Electronic Exam in Electronics Studies

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INTRODUCTION

In small-scale electronic exams have been used for several years at Tampere University of Technology (TUT). Students are accustomed to using electronic exams,

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for example, for proficiency tests and retakes. More extensive use of electronic exams has, however, failed despite the strong development of information and communication technology (ICT). One reason behind this failure could be the lack of appropriate electronic exam systems that take into account the needs of different users and the various features needed by the different fields. For example, problem solving and analyzing is an integral part of electronics studies, which needs to be taken into consideration when designing and executing electronic exams.

This paper introduces an electronic exam project that has been carried out by the department of Electronics and Communications Engineering at Tampere University of Technology during academic years 2014 – 2015 and 2015 – 2016. In this project the final exam of a pilot course in electronics intermediate studies was implemented with EXAM electronic exam system. In addition, experiences that the participated students had on taking the electronic exam are also introduced. Experiences are based on the feedback that was gathered from the students.

1   ABOUT ELECTRONIC EXAMS AND EXAM SYSTEMS

In general electronic exam refers to the use of electronic means, e.g. computer, when taking an exam. More detailed definition restricts the electronic exam by time and the physical exam space [1]. Thus, an electronic exam can refer both to an exam in a computer classroom or in a common classroom with bring your own devices as well as to online exams and assignments. Another variation of the electronic exam is an exam that takes place using a computer in a restricted network environment in a separate examination room under camera surveillance. This restricts the exam by the physical space but not by the time [1]. As the students today face time-related pressure for their studies from the government and the university as well as from their personal life or from the financial point-of-view, an exam that has not been restricted by the time and/or by the place could make the studies more efficient and help students with their time management. It has been studied that electronic exams can assist in strengthening quality of learning as well as support shorter graduation times [1]. Based on the above discussion the electronic exam in this paper stands for the exam with a computer in a camera-controlled room.

Electronic exams do not generally restrict teachers in the assessment types compared to the traditional pen-and-paper exams. Electronic exam systems can be used for diagnostic, formative, integrative or summative assessments. Effective online formative assessment can even aid student commitment [2]. Regardless of the assessment type an electronic exam is a way to demonstrate student's individual performance. Other commonly used assessment types, such as group work or assignments, cannot necessarily guarantee student's own performance. Furthermore, with an electronic exam in a camera-controlled room the students can be identified more carefully compared to, for example, online exams. This paper focuses on the summative assessment type. The electronic exam of the pilot course is a final exam meaning that it is used to assess student's mastery of the course content.

The heart of electronic exam systems is often the question bank. For courses that use electronic exam for summative assessment it is often desirable that the exam for different students is unique but comparable. This is accomplished with a well-written question bank that contains adequate amount of questions. For courses with a large number of students the question bank can thus be quite extensive. It is recognized that initially setting up a well-written question bank can be time-consuming and enough time from the teacher's point of view needs to be reserved for the introduction of electronic exams so that the lack of time will not hinder the adoption of electronic

exams [3, 4]. On the other hand, electronic exam systems enable teachers to use automatic evaluation and it is possible for teachers to share exam questions. Both of these help teachers to save time [3].

2 ELECTRONIC EXAM PROJECT IN ELECTRONICS STUDIES

The electronic exam project introduced in this paper consisted of two separate implementations of the same electronics course. The course consisted of lectures, exercises, assignment and the final electronic exam. During the academic year 2014 – 2015 implementation 39 electronic exams were completed and during 2015 – 2016 37 exams were completed.

2.1 EXAM electronic exam system

The electronic exam was realized using EXAM electronic exam system, which has been developed in cooperation with Finnish universities and universities of applied sciences. At Tampere University of Technology the EXAM system was piloted for the first time in autumn 2014 as a part of this project. At the same time with this project a wider EXAM project took place at TUT. This project consisted of deployment of the exam software, building the camera-controlled exam rooms and creating the process to supervise the students.

