'Homework' example.

Figure 4. 'Test' or 'Quiz' example.

Figure 5. Study progression

When students do 'Homework' I let them access these aids:

- "Help Me Solve This" gives students step-by-step help to solve exercises. Very useful aid for low-skill students
- "View an Example" shows student similar examples.
- "Textbook" sends students to the page in the textbook (eBook) that deals with the type of the task they are working on.
- "Calculator" provides the students with a desktop calculator to do calculations.
- "Print" allows students to print the question statement.

If students choose 'Test' or 'Quiz', they get a similar window to that of 'Homework' but I remove the help options for solving questions (Figure 4).

Students have full control of their own progress and scores throughout the course (Figure 5). They can review each assignment and see where they answered incorrectly and see what the right answer was.

As an instructor/lecturer I have many possibilities to tailor-make my own educational setup in MyMathLab. There are still a lot of options I have not yet had time to try out, since the focus so far has been to implement and try out an eExam.
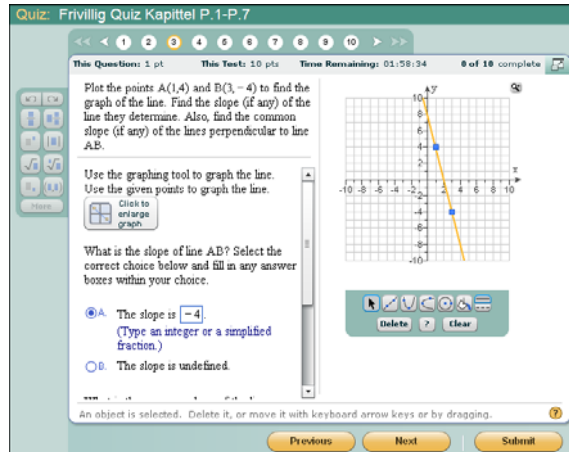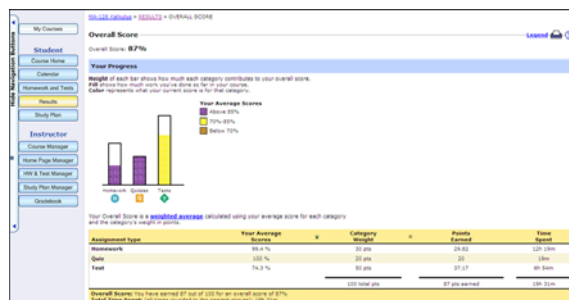
2. Innovation and relevance

My previous research in this area [5] and [6] suggests a number of improvements in how to implement the student use of computer-aided programmes and different learning arenas. I have a lot of experience in using computer-aided programs in my teaching so the next step was to let my students also take their exams on computers.

Students must be familiar with the tool to be able to complete an online eExam. It was therefore required that they got enough training using MyMathLab. Each week I gave students one set of 'Homework' tasks and one 'Test'. The test was a summary of tasks that were given in the 'Homework'. A large database of different questions makes it easy to pick out the appropriate questions to set as homework, assignments and tests (Figure 6). I just choose one type of question, and then choose whether this should be 'fixed' or 'randomised'. That is, if I choose to have randomised questions, students can try again on a similar question if they get it wrong the first time.

All questions from the database are in English. As an instructor, I can create and build my own questions in Norwegian too (Figure 7). When inside the question editor there are lots of options for creating new questions.
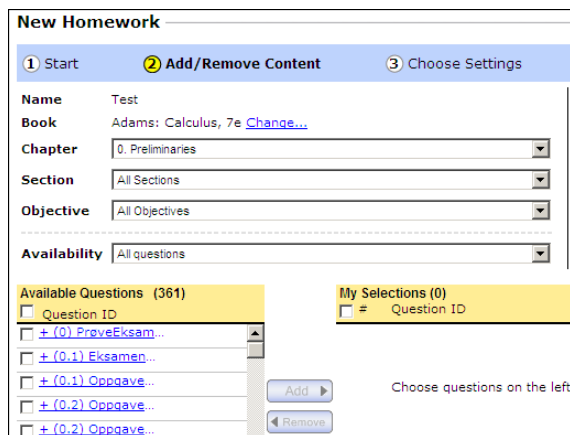
Figure 6.Administration page of "Homework".

