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Study of the Effects of Non-Traditional Examination Methods in the Engineering Education Programmes

Abstract

The way in which we assess our students influences to a large extent what and how they study, and the outcomes of their learning. Thus our choice of assessment methods can be a strong tool for influencing our students' study strategies and, as a consequence, the quality of their education.

In this project we will develop and evaluate non-traditional assessment methods within the Engineering Physics programme. Our goal is that these methods should improve students' learning, encourage good study strategies and affect motivation. We intend to show that these goals are fulfilled, i.e. that the methods are, and not only seem to be, good assessment methods.

We want to answer the following questions:

- how do these non-traditional examination methods affect students' learning with regard to what they learn (e.g. their understanding of central concepts and to what degree this corresponds to relevant knowledge within the field), how they approach their studies (e.g. how they work with the course material and how they recognize their work) and the connection between these issues.
- how can these non-traditional methods be further developed in the light of the new insights and still stay within the budget frames.

An important constraint in this project is that these non-traditional methods should not increase the workload of either students or teachers. Another important constraint is that these methods do not necessitate changes in the infrastructure of the educational programme, for example, in number of courses, number of students, physical layout of buildings etc. It is important that the investigation should give results that are relevant for fields of study other than engineering physics, like computer science, information technology and electronics.

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Study of the Effects of Non-Traditional Examination Methods in Engineering Education Programmes

Final report

Examinationsformer som ett sätt att förändra studievanor
Project number 170/96

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1. Assessment methods as a tool to change students' study habits

How do our students go about to studying? What do they study? And how much? Certainly, it is not possible to give exact answers to such questions, although much research on learning in higher education focuses on these issues. However, research has shown that assessment is a key factor in understanding, and influencing, students' learning. As teachers in higher education, we are well aware of this and can confirm such results: Our students frequently ask questions concerning the exam, and what kind of questions (or tasks) that can be expected on the exam.

With the important role that the assessment play both in study situation and in the life of our students, we assume that a good way to influence, and hopefully improve, the students study strategies is by changing the assessment methods. In this way would not only a better learning outcome be achieved, but we would also enhance our repertoire of assessment methods within the department - and thus within the subject area. In addition, assessment and assessment methods would become on the agenda in the life of the department and we would gain new insights concerning our students' learning and learning strategies and thereby ourselves become better at understanding and performing "good" teaching and assessment.

With these intents the project "EXPRESSO - Study of the Effects of Non-Traditional Examination Methods in Engineering Education Programmes" was performed 1997 - 2000. In the Expresso project the assessment forms, and as a consequence the teaching forms were changed during one study period (approx 10 weeks) for all courses for third year students in the engineering physics program (teknisk fysik).

The ultimate aim of the project was to improve the learning outcome. As teachers, we felt troubled by the frequent questions concerning the exams posed by the students. As we understood, the students, on the other hand, were concerned about finding ways to handle their demanding and complex learning situations with heavy workloads. Later, we have realized that much of the current research into assessment, study strategies and motivation indicates that many (or possibly most students) formulate their goals with a certain course in terms of the requirements stated by the institutions. In particular by the assessment criteria are important for the students, where the written, individual exams have a leading position within the institutions (at least in engineering and computer science - the two topic areas discussed here). Fewer students formulate their intents in the form of learning objectives within the subject area, or as a personal development.

The need for a review and renewal of assessment methods is well documented in Swedish studies performed with engineering students. For example, Jacobsson (1995) points out that students in an Engineering Physics programme tend to study intensively before an examination. Trowald (1996) discusses several undesirable effects of today's assessment methods. Hult (1998) argues that we need a debate about assessment in Engineering education and points to the value of a rich flora of assessment forms. It would be unfortunate if the students met "more or less the same tasks throughout a complete educational program" (my translation). Booth (1992) shows that the correlation between the students' actual understanding of fundamental concepts and the grades they receive is not as strong as we, as lecturers, would like.