The electronic exam in the EXAM system was created on the basis of a question bank that consisted of four categories each of which included 3 - 8 different questions. The categories were selected on the basis of the core content of the course. The questions in turn consisted of essay questions, short open-ended questions and mathematical problems. The exam system drew one question of each of the four categories which constituted the student's exam. The questions inside one category were all comparable. Thus, all students received a unique but comparable exam. As anticipated from the earlier discussion creating the question bank was the most time-consuming part of the creation of the electronic exam from teacher's point-of-view. Creating 3 – 8 different but comparable questions inside each category was challenging and it took time. The names of the four exam categories were visible to students before and during the exam, so students were aware of the way their exam was created. The EXAM system itself does not restrict the number of categories nor does it restrict the number of questions inside one category. Given the core content of the pilot course and the number of students in the course four categories with 3 – 8 different questions each were decided to be sufficient. One category was reserved for mathematical problems so that all students received a problem that was an essential part of the course. Other categories included minor mathematical problems as well so the total number of problems in one exam varied. Although criteria for evaluating the exam questions were planned in conjunction with the question bank, the challenge of comparable questions emerged when evaluating students' exams as students did not always understand or answer the questions as expected - Some answers were insufficient in accordance with the planned criteria. One solution to address this challenge could be to create one core problem with varying parameters. For example, during the second implementation of the pilot course in one question all students received a table that included information of typical properties for printed circuit board laminate materials. The students needed to select the most suitable material for a given application. There were four different application possibilities and the EXAM system raffled an application for each student. This turned out to be a functional approach. This same approach can be used with mathematical problems as well.

When the exam was published for students in the EXAM system, they registered for the exam by selecting suitable time and the exam room from the reservation calendar.

The system then raffled the exact computer in the selected exam room, with which the exam was to be performed. The students were thus not allowed to for example select the exact same exam time with adjacent computers. After registration the exam system confirmed the selected exam time and place as well as informed about the raffled computer.

2.2 Electronic exam arrangements

The exam was arranged in a camera-controlled exam room, where the students were able to enter with their student cards. The exam time was two hours and fifty minutes and the students were allowed to use various software, such as MATLAB and Paint.NET, along with computer's calculator when completing the exam. Computer resources for the exam, i.e. the various software that the students are allowed to use during the exam, are one of the most essential aspects when building the exam rooms. In addition, during the first implementation the students were offered the possibility to use pen and paper as an aid in, for example drafting calculations or structuring essay answers. The pen and papers were provided in the exam room and the students were not allowed to bring their own nor were they allowed to take them along. On the second implementation the pen and paper were replaced with the possibility to use graphics tablet in the exam.

3 RESULTS

Feedback of the experiences on taking the electronic exam was gathered from the participated students with online feedback system. The questionnaire consisted of multiple choice and open questions. During both academic years 35 students gave feedback and these results will be discussed in the following chapters. It should be noted that it was also possible for the student not to answer a question and due to this the number of answers in the following charts does not necessarily add up to 35.

3.1 General arrangements

As the EXAM system and the process for electronic exams were piloted for the first time during the academic year 2014 – 2015 the students were asked for opinion on the general arrangements of the electronic exam. The general arrangements included for example function of registration to the exam, function of the exam room, the computer, the EXAM system and the exam evaluation. As can be seen in *Fig. 1* majority of the students, that is 27 out of 32, during the academic year 2014 – 2015, agreed or totally agreed that the arrangements of electronic exam functioned well. Being a pilot project the process and the EXAM system was carefully introduced to the students before the final exam and the students had a possibility to perform a test exam in order to practise the process and the EXAM system. As *Fig.* 2 indicates the results regarding the arrangements have not changed significantly during the academic year 2015 – 2016. Electronic exams have become more common and thus students are now more familiar with them and the general process. Furthermore, the possibility to perform the test exam is ongoing.
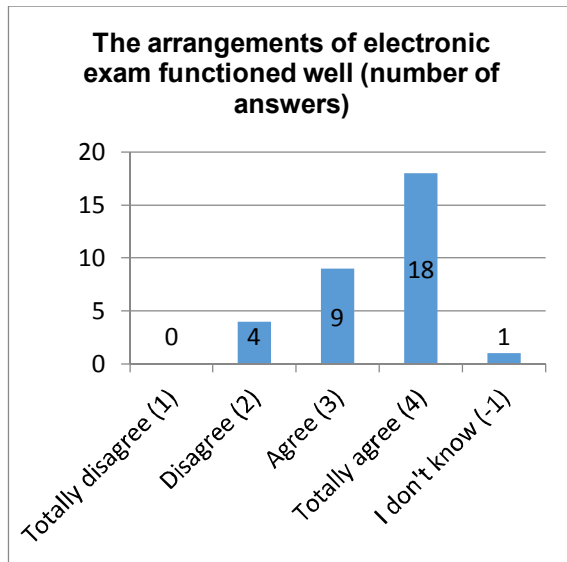
The arrangements of electronic exam functioned well (number of answers)