The editor gives me the opportunity to provide the following types of questions (Figure 8):

- "Algorithmic Values" - with the possibility of mathematical expressions in student responses.
- "Graph", where students will plot correctly to answer the question on a graph.
- Making bar and pie charts.
- "Short Answer" allows students to write short text answers.
- "Multiple Choice".
- "True or False".
- "Essay Answer".

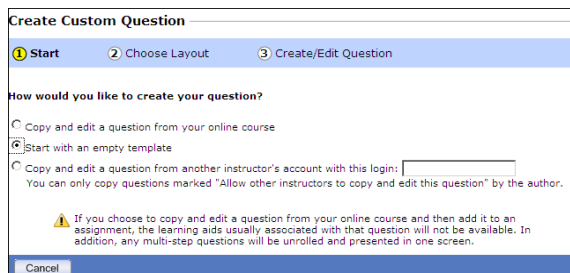This gives a wide range of different questions and possibilities when building eExams.

Figure 7.Administration of question production.

MyMathLab gives me a full overview of my students' performances, just like any other LMS. It is also tailored for use in mathematics, so I knew that it was possible to write and give an online eExam in Norwegian.

So then it was time to test out eExam on my course. First I wanted to see if it was possible to grade the result of the exam electronically. This would save me a lot of work since I have more than 400 students on my course. Then I wanted to see if it is possible to handle 400 students conducting the eExam at the same time on our campus. This was my plan:

- Autumn 2010: test out the eExam on a limited group of students, and compare results of the ordinary grading against electronic grading by MyMathLab.
- Autumn 2011: try out the eExam on a large group of students. The main focus here was to see if everything would work; laptops, power supply, wireless network etc.
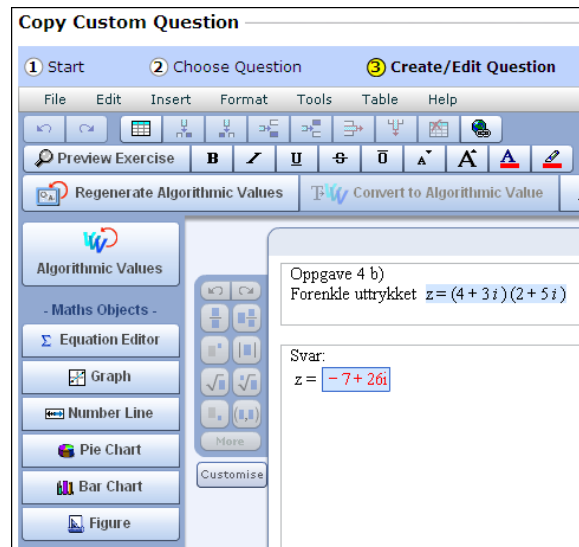

Figure 8. Question editor

3. Results

The most important work in this project is to determine if it is safe to implement online examination on the course MA-154. There is still some work to be done and more data that must be reviewed before any exact conclusion can be made on this but it looks promising. In November 2010, 14 students conducted an eExam using MyMathLab. In December 2011, 279 students sat an eExam. They also delivered the same written examination together with all other students. I will divide the results into 5 parts:

1. Statistics: Use of MyMathLab.
2. Implementation of the eExams.
3. Type of questions on the eExams
4. Grading and results of the eExams.
5. General results

3.1 Statistics: Use of MyMathLab

Table 1 shows the number of students and the number of users of MyMathLab. In 2010, registration onto MyMathLab was voluntary but still 80% chose to register. In 2011, registration to MyMathLab was mandatory; 90% of students were then registered. The last 10% that did not register had to apply for an exemption.

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Table 1. Registered students and MyMathLab users.

year	Registered to exam	Sat exam	Registered MyMathlab
2011	296	280	237
2012	416	387	397

Table 2 shows median time spent on MyMathLab per student. There were some small adjustments to the curriculum from 2010 to 2011, explaining the difference in chapters. The table shows that students have done a great deal of work in MyMathLab. This time is on top of ordinary lectures and organised school hours.