With the leading role of assessment in the students' choice of a study strategy, we were convinced that changes in the assessment methods would be an effective way to influence the

students' study habits[1], and thereby indirectly, the learning outcome (see Figure 1). A key concern in this project has been to study the changes in the students' study habits as they have been experienced by and reported by the students. That is, we have studied the outcome of our work, through the eyes of the students, where a key issue has been to improve their experienced learning situation and their learning strategies. This has been done with the explicit intent of reaching our real aim, to improve learning, in the indirect way that is shown in Figure 1.

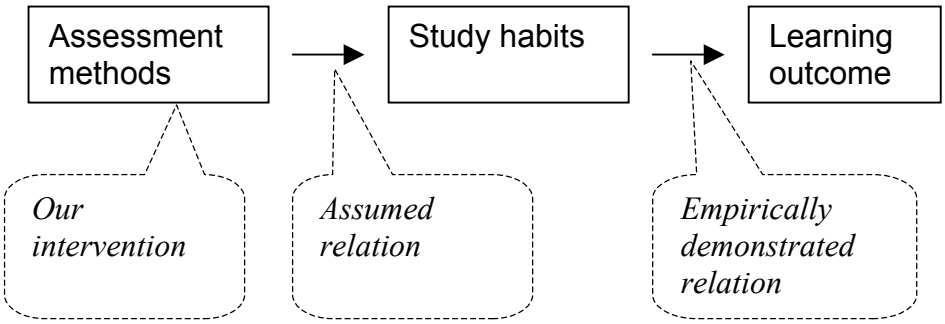

Figure 1. Relation between assessment, study habits and learning outcome

2. Related projects aiming to improve assessment and study strategies

Some practical studies where alternative assessment methods have been developed, used and evaluated have been performed in Sweden in mathematics and computer science. A study concerning new assessment methods, aiming at stimulating creativity and encourage better communication skills have been performed in Växjö Högskola, by Hedenborg and Tengstrand (1997). Martinsson at Institutionen för matematik at Chalmers draws the conclusion that changes in assessment must be followed by changes in the teaching methods to lead to desirable changes. At D++, an initiative at Chalmers University of Technology, aiming at making computer science and engineering education more women friendly (Wistedt, 1998), several relevant studies are performed.

Some studies have also been performed in Sweden concerning how students use their time. Stawström et al (1996) argue, based on their empirical work, that the total time spent on studying, including home work, is approximately 40 hours a week for engineering students. A similar result is obtained by Hedenborg and Tengstrand (1997) for students in mathematics and computer science. The authors clearly state that the students perceive their studies as time consuming and demanding. Scheja (1997) points out that the students experience time pressure, and have difficulties in prioritizing within and between different subject areas. This can, he says, lead to sub-optimized prioritizing, and an experience of a low understanding of

[1] By the expression "study habit" we refer to the "strategic" questioning concerning how students study. Questions like when they study, if they work alone or in groups, their priorities between reading and solving problems are important for this approach. More "technical" or "detailed" questions, like how to underline, the advantage or disadvantage of listening to music while studying etc are not discussed.

the subject area. Similar conclusions are drawn in a study performed with computer science students at Uppsala University, by Sandström and Daniels (2000).

3. The view of learning in this project

Results from the phenomenographic research tradition have played an important role in this project. Berglund (2004) describes phenomenography in the following way:

> Phenomenography offers the possibility to investigate issues related to the students' varying experience of their learning and learning situations. With its study object being the relationship between a learner and a phenomenon, the outcome becomes a description of this relationship as a limited set of qualitatively different ways in which the phenomena are experienced, or understood, by some learners. Variation is in focus in phenomenography; the individuals are "carriers" of different ways of experiencing something or of fragments of a collective way of experiencing it. The results are then to be interpreted at a collective level, without relating a particular way of understanding something to a specific individual or groups of individuals.

A fundamental result in phenomenographic research about learning is that there is a distinction between deep and surface approaches to learning (Marton & Booth, 1997). Jonston (1995) describes the two approaches in the following way:

> Students who use a deep approach are personally involved in the task and seek to obtain some underlying meaning. In addition they aim to understand relationships between the immediate task and other tasks or contexts. Such students are likely to read extensively around a given topic, to discuss the topic and ultimately to achieve higher grades on assessment tasks than students who use a surface approach [...].
> A surface approach to learning on the other hand arises when the student sees learning as a means to achieve an end. [...] Students who adopt this approach are motivated by an extrinsic objective and they will commit unrelated facts to their short term memory but are unlikely to be able to establish meaning or relationships between or within given tasks.

