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An integrated learning experience in the work session physics

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ABSTRACT: The authors' experience shows that students have great difficulties in writing solid reports and understanding disciplinary knowledge, so an integrated learning experience in the work session physics has been introduced. In the first bachelor year, the emphasis is on the importance of written reports and peer assessment for learning purposes. Students perform an experiment with the aid of a report written by a colleague. Additionally, students are asked to review the original report. The results bear out neither obvious positive nor negative influences on students' laboratory skills. Several refinements are suggested. In the second bachelor year, the goals are diversified. Students have to study in depth four experiments. Assessment relies on a written report, oral presentation, practical test and written test. For a small test group, formative peer assessment was also used for presentations. The score given by the teacher-expert and the average score given by the peer group correlates well. On the other hand, the student's own assessment of his/her presentation yielded no correlation with the expert's score or the peer score. Comparing the scores to those of the previous year shows no particular differences, although students' appreciation, as is apparent from an inquiry, is much higher.

INTRODUCTION

Higher education in Flanders, Belgium, has undergone major changes due to the Bologna agreement between the members of the European Union (EU). Starting from the 2004-2005 academic year, the so-called BAMA (Bachelor-Master) structure has been gradually introduced. Curricula have been reviewed hand-in-hand with these changes. As a result, the subject of physics has been reduced in the revised curriculum for engineering sciences. In order to maximise the benefit given the limited time, it was necessary to adapt the approach in the physics work session. According to the *Conceive – Design – Implement – Operate* (CDIO) Initiative, the focus is on an integrated learning experience of disciplinary knowledge and personal and interpersonal skills (Standard 7) [1]. In the first bachelor year, the centre of activity was on acquiring the basic skills when undertaking the work sessions, ie the emphasis was on the importance of the written report. This approach was diversified in the second year.

TASKS

The focus in the first bachelor year is on solid reporting, especially the written report; this is on top of enhancing insight into the theoretical courses and developing a critical attitude. In the course of the work session, which covers over three hours, students are expected to carry out a specified experiment and write a scientific report about it. The experiment is known beforehand and students have to prepare for it in depth in order to optimise the time allocated. In this way, they study profoundly nine different experiments in small groups (2 or 3), ie they must be capable of conducting the experiment and understanding the fundamentals associated with it. This is assessed in a written test held at the end of the semester. During the semester, students are asked to make a formative peer assessment of one of the reports of their colleagues. This is conceived as co-assessment and self assessment, as affirmed by Dochy [2].

In the second bachelor year, the approach is diversified using various methods [3][4]. The number of experiments is reduced; only four experiments have to be studied. At the end of the semester, this is assessed in a written and practical test. Students are allowed to train on a weekly basis in small groups (2-4) in the live experiment. In addition, students themselves are asked to formulate a few model questions as could be used for the written test. As such, they are obliged to reflect about their work. Students are allowed a large degree of freedom to plan their work themselves. They present their results for only two out of the four experiments: one by means of a written scientific report and the other in a ten-minute oral presentation explaining to their fellow students the main goal, principle and results of the experiment. However, students are also left with the responsibility of two additional experiments that will be tested at the end of the semester. Each presentation is followed by a discussion. As such, it is not only the teacher, but also the students, who have to take responsibility in giving appropriate feedback and students are obliged to learn from each other.

CDIO STANDARDS IN THE PHYSICS WORK SESSION

The authors' experience shows that students lack disciplinary knowledge and have great difficulties with solid reporting in both written and oral formats. The educators found it their task to train students in disciplinary knowledge and generic competences. In line with the CDIO Initiative, a few of the typical CDIO model standards were adopted in the physics work session [1]. As the physics experiments had already ben designed and tested, it was hard to speak about a design-build experience. Although personal skills were enhanced, such as critical thinking, experimentation, communication and knowledge discovery, by writing a syllabus that focused on problem solving and through the introduction of formative peer and self assessment (Standards 2, 7 and 8). Interpersonal skills, such as group interaction and teamwork, have also been considered. Moreover, the laboratory, in combination with different tasks, has been conceived so that students support learning from each other and interact with other groups (Standard 6). The assessment of the student's learning is more diversified as it includes written and oral tests, observation of the student's performance, student's reflections, reports, plus peer and self assessment (Standard 11). By undertaking this, the assessment addresses disciplinary knowledge, as well as personal and interpersonal skills.