Fig. 1. Academic year 2014-2015

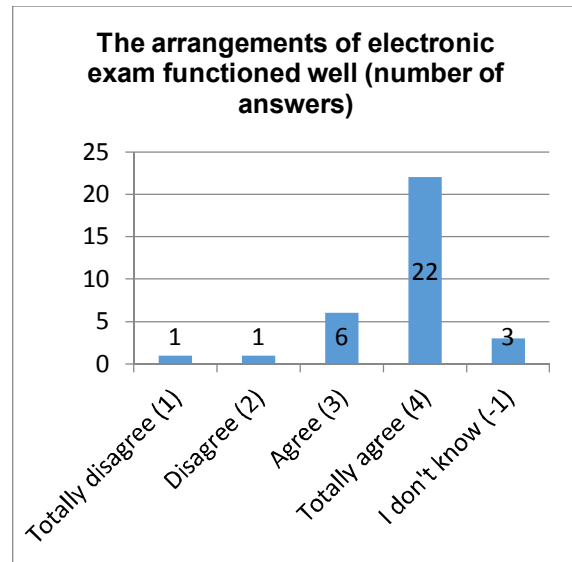**The arrangements of electronic exam functioned well (number of answers)**

Fig. 2. Academic year 2015-2016

The fact that students were able to choose their exam time meant more flexibility to the schedules of students as can be seen in *Fig. 3* and *Fig. 4*. These results support the discussion in Chapter 1. With the possibility to choose the exam time overlapping of exams is avoided and students have more time to prepare for exams. This can in the long run result in shorter graduation times and additionally be a factor in increasing the quality of learning.
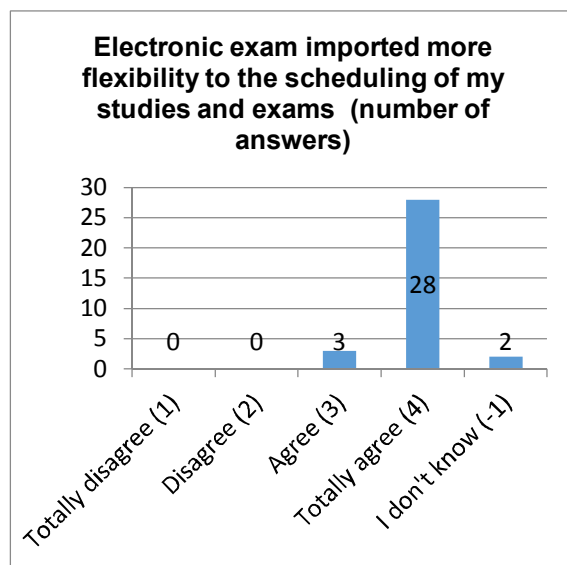
Electronic exam imported more flexibility to the scheduling of my studies and exams (number of answers)