Empirical results clearly indicate that this difference in study approaches results in a difference in the learning outcome. Students with a deep approach to learning show a better understanding. Since students frequently shift between deep and surface learning - that is, the approaches are not tied to individuals, but rather developed in a context - higher education should stimulate deep approaches to learning.

Pask (1976) and Laurillard (1984) have studied students' problem solving strategies and have identified two approaches to learning through problems solving: "operational learning", focusing on the application of rules and procedures, and "comprehension learning", focusing on the meaning of the concepts that are present in the task. In subject areas such as computer science and technology both these approaches are desirable, since a student has to apply rules (for example syntax rules in a programming language) and discuss and apply the meaning of the concepts that are reflected in the language.

In short, these results indicate that a deep learning approach, paired with both operational and comprehension learning are desirable. Thus, the changes in assessment performed in this project aim to effect for such changes in study approaches.

The results of a change of assessment methods, makes the outcome of the assessment, the grade, impossible to use as a measurement of changes in the learning outcome. It would be impossible to judge if a higher grade was the result of better learning or the result of different mechanisms deployed to judge the learning. Instead, the evaluation is based on interviews performed with the students. In these interviews, both concepts from the course contents and issues concerning the study strategies have been discussed. The interviews have been inspired by phenomenography in the sense that they have been semi-structured, and aim to reveal the students' own understandings and experiences.

4. The students

The project has been performed in the third year of the Master Programme in Engineering Physics, specialization towards system technology at Uppsala University. The academic year is, at the school of Engineering, split into four study periods, each of which encompasses 10 weeks.

During this study period, the students took the following courses: Algorithms and Data Structures, Computer Architecture and Signals and Systems. The course load corresponds to full-time studies. That is, the project concerned changes of the full study situation for the students during this study period. Approximately sixty students attended the courses.

The students who took the courses can be regarded as experienced students, having studied at the programme for at least two and a half years. The engineering physics programme is judged as tough and demanding by the students, and the drop-out rate during the first years is high. All students, who took part in the project, are consequently "good students", in that they have adapted to the educational system, and have shown more or less good results. These students, of course, had a rich experience of assessment in earlier courses, and expectations of what it "meant to be a student in Engineering Physics" and how courses were conducted and assessed. When the assessment methods were changed in these courses, their previous experience of "what a student should do" lost some of its value. "To take exams" was in these courses a less important skill, than the students previously had been used to.

5. The changes in assessment

Different assessment methods were used in each of the three courses, since we wanted to

- adapt the assessment methods to the different characters of the different courses,
- encourage different study approaches among the students,
- give options those students, who normally do not do well in written final exam, by offering a repertoire of different assessment methods.
- increase our experience of different assessment methods, as well as letting the students get familiar with other methods than the classic final exam.

The assessment methods chosen were based on a pilot study (Berglund et al, 1996). The changes were:

Algorithms and Data Structures

The final exam was replaced by weekly assignments, each assignment consisting of a small set of programming or design problems. These were corrected in a simplified way, in order to save working time for the teachers. The results on these assignments, that came to mirror the

number of assignments handed in, as well as the quality of the solutions to the assignments, gave the grade. In order to offer fast feed-back, the assignments were discussed in the lecture on the day they were handed in. The course also had larger, loosely defined programming projects.

With these changes we strived to encourage the students to work continuously during the course. While the weekly assignments aimed to stimulate "operational learning" as defined above, the larger assignments were intended to promote "comprehension learning".

Computer Architecture

The final exam was replaced in part by public seminars, organized as mini-dissertations with public opposition and defense on programming projects. The seminars lasted for 15 minutes each, and focused on the "good" aspects of the different solutions, in order to expose the students to different good programming solutions.

The theoretical components of the course content were assessed in a written exam, which was designed to place emphasis on the capacity to analyze, synthesize and judge, that is, on the higher level of Bloom's taxonomy (Bloom, 1956).

During the some lectures, the students were encouraged to volunteer to present solutions to small programming assignments on the black-board. The solutions presented were then discussed in the class.