Table 2. Time spent in MyMathLab

Chapter Textbook	Median time per student **2011**	Median time per student **2012**
0	01:17:35	01:55:35
1	01:35:59	01:41:46
2	03:14:21	02:28:06
3	02:31:43	02:35:22
4	02:26:41	01:19:26
5	03:54:09	03:24:17
6	02:38:53	03:00:08
7	02:05:58	00:05:05
9	01:59:44	01:51:08
12		01:37:03
14		00:09:52
GR	00:06:58	00:15:42
Total time per student	**21:52:01**	**20:23:30**
No. Students registered on MyMathlab	237	397
Total time on course	**4982:27:57**	**8095:18:30**

As we see, my students spent over 8000 hours in MyMathLab over the 15 weeks of my course. I think these 20 or more hours per student comes very much on top of those hours they would put into the course if there was no eLearning tool provided to them.

3.2 Implementation of the eExams

Throughout the semester tests were given each week. In 2010 every test was voluntary. In 2011 three digital tests were mandatory. This meant that I was fairly confident that the exam in MyMathLab would go without any serious problems.
In 2010, 14 students volunteered to take the eExam in MyMathLab along with their ordinary written

exam. This exam took place in a computer lab at campus. where w had full control over the computers being used; only the MyMathLab website was open for use at these computers. Everything went as planned that day. Immediately after students confirmed and submitted their eExam, their percentage score was presented for them. Just five minutes after the exam finished, I had the report showing all scores. The comparison of electronically and ordinary scores are presented in section 3.4.

In 2011, 279 students completed the eExam in MyMathLab. Due to strict exam regulations I could not make the eExam mandatory. For this to happen it had to be mentioned in the ECTS Course Catalogue before the course started. Therefore again the eExam had to be voluntary but that was not really a problem; we did a full scale test anyway. This time the main objective was to determine whether we could handle an eExam for such a large group of students. These were some of the key challenges for us:

- Our university does not have enough computers at our lab facilities so students needed to use their own laptops.
- Could our wireless network cope with this?
- Did we have enough power outlets in our rooms? And also did we have enough rooms? Students couldn't sit too close to each other or right behind each other, as they could easily see another computer screen.
- How about communication with others through computers?
- Could we restrict the network?
- What aids did students have on computers, and what aids should we allow them to have?
- Backup? What if the computers went down?
- What about students who did not have their own laptop?

Since use of computer labs was out of the question, students had to use their own laptops. Then we had no control over what they had downloaded in terms of programmes and documents. So it was clear to me that I needed to allow students all written and digital aids during the exam. I also needed a backup plan in case any computers should go down before or during the exam. If this should happen, students would be able to switch to the ordinary written exam. Then each laptop needed a power supply so to solve this challenge we put students into 30 different rooms on campus. This also made it easier to place them in a way so that they could not see another computer screen. Students without their own laptop were put into computer labs.

Two main challenges took a lot of investigation and discussion with our technical staff. I wanted to get a secure 'exam' wireless network outside the ordinary student network. With this we could control URLs: that is close down MSN, Facebook, and Skype etc. Uncertain whether this network could cope with that amount of users, we decided that this could not be done at that time, but is something that probably will work next semester. However, even if this network were available, we could not stop students using the ordinary network. We then had to close the ordinary network, and that was not really a good solution since many other people on campus use this.

Another difficulty was laptops that have built-in 3G wireless cards. Today you get computers that have a SIM card slot built in, which can reach the internet through 3G. This is beyond our control. A student can also create a mobile hotspot on a mobile phone in a bag or jacket. They could then go online through the wireless web to mobile and then to the internet via 3G. This is also beyond our control.

All this considered I chose to let them take their exam on the ordinary wireless network on our campus. We closed down one specific website that solves maths problems but everything else was available for students. We made sure students knew that we could log data traffic but we did not actually do that. We also put out more exam officers than usual and put them behind students and not in front, so that they could monitor their screens. This was to prevent communication between candidates. We will never be 100% sure that candidates do not cheat.