Fig. 3. Academic year 2014-2015

Electronic exam imported more flexibility to the scheduling of my studies and exams (number of answers)
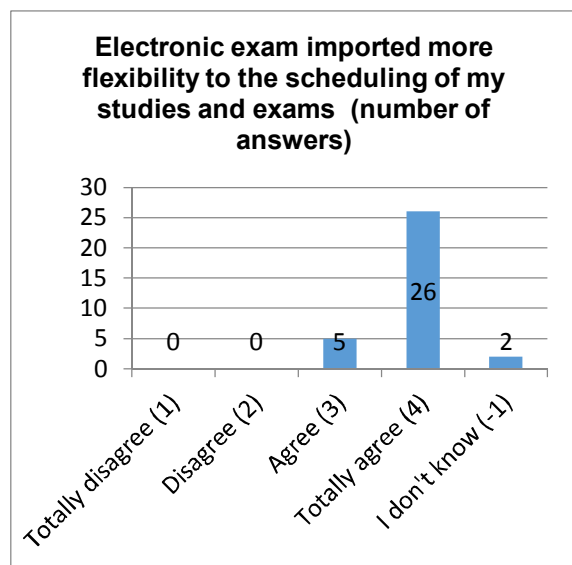
Fig. 4. Academic year 2015-2016

3.2 Question bank

As stated earlier a high-quality question bank is an essential part of electronic exams. However, building one can be challenging and time consuming. *Fig. 5* and *Fig. 6* indicate experiences the students had on the content of the exam and its relevance to the core content of the course. Although every student received a unique exam, the majority of the students agreed or totally agreed that the questions in the electronic exam evaluated the issues they had learned during the course. From this point of view the question bank seemed to be successful in both academic years.
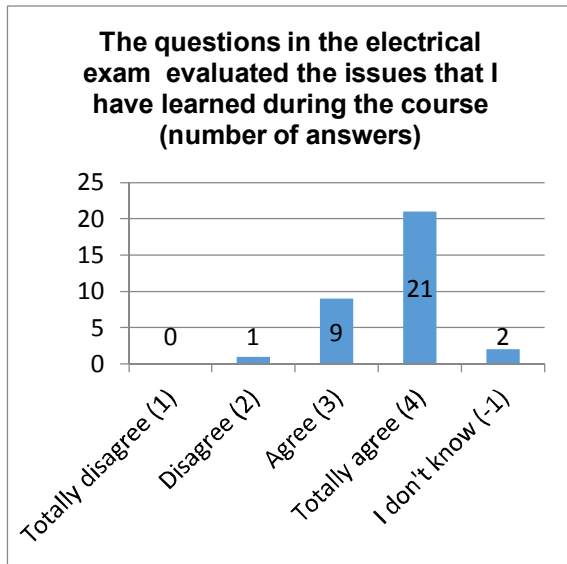
The questions in the electrical exam evaluated the issues that I have learned during the course (number of answers)

25
20
15
10
5
0

0 — Totally disagree (1)
1 — Disagree (2)
9 — Agree (3)
21 — Totally agree (4)
2 — I don't know (-1)

Fig. 5. Academic year 2014-2015

The questions in the electrical exam evaluated the issues that I have learned during the course (number of answers)

25
20
15
10
5
0

0 — Totally disagree (1)
1 — Disagree (2)
6 — Agree (3)
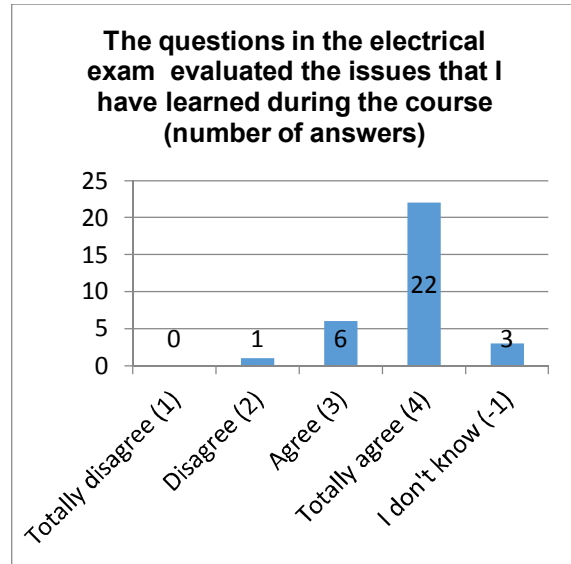22 — Totally agree (4)
3 — I don't know (-1)