With these changes we strived to assess at the higher level in the Bloom hierarchy and to train the students to present and discuss issues in computer architecture. We also assume that the discussions would promote a deep approach to learning, and in this way a better learning outcome.

Signals and Systems

The final exam had reformulated questions designed to reflect the higher level in Bloom's taxonomy. The teaching was changed to be more interactive, with the lecturer encouraging a debate by asking questions.

6. Results

In the light of these changes, the following issues seemed relevant to explore:

- Have the students understood the core concepts in the course?
- In what way have their study habits changed?

Since the evaluation of students' performance sets the grade of the students, a comparison of grades would only give a weak indication of how the alternative assessment methods could have influenced learning. Other factors, like for example "how difficult the exam is" would probably have an influence that is at least as important on the results.

Instead, we interviewed ten selected students at intervals during the study period about their understanding of core concepts of the subjects concerned, their experience of learning during these courses compared to their previous study experiences, their study habits, and other factors that influenced their learning.

With this design, the students' experience came to create the core of the evaluation result of the project, since the value of the changes was analyzed from the students' perspective. In the sub-sections below some conclusions are presented.

a) Study habits

Order between exams

As expected, the assessment is an important factor for the students' selection of a study strategy. Not only the exams and their "expected difficulty", but also issues as when the exam appears, and in what order in relation to other exams are important issues. Virtually all students study, more or less, by solving questions on exams from previous years.

Relevance of grade

A majority of the students aims for the highest possible grade. This is also true for those who state that their main concern is to understand the subject. A relatively large group of the students are content with a passing grade.

Factors influencing priority between different tasks

The students' priorities between different assignments are to a large extent determined by the dead-lines on the assignments that are set by the teachers. Many students work with the assignment having the nearest dead-line, even if this prevents them from achieving a good result in later, more important and more time-consuming tasks. The preferences and opinions of the study partner and his or her priorities are also a key issue for prioritizing between different tasks. Also the attitudes of the teachers, as well as previous experiences of collaborating manifest themselves as relevant issues in the students' decisions.

The study thus clearly indicates, that the students' decisions are taken on a complex and varied ground, where the grade is one factor among many. Particularly, we want to stress the importance of the dead-lines, and interaction of dead-lines between different courses. To us as teachers, this seems to be an undervalued factor in our planning of the courses. This indicates that we have a stronger tool to influence learning by a conscious use of dead-lines than we are aware of. As the students are studying in one study environment, consisting of several courses (among other issues), dead-lines interfere over courses. Thus decisions taken by one teacher in one course can have a major influence on other courses.

Students liked the new assessment methods

The students liked the changes and our efforts. However, we cannot judge to what extent the changes themselves, the fact that we made changes, or just simply the attention we showed to their experiences are the reasons for these opinions.

Aspects on the work-load

Clearly the introduction of these new assessment methods has increased the work-load both for students and teachers. The increased work-load for the students is mirrored (as will be discussed in the next section) in a better learning outcome. At the time when the project was run, we could not judge if the increased work-load for the teachers was due to the fact that we made changes (that is, a price for the transition), or a result of the new assessment methods. Subsequent experience has shown that the assessment methods themselves (with the exception of the weekly assignments used in Algorithms and Data Structures) do not increase the work-load for staff. On the contrary, the seminars rather decrease the time spent on the tedious task of correcting projects.

We have also come to realize that much of the effort we put into the assessment in this project was due to the fact that we completely changed the whole assessment process during the study period. Neither we, nor the students could build on previous experiences. If instead, as we have done later, the assessment methods were used as a complement to more normal ways of teaching and assessing a course, the work-load decreases considerably

The selection of a study partner
Most students reported that they normally studied (read literature, made assignments etc) in pairs. Data clearly shows that the selection of a study partner is important. Several factors that influence and determine this selection have been discerned in the study. In general, our study indicates that the students search for a partner who "resembles" themselves, or can "complement" a weak point. The factors that we have identified that influence the selection of a study partner are:

- Friend. You have to get on well with your study partner, share a sense of humour and some interests. He or she must be "en god kompis".
- Diligence. Many students search a study partner who is more ambitious or hard-working than themselves, in order to get stimulated, or pushed, to work harder. However, it is not uncommon with students seeking someone who is less ambitious, as a help to keep a mental distance to the studies.
- Intellectual capacity. Preferences have been identified both for an intellectually stronger partner (so that the student should learn from his or her partner) and for an intellectually weaker partner (so that the student needs to explain, and learn through that dialogue), as well as for a partner on equal intellectual grounds. However, the differences discusses by the students are minor; virtually all students collaborate with a partner within the same range as himself or herself.
- Habit. That you "know each other" and that you have worked together during earlier courses are other important criteria for the selection of a study partner.

A conclusion is that is important that the students "get to know each other" from an early stage, so that they can find good partners to collaborate with in the future. The students own initiatives to study in pairs shall not be confused with teams of groups that are sometimes created by the institutions for particular assignments or courses. While the first form of collaboration aims at handling everyday learning in informal situations, the latter aims at training the students to work with different individuals, that is, it aims at promoting social skill useful in a working situation.

The joy of understanding
Most students express that they feel an enjoyment or satisfaction in understanding the concepts taught in the course and to understand the relation between theory and practice. Even insights gained during an exam can offer the same feeling of contentment. Only a small minority of the students express that these feelings are important enough on their own to motivate them to take a course.

The "pace of studying"
Some students, mainly those who adapt a deep learning approach to their studies, reported that weekly assignments broke up, or interrupted, their pace of study. The assignments then made them prioritize in a new way, less suitable for their learning aims. This insight points towards that the outcome sought for by the introduction of the new assessment methods is damaged for a sub-set of the participants. However, since we wanted to add some new assessment methods the methods already deployed, instead of totally replacing the "old" methods within the department, this is an acceptable sub-result. As was pointed out above, a variation of methods stimulate a larger group of students.

The role of lectures
A majority of the students reported that they experienced the lectures as an important component of the teaching. They used terms or phrases as such "organize the studies", "lectures offer a thread", "important ideas" and "overviews" when discussing what the lectures meant to them. Only in some very rare cases lectures were presented as a passive way of learning. Some students also pointed out that the lectures did not need to describe the full course content, it was, and they said enough if the skeleton was given. This way of experiencing lectures, as an active way of learning, differs from that which is commonplace in much current literature.

Seeing the study situation as a whole
The students stressed throughout the interviews, that the issues of assessment, workload and dead-lines must be seen over all courses the students take in parallel. Questions such as "What would have happened if all courses had weekly assignments?" have been discussed.

b) Observations concerning the learning outcome

The data collected during the interviews, indicate that the students had an understanding of the material studied that at least corresponded to the "normal" level. We base this conclusion both on questions asked concerning specific concepts, which were elements of the course content, and from questions which prompted the students to judge their own understanding in relation to their expectations. In fact, we have reason to assume that the understanding of basic concepts was slightly better than would have been expected. However, this corresponds to the fact that the students had invested more time than normal on the courses, and possibly even to the fact that we made a change (the Hawthorne effect) and that we showed our interest in their learning.

The students reported a progressive development in their understanding during the course, an observation that was confirmed through those questions in the interviews that investigated the students' understanding of the course content

The students frequently referred to examples from the lectures in the explanations given during the interviews. Often their interpretations of the examples were incorrect, particularly when a concept was recently introduced in the course. At later interviews, when these concepts again were brought up by the interviewer, many students showed a deeper understanding, now using the examples in a scientifically correct way.

Of course, we cannot neglect the fact that interviews themselves influenced the learning. Firstly, the interview occasions also served as learning occasions. Secondly, students reported having discussed the interview topics, and even having tried to predict coming topics.

c) Open issues

The discussions with the students during interviews have raised several new questions:

- What is a good "lab"? It may neither be too "hard" or too "simple", and should illustrate important concepts.
- What is a good lecture? As is indicated above, the lectures are important for the students' experience of learning, so the issue of lectures deserves attention.
- How do we encourage the students to plan well and to follow their plans?
- The order of "dead-lines" between the assignments given in the courses has been identified as a key issue in understanding how the students plan their studies. How should this observation be deployed in everyday teaching?