RESULTS

The first focus is on the scores in the second bachelor year. The score for the different parts of the work session are summarised in Table 1 (score with a maximum of 10 ± standard deviation). All assessment scores are given by the teacher-expert. A few remarks have to be made in order to gain a good comparison of the results. For the 2004-2005 academic year, the score for the report was on the average of eight reports per student. This allowed room for improvement due to specific feedback. In the 2005-2006 year, there was only one report per student. These students receive no systematic and written feedback of all the experiments (ie the practical test involved the two experiments on for neither a report nor a presentation was made). The only feedback that students received came from the oral presentations of the different experiments, thereby encouraging students to enhance their interpersonal skills.

Table 1: Scores for the different parts in the work session.

	No. of Students	Report	Presenta-tion	Practical Test	Written Test
04	232	6.6 ± 1.3		6.2 ± 1.9	4.5 ± 1.7
05	226	6.5 ± 1.2	6.6 ± 1.0	5.8 ± 2.4	4.6 ± 1.7

From Table 1, it can be concluded that there were no major differences between the scores for the 2004-2005 and 2005-2006 years. While the score on the practical test was a bit lower in 2005-2006, the standard deviation was a bit higher, suggesting a wider variation in the scores.

These scores can be compared to the results obtained in the first bachelor year. For the 208 students in the 2004-2005 year (concerning approximately the same students as in the second bachelor year in 2005-2006) the results comprised an averaged report score of 6.0 ± 1.4 and a written test score of 4.3 ± 1.7. In 2005-2006, there were 218 students in the first bachelor year who scored 5.7 ± 1.5 as an average on their reports. As such, it can be concluded that students' skills in writing good reports improved during the first year, which resulted in higher report scores during the second bachelor year. The results of the written test in the first and second bachelor year are comparable, meaning that enhancing students' insight into the physics behind the experiments was not completely successful.

Besides giving scores to the students, a small inquiry was also performed about how their experiences in the work session. The students were asked, after giving their presentations and before they undertook any test, to give their opinion about a few statements. It can be concluded that, although there was no difference in the scores between the old and new regimes (as mentioned in Table 1), students appreciated the new, diversified approach and preferred it above *just writing reports*. According to students, the preparation for the test was more difficult, which might explain the lower score in the practical test. However, a majority of students found the presentations valuable to gain information about the experiments.

It was also recognised that students studied the experiment more profoundly for the presentation. They searched the Internet for applets or films and searched for relevant applications of the theory presented. This was also reflected in their scores for the written test. The score for the question about the experiment for the presentation was some 10% higher than the scores for questions about the other experiments.

PEER, SELF AND CO-ASSESSMENT

Peer assessment can be described as a process whereby students evaluate the products of their fellow students. It is important to emphasise that peer assessment is not just about giving scores, but is also a part of the learning process wherein certain skills can be developed. As such, peer assessment can be considered a part of self assessment and cannot be fully separated from it [2]. To develop the skill of critical thinking, educators opted for formative peer assessment in assessing learning, instead of summative peer assessment in assessing learning. Students had the opportunity to evaluate each other, but the final score was given by the teacher-expert, which concerned the so-called co-assessment.

Peer Assessment in the First Bachelor Year

Next to learning to perform measurements that are accurate and qualitatively good, the emphasis in the first bachelor year lies mostly on developing the skill of generating effective written reports. A chief goal of a good report is that it must be readable for a (large) public. The educators sought to confront students with the reports that were received and hoped to enhance their critical mind by having them read another student's report. One important benefit is a reduction of cumulative and repeatable errors. It is also a great opportunity to develop social and communicative skills, as well as working and learning in teams, active learning, evaluating, giving feedback and diplomatic handling.

