

Effects of Elective Oral Examinations in a Semiconductor Devices Course for Computer Engineering Students*

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The positive educational effect of elective oral examinations as part of a university course in semiconductor devices for computer engineering students is revealed by final examination results and records of student response. The personal meeting taking place during the oral examination is argued to be an important complement to the parts of the education program which lack direct personal interaction between students and teachers, such as large class lectures and computer-based learning.

INTRODUCTION

THE COMPULSORY course in semiconductor devices given at Chalmers University of Technology in Göteborg, Sweden, for third (or second) year students on the computer engineering (CE) program is faced with a challenging problem: less than half of the students state that they have a genuine interest in learning the semiconductor subject. (19 of 48 students participating in the oral examination chose the answer 'to learn something' when asked why they were taking the course, whereas 22 students chose: 'because I have to in order to get my MSc degree'.) The main focus of the CE program concerns computer system issues. The CE program encompasses approximately 20 elective courses in programming, networks and mathematics, and only around 5 elective courses concerning hardware design (1997/98). So it is not surprising that the sympathy for learning the physics of semiconductor devices is low. This puts an extra load on teachers, who are obliged to achieve an acceptable educational result notwithstanding the student attitudes.

Even if we try our best to giftwrap the course content we still suffer from the prevailing attitude profile of the students. Because of their low degree of motivation, there is an enhanced 'whiplash' effect: the students who find the carrot distasteful are motivated only by the whip, which in this case is made up of superficial demands of results for student financing among other things. The risk that these students focus only on passing the exam rather than learning the subject is obvious, hence our need to achieve a higher correlation to student understanding of the subject. We want to present

an exam which helps the student to focus on understanding.

The traditional written examination takes place at the end of the course. During four hours, the students are to individually compose written answers to: 10 short questions on facts, 3 numerical problems, and 3 problems aimed at demanding a coherent understanding of concepts and relations in the course. In our experience the student performance on the latter is much worse than for the numerical problems and the overall ratio of students passing the exam has been low (around 57% passed, whereas the average ratio for courses during the first term of the CE program is 75%).

With the aim to more clearly guide the students to the desired kind of learning, we decided to modify the form of the examination during a period of trial. During the years 1994–1997 the course has been given four times and each time the students have been given the opportunity to take part in an elective oral examination (OE). As will be shown, this has had a quantifiable and beneficial effect on student learning. This report gives an account of the motives for introducing the OE, the beneficial effects we have observed, the problems we have encountered, and the conclusions we draw from our experiences. We will argue that for existing university courses with a particular profile it is cost effective to include oral examinations as part of the curriculum.

EXPERIMENT

The OE occurs in the middle of the course and those who choose to partake can gain a bonus with a value of about 10% of the total score of the final written examination. Around 60 of the

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100 students taking the course each year agree to take the OE. The practical details of the OE arrangements go as follows.

The students sign up for the OE, which takes place during one afternoon. There is no penalty for signing up and then not showing up. Having signed, they know during which time interval (with a span of 30 minutes) they are to be available in the coffee room of the department. There is room for 10–20 students during each 30-minute interval. The teachers come to the coffee room and pick out the students for OE one by one. It is then up to the 10 or so teachers to keep up with the flow of students, which demands that each teacher takes care of approximately three students each hour. The waiting students are offered something to drink and a light snack of some sort.

After the closing of each OE, the student receives a diploma. In some cases the OE score is withheld until the next day, and in some cases the students who wanted to could have their results immediately, providing that the teacher was able to tell them that right away.

The discussion, or dialogue, that constitutes the OE will test the student's abilities in a significantly different way than a written exam. The focus will not be on formal details but on the meaning of concepts and their interrelations, and the inherent interactivity of the dialogue will enable a rather thorough examination of student conceptions. In our meaning of the word, understanding is more explicitly tested in the OE than is feasible in a written exam. We also try to convey this main purpose of the OE to the students as clearly as we can. Thus we hope that the students will adopt a different approach to learning than if they were motivated by the traditional exam alone.