Fig. 6. Academic year 2015-2016

3.3 Mathematical problems

When students were asked about their experiences on using a computer to answer the questions in the electronic exam, the answers varied more than with the previous questions. During the academic year 2014 – 2015 10 students and during the academic year 2015 – 2016 13 students disagreed or totally disagreed with the statement that using a computer to answer the questions in the electronic exam was convenient as *Fig. 7* and *Fig. 8* indicate.
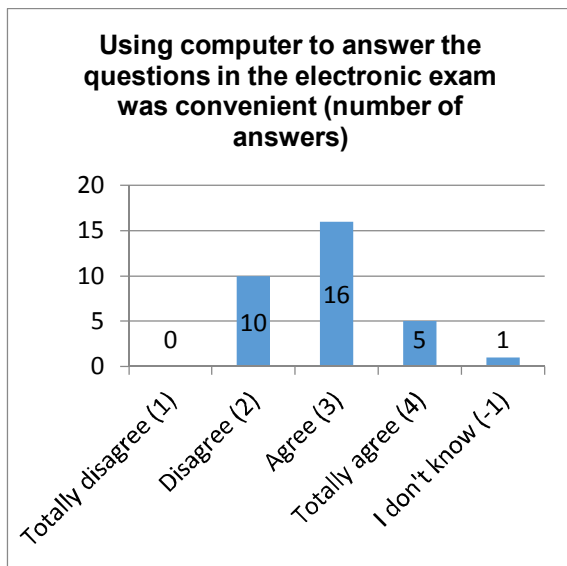
Using computer to answer the questions in the electronic exam was convenient (number of answers)

20
15
10
5
0

0 — Totally disagree (1)
10 — Disagree (2)
16 — Agree (3)
5 — Totally agree (4)
1 — I don't know (-1)

Fig. 7. Academic year 2014-2015

Using computer to answer the questions in the electronic exam was convenient (number of answers)

14
12
10
8
6
4
2
0

2 — Totally disagree (1)
11 — Disagree (2)
12 — Agree (3)
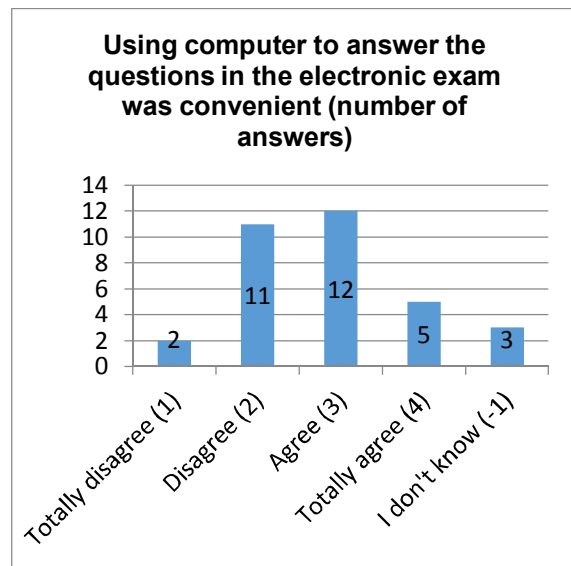5 — Totally agree (4)
3 — I don't know (-1)

Fig. 8. Academic year 2015-2016

These results reflect the challenges of incorporating mathematical calculations and problem solving into electronic exam systems. The user interface of the EXAM system did not support mathematical equation writing sufficiently enough and the computer's calculator was considered unpleasant as the following quotations from the open ended questions regarding the positive and negative sides of the electronic exam indicate:

"The calculator should be better and producing calculations should be easier"
"It's really slow and hard to make calculations (even with the graphics tablet)."
"I prefer pen and paper exam, because for example producing problems is painful with the equation editor of the EXAM software."

"The weakness of the exam was that one could only use window's own calculator, which is really hard to use compared to one's own calculator. I often ended up calculating problems in Excel, which cost extra time, when the windows calculator did not cooperate."