After students had written five reports, they were asked to evaluate the report of a fellow student. In most cases, the fellow student was present during the work session, offering them the opportunity to communicate about the reports. For that purpose, a prepared evaluation form was utilised as a guideline [5]. Students were asked to give a score based on a few criteria for a good written report. To evaluate the content, students performed the measurements themselves, and made the necessary calculations and graphs. Thus, peer assessment is more intended as a self assessment for their own reports. Students were evaluated on their ability to give a profound and well-founded evaluation of the report on the one hand and, on the other, on their own measurements, calculations and graphs. The teacher-experts evaluated both reports, namely the original report on which students' evaluations were based (further indicated as original) and students' peer assessment based on this original report (further indicated as evaluation). The measurements and conclusions of the original and evaluation were compared, and higher score given to the evaluation if the it was well-founded and/or the measurements improved. If students made the same mistakes as in the original, then the score is diminished. In undertaking this, it was hoped that the critical attitude would be enhanced and that there would be a reduction in the cumulative errors, which were not only made in the original report, but also in their own (previous) reports.

The result of this peer assessment is summarised in a few graphs (see Figures 1, 2 and 3). The full data set consists of

122 reports. The histograms indicate the frequency of the difference in the score between the evaluation and original. If this difference was positive, then this means that the report was improved by the evaluators, while a negative score meant a worse report. Figure 1 shows the total frequency of this difference. As can be seen, the histogram peaks at a result for evaluations of 0.5 or 1 point less than the original.

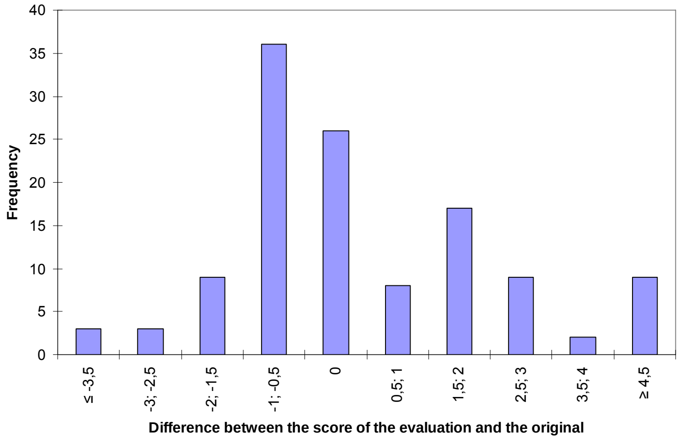

Figure 1: Global histogram.

This result was somewhat surprising, as a more profound evaluation had been made. The scores on the reports were divided into three categories, namely: a bad report scored ≤ 4.5, an average report scored between 4.5 and 7, while a good report scored ≥ 7. The original reports were first divided into the above categories and the relative frequency identified, as shown in Figure 2. Figure 3 shows a similar histogram but focuses on the evaluation reports (see also ref. [5]).

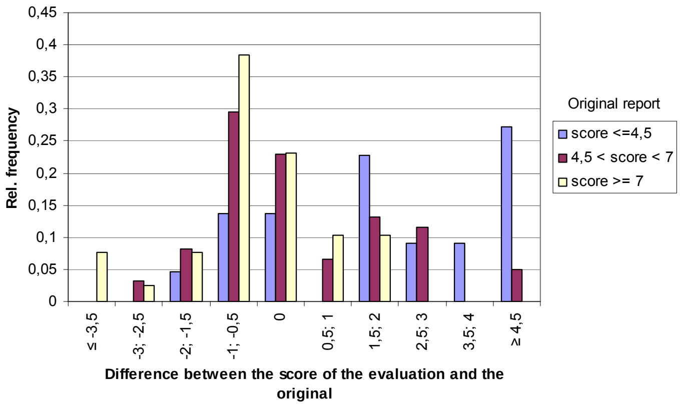

Figure 2: Histogram focusing on the original reports' scores.