I also prepared my students on what to do at the exam if their computer failed or broke down; there would be no technical support and they just should continue with the ordinary written exam. A few students experienced problems with their laptops, mostly due to problems with the flash player needed to run MyMathLab. Comments on how the implementation worked out is given in section 3.5.

3.3 Type of questions on the eExams

When giving scores to mathematical questions, there will always be some points for correct process or procedure even though the answer is not correct. This is not possible on eExams where answers can only be right or wrong. It was, and still is, a challenge to design eExam questions correctly. If possible, I want to make sure that I pick up those students who demonstrate the correct procedure during problem solving. This was my main focus during the 2010 eExam. I tried to solve this challenge in two different ways:

- By enabling a wider range of options in response to the questions.

- By splitting questions into multiple parts. This would only be one question on an ordinary written exam.

By splitting questions, the students gained a certain percentage for each part they answered correctly. Figure 9 illustrates how I added additional multiple choice questions on the eExam. It is also possible to weight each part of a question differently on the eExam.
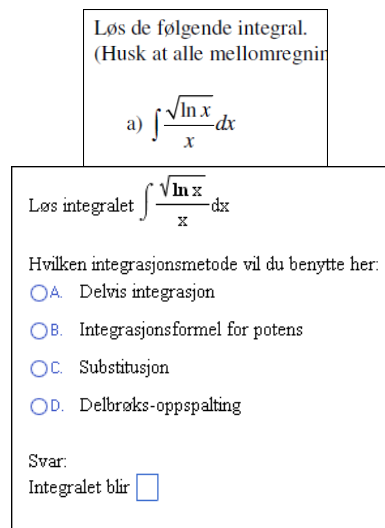

Figure 9. Example of the same question on the ordinary written exam (top) and eExam (bottom).

3.4 Grading and results of the eExams.

After the 2010 exam I chose not to go into MyMathLab to see the score of the eExam as I wanted to see the score from of the ordinary written exam first. The ordinary grading was conducted by one external professor and me. Percentage scores were given to each candidate. The percentage results from the eExams came directly from an exported file from MyMathLab. This file can be exported immediately after the eExam, and if electronic scoring were allowed, be sent directly to the exam office. The file is shown in Table 3.

Table 3. Scores from eExam 2010. Percentage scores can be read as the last value.

Table 4 shows the results from the written exam and the eExam from November 2010. Column 2 and 3 are results from the ordinary grading. Column 4 and 5 are results directly from MyMathLab. Not surprisingly, the grades are lower for the eExam; the computer only gives credit for the correct answers, while manual grading also gives some credit for the correct process. This is one of the challenges we face with the eExam.

Table 4. Results from the written exam, compared with the eExam, November 2010.

Cand. number	Results in %	Final grade	Results % e-Exam	Grade e-Exam	Difference in %
209	68,85	C	45,5	E	23,35
241	88,45	B	86,4	B	2,05
272	25,4	F	24,2	F	1,2
347	40,95	E	33,3	F	7,65
360	75,1	C	57,6	D	17,5
370	68,85	C	63,6	C	5,25
403	34,65	E	31,8	F	2,85
406	27,15	F	24,2	F	2,95
415	100	A	95,5	A	4,5
435	87,2	B	81,8	B	5,4
454	98,25	A	84,8	B	13,45
468	93,7	A	86,4	B	7,3
469	69,1	C	56,1	D	13
524	68,1	C	51,5	D	16,6
				Average deviation	8,79

The average deviation was at 8.8%. 8 of 14 candidates dropped one grade, and one candidate dropped two grades. Further investigation of scores was needed. If we look at candidate 209, the difference between their ordinary score and eExam score was 23.35%. For candidates 209, 360 and 524, all with a grade C, we see that we have the greatest deviation. This was not unexpected, as these candidates often have many "almost" correct answers and get bonus points for correct procedure. Candidate 454 got an A and had a deviation of 13.45%, which was more unexpected. To understand why we had this deviation I looked into each answer the candidate made in MyMathlab. Figure 10 shows an overview of responses from candidate 209.

Figure 10. Answers from candidate 209.