Having the OE occurring in the middle of the course is thought to be a good idea on several grounds. One important reason is that there exists a natural, and significant change in the subject at this point. The material being covered during the first half of the course is the basis for all that is to follow. If the student does not grasp the first half, he is destined not to understand the rest either. By introducing the OE at this point, we put extra emphasis on the importance of the first part of the course.

Due to the tendency of non-interested students to delay their studies to as late in the course as possible—stuffing their brains full for subsequent emptying on next day's exam—the division of the examination should help guide the students to a more continuous line of study.

RESULTS

One reflection of the impact of the OE can be obtained from the results of the written exam at the end of the course. The OE should lead to a better result for the students who participated, even if the bonus received for the OE is not

counted. The total number of CE students taking the OE during the evaluation period is 232. The pass ratio for these students on the written exam is 70%, not counting the OE bonus. For the students (140 in all) who did not participate in the OE this ratio is only 52%. Such a direct comparison is probably severely distorted by the fact that those who choose to take the OE are the more motivated students, and these students do better on the written exam, OE or not. We will now attempt to take this effect into account, and thereby gain a more reliable measure on the effect of the OE.

In the following we will assume that we are dealing with two groups of students: those who are more motivated (and will participate in an OE), and those who are less motivated. See Fig. 1. We will further assume that these two groups are equally weighted (62% motivated, 38% unmotivated) during the years 1990–97. Finally, we take the pass ratio for the latter group, 52%, as this group's pass ratio also for the years 1990–93 when no OE was given.

Given the pass ratio of all students during the years 1990–93, which is 57%, we can find the pass ratio for the group of motivated students, PRM, during these years (see Fig. 2) from the expression:

$$57\% = 52\% \times 0.38 + \text{PRM} \times 0.62 \rightarrow \text{PRM} = 60\%$$

Comparing this number to the pass ratio of 70% for the motivated group during the years of OE, we feel confident that we see a reflection of the impact of the OE on the students' achievements. This difference of 10% can be directly related to institution economy, where money is gained for passing more students. The confidence in this measure relies on our written exams not being significantly more difficult during 1990–93 than during 1994–97. It has been our intention not to alter the standard of the exams.

The fact that the students might change in distribution between motivated/unmotivated over the years can also distort our analysis. The pass ratio for the group examined during 1990–93 was

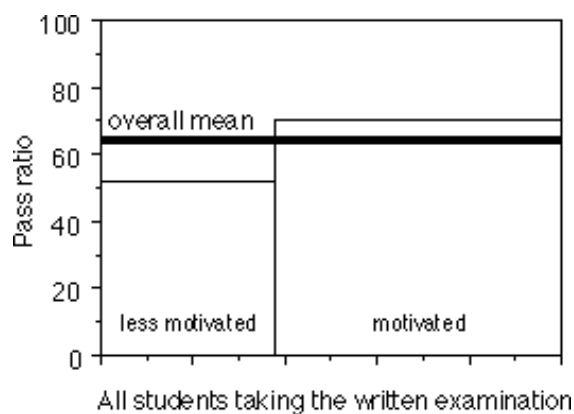


Fig. 1. Pass ratio of written exams during 1994–97 with students divided into two categories: those participating in the OE (motivated) and those not participating (less motivated).

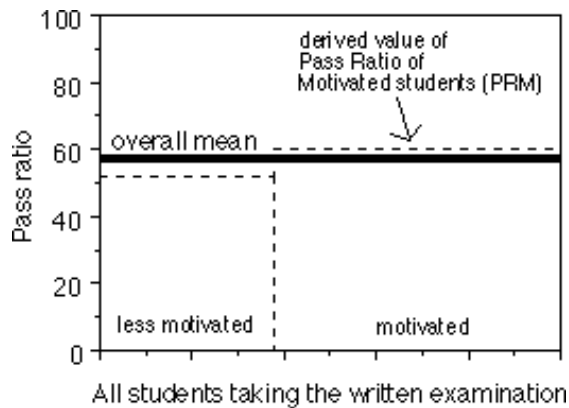


Fig. 2. Pass ratio of written exams during 1990–93 with students divided into two categories: motivated and less motivated. The pass ratio of the motivated students has been derived assuming the same distribution of motivated/less motivated students during these years as during 1994–97, and a constant pass ratio of 52% from 1990–97 for the less motivated students.