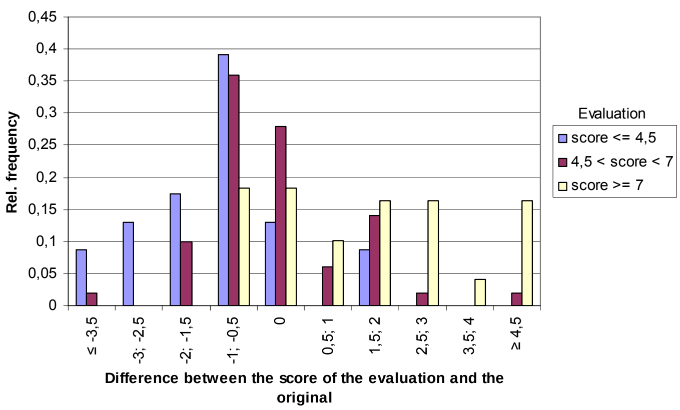

Figure 3: Histogram focusing on the evaluation scores.

From Figure 2, it can be concluded that the influence of the quality of the original report is not that huge. A bad report is mostly improved, as could be expected, but a relatively large part of good reports were also made worse. By focusing on the scores of the evaluation, as presented in Figure 3, it can be seen that if the evaluation is good, then this is mostly due to improved measurements and conclusions, and a bad evaluation means worse measurements than the original. Perhaps the student's preparation of the experiment was less than normal due to the fact that he/she did not have to make a full report. It is thought that some students relied too much on the data presented in the original report and let it bias their own data. It also indicates that students did not sufficiently understand the experiments, which was also reflected in the scores of the written test last year. A bit of training in evaluating is certainly necessary and a more critical attitude towards the measured and presented data should be encouraged. In the future, the intention is to give the *original* report, not at the beginning of the work session, but rather in the last hour, thereby putting the focus first on carrying out good measurements and drawing good conclusions without the influence of the data presented in the original report. It may be necessary to redo the peer assessment experiment before major conclusions can be drawn, but there is a lack of time to undertake this task this year.

An attempt is made to assess the learning effect due to peer assessment. The averaged scores of the successive reports can be compared so as to investigate if the evaluation of a report gives a higher score for the next report, taking into account that the score will enhance during the year as students gain feedback and improve their report writing skills. This data is summarised in Figure 4. For the first report, EHB, all students performed the same experiment, namely a study of periodic harmonic motion and were guided throughout their report. R4 is the *original* report, R5 the *evaluation* and R6 the report of interest after the evaluation. From Figure 4, it can be concluded that there is no direct effect on the score due to peer assessment. The enhancement of the score for R8 probably indicates that the assessors were *mild* for the last report.

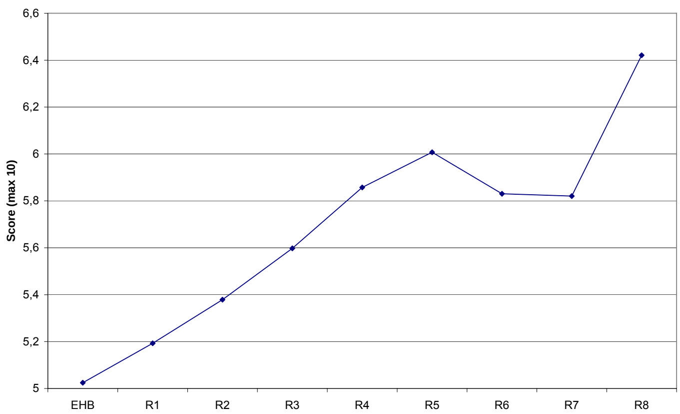

Figure 4: Averaged scores of the successive reports.

Peer Assessment in the Second Bachelor Year

The physics work session is more diversified in the second bachelor year. All presentations are evaluated by the teacher-expert, who is also responsible for the final score for this component. For a small test group (48 students and 16 presentations), students were asked to perform a formative peer assessment. Independent of the given score by the expert, they gave a ranking score between 1 and 4 for the different presentations. Several conditions made it impossible for students to give their colleagues a score of 4. Students were also asked to evaluate their own presentations. The averages of the peer score were compared and linearly extrapolated to a score out of 10, with the score of the expert as presented in Figure 5. The error bars indicate the standard deviation of the peer scores.