At the top of the figure we see markings of 10 questions given in the exam. The student gets a green tick for a correct answer and a red cross for a wrong answer to the exercises. Some questions are divided into two parts and then the student can get it partially right. I can place the cursor over the correct answer and the yellow field will show what the candidate answered. I then compared these answers with the same question given on the ordinary paper exam. I discovered that some deviation was caused by entering a correct answer from the paper exam wrongly into the eExam. 7 of the candidates had made this mistake. This could be as simple as just an omitted minus sign, or forgetting to square x.

There are also several versions of correct answers to a question. I soon discovered that I had not entered all versions of correct answers in the database when I created my own question.

I thought it would be interesting to see what kind of deviation there would be if candidates had entered the right answer from their paper exam and all the versions of correct answers were entered in the database. So I corrected the candidates' answers in the eExam, so that they matched their paper exam. All correct versions of answers were put in the database and immediately I saw changes in the results. The results after these changes can be seen in Table 5.

Table 5. Results from the written exam, compared with the eExam, November 2010.

Cand number	Results in %	Final grade	Corrected e-Exam %	Corrected grade	Difference i %
209	68,85	C	54,5	D	14,35
241	88,45	B	86,4	B	2,05
272	25,4	F	24,2	F	1,2
347	40,95	E	37,9	E	3,05
360	75,1	C	71,2	C	3,9
370	68,85	C	63,6	C	5,25
403	34,65	E	31,8	F	2,85
406	27,15	F	24,2	F	2,95
415	100	A	95,5	A	4,5
435	87,2	B	81,8	B	5,4
454	98,25	A	95,5	A	2,75
468	93,7	A	90,9	A	2,8
469	69,1	C	60,6	C	8,5
524	68,1	C	66,7	C	1,4
			Average deviation		4,35

With these adjustments, we see that the average deviation was halved to only 4.35%. Again it was candidate number 209 that stands out with a deviation of 14.35%. There were now only 2 candidates who received one grade lower on the eExam.

So with these adjustments, we see that the differences between digital and ordinary scoring are not that great. The rating scale used at the University of Agder is shown in Table 6. On this particular exam in November 2010, 35% was set to pass.

Table 6. Rating scale for MA-154.

Prosent	Karakter
90-100	A
80-89	B
60-79	C
50-59	D
40-49	E
0-39	F

At the eExam in 2011, a comparison of grading was not the main issue. I did not put in any effort to divide or rewrite questions so they would fit the eExam, nor did I put in all the correct versions of answers in the database. The standard deviation then was 14.85%, much larger than the year before. This only proves that if digital scoring should be used, adjustments and "new thinking" in how questions are built need to happen.

3.5 General results.

It is also interesting to compare results of the annual exam from 2009 up to 2011. I have lectured all three years in the same way. In 2010 I introduced my students to MyMathLab as a tool they could use if they wanted to. Did this have any impact on grades? Figures 11, 12 and 13 show the distribution of grades from 2009 to 2011. Here 1 corresponds to grade A and 6 corresponds to grade F.
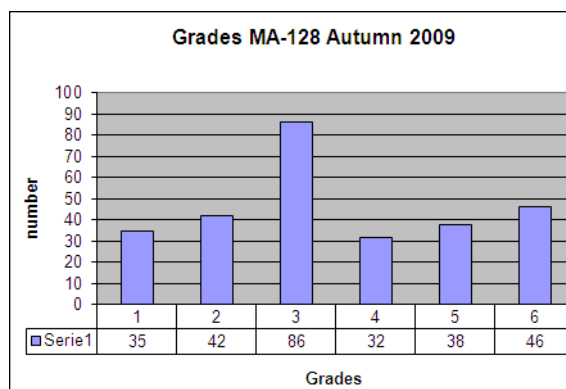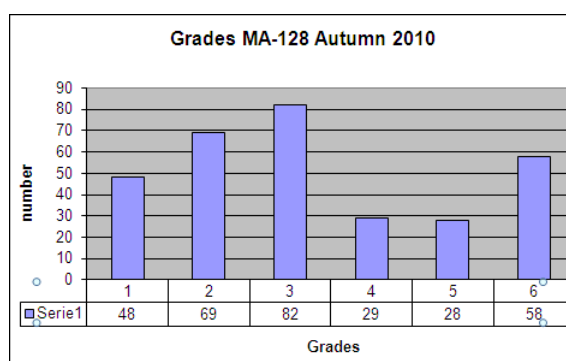