on average 75% for their initial semester on the CE program, whereas it was only 67% for the students who were subsequently examined in our course 1994–97. It is thus quite possible that the number of students with low motivation is significantly larger during 1994–97 than during 1990–93. The effect of assuming a 80/20 distribution of motivated/unmotivated students during 1990–93 will change the PRM during these years to 58%.

During the last semester, 1997, the course saw a larger revision, since the entire CE program was changed. The surrounding curriculum has then been altered, and the book used in the semiconductor devices course was also changed, although the course content remained almost identical. This causes some uncertainty in the effect of the OE during this semester, but the data has been treated without considering this effect. The trend is the same this year as for the other years; a majority of the students take the OE and score significantly better than those who do not (PRM = 58% compared to 49% for those who did not take the OE).

The results of questionnaires given to the students after the OE offer another view of the OE results. Two different questionnaires have been given. In 1994 48 students responded, and in 1995 we received 46 answers. The response to the question of how the OE had affected the studies of the students could be divided into two main categories:

- 59% state that they had studied more up to this point in the course than they otherwise would have done.
- 36% claim that they had studied with more of an approach towards understanding the subject than they otherwise would have done.

The effect of the actual OE situation was described by students in a way which we can classify in four different categories:

- 44% claim to have realised during their OE that they had not understood all and that they needed to study more.
- 33% state that they gained new knowledge of the subject during the OE.
- 14% say that they received a confirmation of their knowledge.
- 11% say that they realised that they would have needed to train more on oral presentations.

The general attitude of the students who respond to the questionnaire is very positive. The main issues that are brought up as criticism concern practical matters: long waiting time, no milk with the coffee, etc. Seven students would have preferred more concrete questions than was the case. There are also a few complaints about stress and anxiety. The most appreciated aspect of the OE is the learning element. The emphasis on this aspect might reflect the students' pre-OE bias towards seeing the OE more as a test than as a learning event, and thus being favourably surprised by the actual course of the OE.

A last perspective (by no means the least important) on the results of the OE comes from the outcome of using video recordings of OEs as base material for a phenomenographic study [1]. Analysis of eleven OEs made possible a classification of three qualitatively different student views of an important concept in the course. The OE thus makes it possible not only to judge whether the student knows his subject or not, but also enables a description of *how* the student understands the subject.

The concept in question was diffusion of charge carriers. The three different categories of views that were found follows:

- Net transport of charge carriers due to their random motion and spatial differences in concentration.
- Random motion of charge carriers (no net transport).
- Charge carrier motion due to interaction of carriers of different charge.

The desirable view is the first, and the other two are unacceptable.

With knowledge of existing misconceptions teachers have a chance of understanding why the students 'don't get it', and we are better equipped to battle these prevailing misconceptions. Teachers that are aware of their role as students of misconceptions have a real opportunity to improve their teaching skill during the OE by becoming more in tune with student needs. The opportunity to disclose student misconceptions during the OE is by far superior to a written exam, where in many cases you just end up with a blank sheet of paper instead of feedback on student understanding.

Information on the reasons for student failure is the key to overcoming low pass ratios. OE can give important information, and properly used, it is

likely to be a most efficient remedy for unhealthy low pass ratios.

DISCUSSION

The main problem with the OE as an elective event is that the students who choose to participate probably are those who are the most interested in the subject anyway. Such students are very open to the message of the OE, and they find it being a very nice and agreeable concept. Students with *a priori* negative attitudes to the course are at risk of finding the OE confrontational if it were a compulsory event. To put it bluntly, the OE is likely to miss the main target. When asked, 22 of 48 students taking the OE say that they take our course only because they have to, not because they have an interest in the subject. A possible solution to this dilemma is to try to make the OE appear in such a way that the student who participates has 'everything to gain and nothing to lose'. Making the OE compulsory would probably enhance the impact of all problematic issues, such as those discussed below.