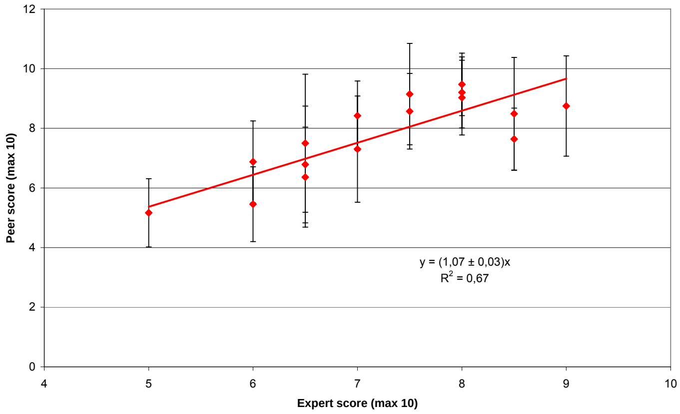

Figure 5: A comparison of the peer and expert scores.

From the data presented in Figure 5, it can be concluded that there is a clear linear correlation between both scores (correlation coefficient R^2 = 0.67). The slope is 1.07 ± 0.03, meaning that the ranking given by the peer group is comparable with the score given by the expert. This assumes that there is a strong parallelism in marking criteria, although they were not specified by the expert. The self assessment of the presentation (the average of the three or four members of the group) shows no correlation with the score of the expert (R^2 = 0.14), or with the score of the peer group (R^2 = 0.15). Therefore, it can be concluded that the self assessment was not objective.

FUTURE IMPROVEMENTS

A critical look at the results is taken and some suggestions for improvements are given as this is the first attempt at dual learning taken by the University. The first goal of the work session is to enhance students' insight into the theoretical lessons by carrying out relevant experiments. As observed, the connection with the theoretical background and understanding of the experiments is rather poor. Therefore, changing the written assessment in an open book test was carried out. In doing so, it was hoped that students would focus more on insight and less on reproduction. This has been tested this year in the first bachelor year. The result of the written test is 4.3 ± 1.5. So it can be concluded that there was no influence as to whether or not students had an open book test. However, this is only a first attempt and, in the future, students will be in preparing for the open book test. Other improvements, such as utilising applets and extra testing possibilities, are also suggested in order to enhance students' insight into the physics behind the experiments.

The target was also to reduce the cumulative errors in the written reports of the experiments. This is one of the main reasons to introduce peer assessment of the reports. Here, it can be concluded that the experience levels of students is still not sufficient to interpret a report correctly; as such, it is being considered to enhance the feedback given by the expert by introducing a similar assessment form to the one that students use for their evaluation. A form will be created with a few criteria of importance. Students then fill in the form systematically for all the reports, besides the written and oral feedback on the reports. This may be more readily surveyed for both the student and the expert.

The results of the peer assessment of the oral presentations offer proof that it is reasonable to allocate responsibility to students in their assessment. In the future, it s hoped that a score be evolved that is based on a co-assessment of both the peer and expert. This will stimulate the student's attention and criticism.

CONCLUSIONS

Due to change in the curriculum for the engineering sciences, an integrated learning experience for the physics work session was selected. Besides the traditional performing of experiments and training the skill of generating good written reports, more freedom, oral presentations and peer assessment were introduced. So far, the scores indicate no major changes over the years, but the appreciation of the students, as made apparent from an inquiry, is much higher. Students preferred the new approach over the method of merely writing reports of all the various experiments.

Peer assessment was introduced for the first time in the first bachelor year. Students were allowed to train an experiment with the aid of a report made by one of their colleagues. In addition, they had to review the report. Major conclusions regarding the effect cannot be drawn from it, as it is still too soon. Obviously, students were not used to interpreting measurements and had to be trained in doing so. In combination with an enhanced feedback from the expert, it is believed that this can be a useful tool for the future in order to reduce cumulative errors.

In the second year, where students were asked to assess oral presentations, the averaged score from the class group was found to be comparable to the score from the expert within the given set-up. This allowed for the use of peer assessment as a summative assessment and the evolution of co-assessment for both peer and expert. In this context, self assessment appeared to be not objective.

This new approach addresses more skills than before; therefore, it also asks for new forms of assessment. In diversifying assessment, not only the disciplinary knowledge, but also other skills are included in the final result. As such it is hoped to introduce several CDIO Standards in the physics work session.

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