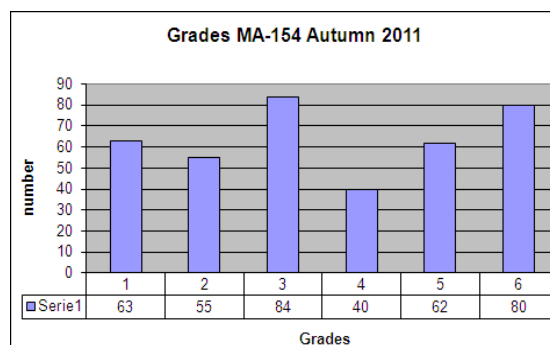Figure 11. Grades autumn 2009

Figure 12. Grades autumn 2010

Figure 13. Grades autumn 2011

This is what we see:

- The percentage of failure F shows a small increase for each year, from 16.5% in 2009, 18.5% in 2010 and up to 20.8% in 2011.
- The share of grade C declines slightly, from 30.8% in 2009, to 26.1% in 2010 and 21.9% in 2011.
- The share of As and Bs increased from 27.6% in 2009, to 37.3% in 2010 and was 30.7% in 2011.

So grades have improved. From 2010 to 2011 about 120 extra students took MA-154. These students are what we call "Y-vei" students. These are student with vocational certificates in areas like carpentry, electronics and maintenance technology. They have only a 6 week pre-course in maths over

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the summer before starting university and the MA-154 course. With this in mind we expected a higher failure percentage 2011 but it was just over 20%. With MyMathLab it is easy to make and approve mandatory tests. With such a large group of students that I have on MA-154, there is no way that I can manage mandatory written submissions throughout the course. The advantage of electronic tests in MyMathLab, where the questions are randomly generated, is that there is no use in one student copying from another, since all students get different questions. This prevents the sharing of answers that used to be common among students. I believe more mandatory tests will improve grades, as the student must put more effort in to it.

4. Conclusions

Results from these two years of testing eExams using MyMathLab have only given positive results so far. The full potential of MyMathLab is still not used or been investigated. Feedback from students is very positive: they say the tool is challenging and exciting. There have been some initial problems regarding registration to MyMathLab and support from Pearson was then needed. I hope to solve this by getting a site license for our Faculty, rather than each student registering themself.

Before implementing the eExam I put up some key points for my students:

- Be prepared, i.e. know your way around MyMathLab.
- Make sure your laptop works, and remember the power cable.
- If your computer breaks down during the exam, there is no time for technical support, so then the ordinary written exams counts.

Results from the eExam taken in November 2010 and December 2011 indicate that everything is in place to implement an eExam for all students on MA-154 in autumn 2012. Some adjustments are required but there are no major problems that are not resolvable. A short summary of testing and solutions are:

- No problems handling a large number of students with their own laptops. If computers break down, students switch to ordinary written exam.
- Allow all aids, both written and digital, on the exam.
- A separate wireless network will hopefully be in place by autumn 2012. This will help prevent communication between students during the exam (via MSN, Skype etc.).
- Some work still has to be done so that grading is correct. This requires extensive work with the development of questions and statements when writing my eExams.

One other aspect that I have not commented on here, but that is of great interest, is the right for students to appeal and complain about their grade. This needs to be discussed in collaboration with the graduation office. I do not think today's exam rules are updated to also fit digital exams.

My experience with MyMathLab has been very positive. Students are happy even though it is in English and not Norwegian (except the questions I have written myself in MyMathLab). There have been very few technical problems throughout and support from Pearson is good. Other positive experiences from users of MyMathLab can be found here [7].

5. References

[1] University of Agder Web address: http://www.uia.no/
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[3] MyMathLab. http://www.MyMathLab.com/global
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