The fairness and accuracy of oral examinations have been questioned in other studies [2–4]. Objectivity is a problem when individual teachers alone form their opinion of the student's merits, an opinion which could be influenced by factors such as the student's general behaviour and way of dressing [3]. One way of trying to deal with some of these problems would be to control the details of each OE by having all the teachers follow the same questionnaire and by employing

some kind of common assessment scheme specified in detail. We feel that this way threatens to degrade the OE of its unique characteristics as an event of flexible personal interaction. We have accepted the inherent drawback in objectivity when letting each examination take its own course, thus paying a price for the flexibility and ability to tailor each teacher/student meeting as it goes along. Our efforts to obtain at least a tolerable degree of fair judgement goes as follows.

Before the first round of OEs the teaching staff were asked to grade two oral exams using two graduate students from neighbouring departments to pose as undergraduate students. The result of these trial OEs gave each teacher feedback on how tough or lenient they were when setting grades, and with this information they could try to take their inclination to give lower or higher markings into account when setting future OE scores. The content of the OE was specified and categorised in a protocol, which was to serve as a guiding document during the OEs. The teachers were expected to use the protocol for support only, and they were not to follow it in detail (which was not possible in the limited time of the OE anyway). The grading was set at only a few levels for all cases, at most from 0 to 5. This helps smooth out teacher differences in scoring, but having so few levels (pass/no-pass) leads to an inherent injustice since students with different ability are given the same score.

Figure 3 shows the results of having eight teachers grade eleven transcripts from video-recorded OEs. The grading was from 0–5, with 0–2 being no-pass results, and 5 reflecting student

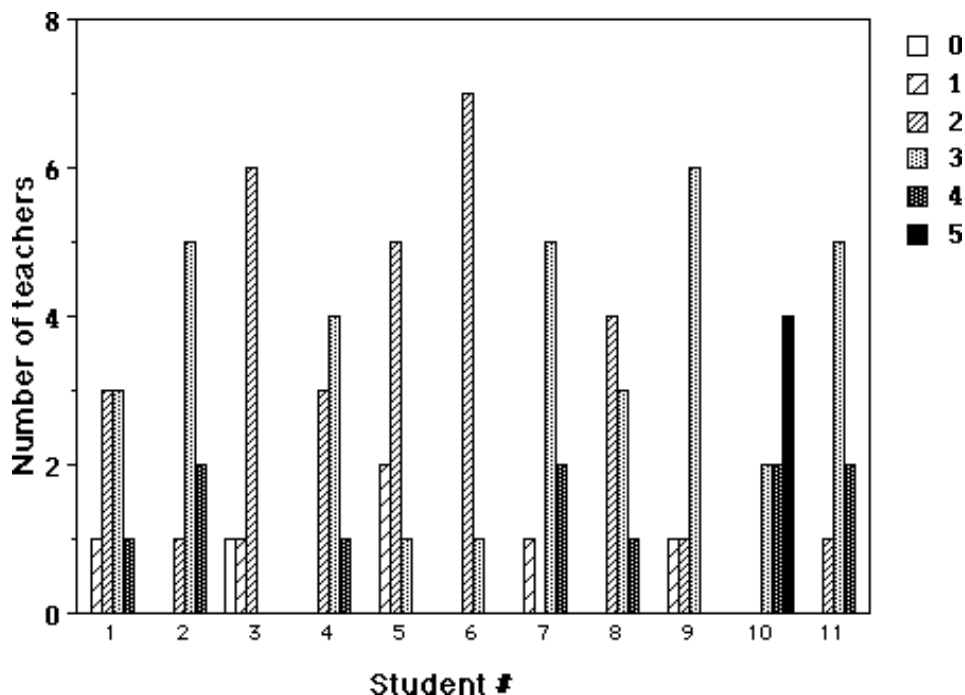


Fig. 3. The results of having eight teachers grade eleven transcripts from video-recorded oral examinations. The students appear on the columns of the x-axis (1–11), each with bars representing the number of teachers giving a certain mark (0–5).