The challenges of mathematical calculations and problems were known before the project so students were allowed to use a pen and paper during the academic year 2014 – 2015 implementation. With the pen and paper the students could, for example, draft calculations. In many courses at TUT a pen and paper along with a calculator is still the most common way to solve problems. The majority of the students considered the pen and paper helpful as the *Fig. 9* shows. Furthermore, some of the students considered the pen and paper to be an essential part of problem solving as the following quotations from the open ended questions indicate:

"The use of a pen and paper was really good, because it could be deftly used to draft thermal calculations and FTY assignment. Without the pen and paper one could have made more mistakes"
"The pen and paper was absolutely necessary in an exam with calculations."

It should be, however, noted that many students seemed to first calculate the problems on the paper and then transfer this answer to the EXAM system. This naturally took time.
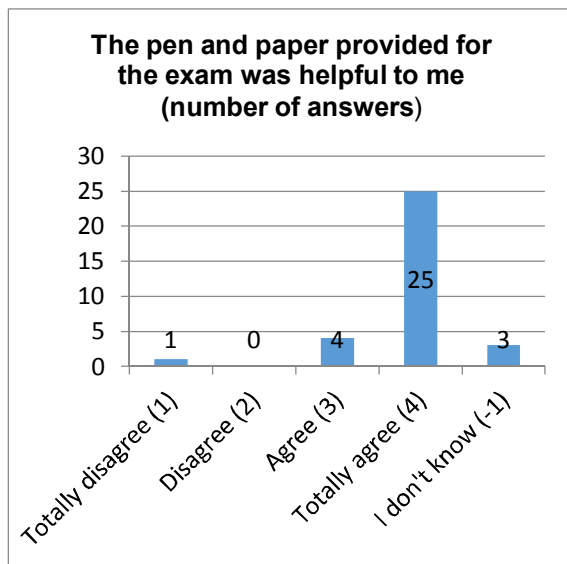

The pen and paper provided for the exam was helpful to me (number of answers)

Fig. 9 Academic year 2014-2015

The pen and paper practice is not considered to be a part of the electronic exam process so it was not offered anymore during the academic year 2015 – 2016. Still, keeping in mind the challenges of problem solving on the EXAM system the students were offered the possibility to use graphics tablet in the exam during the academic year 2015 – 2016. The graphics tablet was introduced to the students a few times during the course, but still it was not widely used in the exam nor was it found to be useful or a good replacement to a pen and paper as the following quotations from students' feedback regarding the graphics tablet show:

"I didn't use [the graphics tablet]. The graphics tablet would have been okay if one used one anyway in daily life. For the exam of one course the motivation was not high enough to learn to use one conveniently.
"I didn't use [the graphics tablet]. In general I think that the use of the graphics tablet is too difficult to be used in an exam and I wouldn't want to learn how to use it just for one exam."

"I used [the graphics tablet] and I didn't find it useful at all. Writing equations to the MS paint is as clumsy as using a mouse. I missed a pen and paper – at least if the exam were to be slightly more mathematical."

As the above quotations show learning how to use graphics tablets for the first and only time during the final exam is not efficient and thus not recommended. To avoid this graphics tablets should be used as a learning device more intensively during courses.

One more interesting point was revealed when examining the feedback regarding the positive and negative sides of the electronic exam. Students, who used MATLAB software for problem solving, considered the software helpful when solving the problems. This is illustrated in the following quotations:

"The use of Matlab helped calculating long expressions."
"I liked especially that Matlab could be used in the exam. It is much more meaningful to calculate with Matlab than with one's own calculator. Symbolic calculation makes problems really easy."

These experiences support the fact that the possibility to use various software is one of the advantages of electronic exams compared to the pen-and-paper exams [5].

3.4 Other experiences

Another advantage of the electronic exam compared to the pen-and-paper exam arises with the essay answers. With a computer the answering is pleasant and quick, and the computer enables more structured essay answers than pen and paper due to computers' text editing options. The following quotations from the students' feedback regarding the pros and cons of electronic exam confirm this:

"Writing answers with a computer was clearly faster and more pleasant than by hand."
"Writing was faster than with a pen and paper."
"The strength of electronic exam is in answering written questions. Structuring, editing etc. of text is easy."