- The possibility to retake exams, or to take an exam at a later moment, is a way for the students to influence their own study situation. This issue deserves a further attention.

7. Remaining influences

The courses were given in a similar way to that which has been presented here for three years. With the changes of staff at the courses, and more importantly, the reorganization of the Engineering Physics Programme, removing the system technology specialization and some of these courses, the platform for this particular study was removed.

Still, the experiences gained have influenced education in the department in several ways. Most probably, thanks to the visibility of the project, teachers at other universities have learned form our experiences.

Remaining influences can be traced in the following:

- The issue of assessment is still on the agenda of the department, and the atmosphere has changed towards an open attitude to alternative assessment methods. The discussions have also changed in the way that they now to a larger extent than before are built on theories of learning and empirical evidence.
- Several of the teaching methods and assessment methods developed within the project (such as lectures with students at the blackboard and seminars) have spread and are currently used in a number of different courses within the department.
- The visibility and the engagement within the department for educational development is probably the most important of the long term effects. The project has served as a source of inspiration and as a sign of recognition for the work performed by our group, and is one of the key reasons to why computer science education is now an active field of research within the department.

8. Visibility

The project has been presented and discussed in public at several events, and has become a topic for intensive discussions. In appendix A, a list is given of publications as well as of informal events, where Expresso has been in focus

9. Conclusions

The project clearly indicates that it is possible to change assessment methods, even within the regulated and structured master programmes in engineering. It also points out that there is a strong link between the assessment methods and the students' study strategies and thereby their learning. To change the forms of assessment is thus a powerful way to influence what the students learn.

The project has pointed out issues that are important for a good learning outcome, such as the importance of seeing the study situation as a whole, the role of dead-lines, and the lectures as a tool to organize studies, the selection of a study partner. These factors must, together with teaching and assessment methods, be considered in our development of courses.

10. Acknowledgement

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Appendix A

Refereed journal articles and refereed conferences

Petre, M., Daniels M., Berglund, A.: Building a Rigorous Research Agenda into Changes to Teaching (the project was discussed as an example of the relationship between educational development and research in computer science education, ACM SIGCSE 3rd Australasian Conference on Computer Science Education, Brisbane, Australia, July 1998.

Berglund, A., Daniels, M., Hedenborg, M., Tengstand A., Assessment to Increase Students' Creativity:Two Case Studies, European Journal of Engineering Education, Vol 23, No 1, 1998.

Berglund, A.:"Changing Study Habits - a Study of the Effects of Non-traditional Assessment Methods", Work-in-Progress Report, 6th Improving Student Learning Symposium, Brighton, UK, Sept 1998.

Berglund, A.: Changing study habits by changing assessment methods - is it possible?, Presented at SEFI workshop on Assessment in Higher Education - What have they learnt?, Delft, Holland, April 1999.

Berglund, A., Daniels M., Almstrum, V.: A Smorgasbord of Pedagogical Dishes. Presented at Second Australasian Computer Science Education Conference in Melbourne, Australia, July 1997.

Other events

Discussion topic at the ACM SIGCSE 2nd Australasian Conference on Computer Science Education, Melbourne, Australia, July 1997 (pilot project and pilot plan)

Seminar in the course "Research Methods in Computer Science Education",

Seminar at the department of education, Uppsala University, Oct 1997 (discussion of project plan)

The internal conference on undergraduate education, Feb1998

Doctoral Consortium, ACM SIGCSE Technical Symposion, Atlanta, GA, USA, Feb 1998.

The AAPS-group workshop (Animation Aided Problem Solving) workshop, Helsinki University, March 1998.

Swedish Broadcasting Cooperation "Riksradion", P3, March 1998 (Interviews with project leader and some students)

Presented at the visit at the Department of Computer Systems by the Minister of Education, Carl Tham, April 1998

Presented at the 2nd and 3rd CSERGI (Computer Science Education Research Groups International) Workshops in Stockholm and Uppsala, Oct 1998, May 1999.

Presented at seminar at Mälardalens Högskola, April 2000.

Presented at the conference Kvalitet och förbättringsarbetet vid universitet och högskolor, Jan 2000, Eskilstuna, Sweden.