excellence. There is evidently a significant spread in the grades given. In this case there are six occurrences (of a total of 88) where the grading is significantly lower (>1 level lower) than the score given by the majority of the teachers to that particular student's transcript. This can be translated into having about 7% of the students receiving a score which is significantly lowered by their lack of luck when being assigned a teacher during a real OE. This measure is distorted in a way which is most certainly accentuating the problem, since in the real OE situation the different teachers are not grading an OE conducted by another teacher, as is the case in Fig. 3; the scoring of Fig. 3 does to some extent include the grading teacher's judgement of the questions being put to student.

The question of fair assessment and accuracy is probably more strongly brought into focus when the student has much at stake; by having the OE as an elective bonus-giving event, the negative impact for the poorly scoring student is not so severe. A handful of students have been disappointed with their OE scores, but the issue of fair assessment is not seen as a general problem. (None of the 94 answered questionnaires to get student feedback on the OE mention the subjective assessment as a problem.) For the disappointed student, the problem is not so much of subjective teacher grading as a problem of not being able to use the result of the OE in a constructive way. If the disappointed student feels less of an inclination for further studies after the OE, we have failed in a more crucial way than by giving an unfair judgement.

The cost of the OE is substantial. In our case, with one hundred students, the elective OE will take up ten teachers' time for three to four hours per course, or about forty teacher-hours. The total extra load for the individual student is somewhere between half-an-hour and an hour. This should be compared to the cost of the written exam. The making of an exam takes perhaps ten teacher hours. The grading of the exams takes another forty teacher hours or so, which makes the written exam more expensive than the OE. Adding to this the examination's time cost for the students of about five hours, the total cost of the written exam is many times higher than the cost of the OE. Since the oral examination can achieve things the written exam cannot, it is well worth considering a shift of resources from the written exam to the oral.

The stress related to participating in the OE will have negative influence on the learning of students with low motivation in particular [5]. In the elective OEs the students who feel stimulated during the OE outnumber those who feel stressed by a factor of ten according to the questionnaire. If we make the OE compulsory, this ratio will most likely drop significantly. The students who feel forced to come to the OE, and who are low on motivation will probably gain much less from the OE than the students participating today.

One important aspect of the elective OE is that the students feel that the department is really concerned about their learning. This helps create goodwill and perhaps motivation also among the students, although this is not an effect of the actual form and content of the OE but a reaction to the fact that we are at least doing *something* to stimulate them. From having been a course with a less favourable reputation we have lately been nominated twice for the 'best lecturer' award of the CE program, and won it once during the time of OEs. This award actually reflects the entire course more than the lectures *per se*; the prize goes to the person responsible for the course. The content of lectures, tutorials and laboratory work has been modified slightly during 1994–97, and it is possible that a part of the positive educational effect ascribed to the OE in this report is due to such modifications, but these changes consist only of the continuous course development taking place during 1990–97. Only one other major change was made: a new course book was introduced in 1997. Except for the last semester, 1997, when the entire CE program was rescheduled, the surrounding curriculum was kept constant.

CONCLUSIONS

The elective oral examination in the semiconductor devices course on the computer engineering program at Chalmers University of Technology has a positive influence on the effects of the course. The students who partake in the oral examination score better on the written exam than they otherwise would have, they state that they study more with an approach towards understanding, and they have a positive attitude towards the oral examination concept. The teachers gain important information on the nature of student views of course content.

Being elective, the oral examination is at risk of not reaching the students who lack motivation for learning the course content. We believe that the way to address this problem is to make this elective event as enticing as possible rather than making it compulsory. The latter approach would add to the problems connected with student stress.

The highly interactive and personal nature of the oral examination further commends its use in courses where this important dimension of teaching is lacking. Twenty minutes one-on-one testing is something very much different than hours and hours of hundred-to-one teaching in the lecture hall.

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