Overall the experiences of students of the electronic exam and the exam process were positive. The majority of the students in the academic year 2014 – 2015 were willing to take electronic exams on other courses as well (see *Fig.* 10). *Fig.* 11 shows the results for the academic year 2015 – 2016. The results varied more than the previous year, but still more than a half of the students agreed or totally agreed with the given statement. This is a good basis to continue developing the EXAM system and electronic exams at Tampere University of Technology.
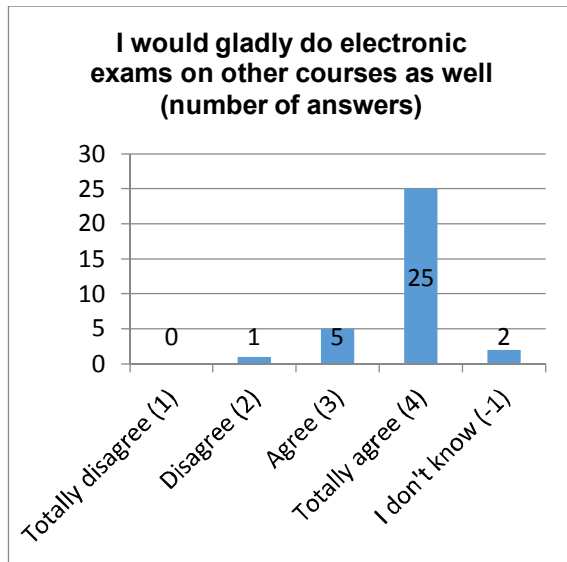
I would gladly do electronic exams on other courses as well (number of answers)

Fig. 10. Academic year 2014-2015

I would gladly do electronic exams on other courses as well (number of answers)
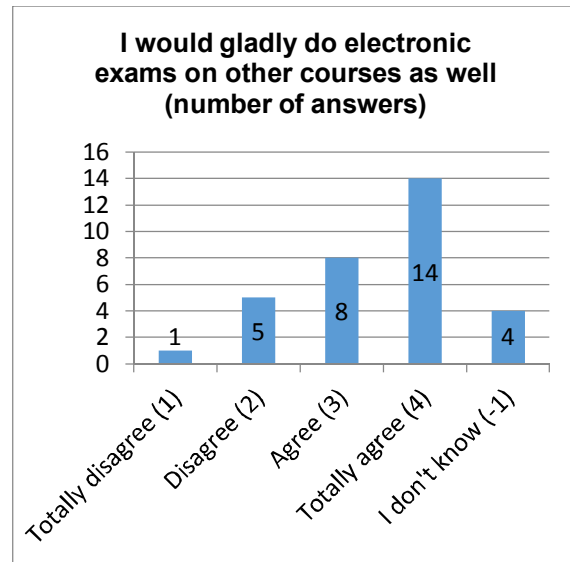
Fig. 11. Academic year 2015-2016

4 SUMMARY

Electronic exams will become more common the following years as new students studying in universities are more and more used to digital devices. In addition, the matriculation examination, including mathematics and physics, in Finnish high schools will be digitalized by 2019 [6]. Students' working methods as well as the teaching will thus be digitalized, which will directly create expectations of and requirements for teaching and exams in universities. The results of the project introduced in this paper support the fact that the use of software as part of an exam as well as flexibility of scheduling are some of the key advantages of electronic exams. However, in electronics studies mathematical problem solving is an integral part of studies, and as the results indicate the EXAM electronic exam system has not been able to meet these demands as satisfyingly as hoped. Most suitable and often desirable electronic exams are in the fields of testing computer-based skills, for example programming, as they allow more realistic assessment technique compared to the pen-and-paper exams [7]. From electronics point of view more development of electronic exam systems and more research on the adequate integration of problems to the exam systems are needed.

This paper concentrated on the experiences of electronic exam and the EXAM system based on students' feedback. As the EXAM system also records various type of data, such as points of each question, exam duration, time period when student performed the exam and previous exam attempts, other types of analyses are also possible. In future it would be interesting to study, for example, the correlation between exam duration and grade or to build the exam from successive step so student's learning could be analyzed in more detail.

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