AC 2012-3914: EVALUATION OF A TECHNICAL WRITING PROGRAM IMPLEMENTED IN A FIRST-YEAR ENGINEERING DESIGN COURSE

Dr. Christel Heylen, Katholieke Universiteit, Leuven

Christel Heylen obtained her master's of science in materials engineering in June 2000 and the academic teacher training degree in 2004, both from the Katholieke Universiteit Leuven (Belgium). She is a member of the Tutorial Services of the engineering faculty and is responsible for the implementation and daily coordination of the course Problem Solving and Engineering Design in the first year of the bachelor's of engineering program at the Katholieke Universiteit, Leuven, with a special focus on the didactic interpretation. Regarding this subject, she obtained a Ph.D. in engineering in Aug. 2010 from the Katholieke Universiteit, Leuven. She is a member of LESEC (Leuven Engineering and Science Education Centre).

Prof. Jos Vander Sloten, Katholieke Universiteit, Leuven

Evaluation of a Technical Writing Program Implemented in a First Year Engineering Design Course

C. Heylen[1] and J. Vander Sloten[2]

[1]Christel Heylen, Faculty of Engineering, Tutorial Services, K.U.Leuven, Belgium
christel.heylen@mirw.kuleuven.be

[2]Jos Vander Sloten, Faculty of Engineering, Division of Biomechanics and Engineering Design, K.U.Leuven, Belgium

Technical communication and technical writing are important skills for the daily work-life of every engineer. In the first year engineering program at KU Leuven, a technical writing program is implemented within the project based course 'Problem Solving and Engineering Design'. The program consists of subsequent cycles of instructions, learning by doing and reflection on received feedback. In addition a peer review assignment, together with an interactive lecture using clicking devices, are incorporated within the assignments of the second semester. A checklist of desired writing abilities makes it easier to grade the large number of papers. Furthermore this ensures that all staff involved in the evaluation process uses the same criteria to grade and for providing feedback. This paper describes the implementation of the writing program and how it was evaluated by collecting survey-data.

Keywords: technical writing skills; peer review; interactive lecture; project-based learning; first year engineering course

1. Introduction and Course Description

The KU Leuven is a Catholic University situated in the Dutch speaking part of Belgium. The engineering curriculum at KU Leuven consists of a three year Bachelor's program that prepares the students for a subsequent Master's program of two years. The Faculty organizes Master's programs in several disciplines, like Architecture, Electrical Engineering, Mechanical Engineering, Chemical Engineering, Materials Engineering, Civil Engineering, Biomedical Technology, Computer Science, Energy Engineering, Nuclear Engineering, Industrial Management, Nano science and Nanotechnology, Mathematical Engineering, Bioinformatics and Statistics.

The Engineering Bachelor's program is divided in two consecutive phases. The first phase of the Bachelor lasts three semesters and is common for all engineering disciplines with the exception of the study leading to the degree in Architecture. For the subsequent three semesters, this is the second phase of the Bachelor's program, the students choose a Major and Minor discipline, that will prepare them for the subsequent Master's program. That way the Faculty of Engineering combines teaching a broad base of scientific knowledge with educating very specialized technological knowledge and skills.

This paper discusses the technical writing program in the first year of the Engineering Bachelor's program, which is common for all engineering students. The courses are subdivided into three groups: mathematics, energy and material science, information and communication science. Parallel to the regular coursework, all engineering students take the project based course 'Problem Solving and Engineering Design' (acronym 'P&O') that

introduces them from the first semester onwards into real engineering practice and teamwork[1]. The concept of this course is to integrate basic principles of the regular scientific courses while working in small groups on design projects. The size of the student teams (eight students) is rather large, because of the explicit focus of learning to work in a team and project management. That way the students gradually acquire technical and social skills like communication skills, information and simulation tools, experimental work, systematic approach to problem solving and engineering design, teamwork, critical attitude and creativity. Throughout the first three semesters of the bachelor, a gradual transition from solving closed engineering problems to working on open-end design projects is implemented. The assignments of the first year relate to one technological area, from 2003 until 2006 this area was 'Aerospace engineering', from 2006 until 2009 'Energy' and currently the first year students are working on problems related to 'Health science and sports'.

A typical engineer can spend up to half of his work-day on writing[2]. This makes technical communication and technical writing an important objective for engineering students, which is incorporated within the project-based course P&O from the first semester onwards. By embedding the technical writing program within an engineering design course, the writing assignments are meaningful for the students and the contents of the reports matter as well as the writing style. This paper describes the mixture of teaching and assessment methods implemented within the first year of the engineering curriculum at KU Leuven to ensure that all 400 students gradually learn more about the basic principles of writing technical reports. After instruction by the didactic team, the students are practicing by writing technical reports (learning by doing). After grading, the student teams are forced to reflect on received feedback. Furthermore, an interactive seminar using clicking devices is implemented, together with a peer review assignment. The paper first describes the implementation of the technical writing assignments. To study the efficacy of the writing program, survey data was gathered. The feedback from students and staff is discussed to evaluate the writing program and formulate some recommendations for the future.

2. Implementation of the Technical Writing Program

2. 1. Introduction

Mastering technical writing skills is difficult for first year engineering students. Leaving secondary school, they are not familiar with common technical writing style or best practices. They tend to write their reports last minute by using a journal-type style. Often they do not proof read their manuscripts and forget about feedback on previous reports. When the graded report is returned, most of the students' focus is already on their next assignment and they may not even reflect on the received feedback[2].

Within the course 'Problem Solving and Engineering Design' a mixture of teaching and assessment methods was implemented to gradually improve students' technical writing skills. Subsequent assignments force the students to reflect upon the basic writing principles and to learn from their previous mistakes. The program consists of consecutive cycles of instruction, learning by doing and reflection on received feedback. Furthermore, an interactive seminar using clicking devices is implemented, together with a peer review assignment.

The didactic staff involved in providing feedback on the writing assignments consists of three teaching assistants, one coordinator and one full professor. They all have a degree in engineering themselves.

The remainder of this section describes the different writing assignments implemented within the first year course, starting from a literature assignment in the beginning of the first semester. Table 1 gives an overview of the assignments, indicating the number of students that work together and details about the instructions and evaluation process.

Table 1. Overview of subsequent assignments within the first year engineering program to ensure that all students learn to write technical reports.

	Assignment	**Timing**	**Number of students working together**	**Instruc-tions**	**Graded**	**Feedback**	**Focus of feedback**
Intro-duction	Literature (2 pages)	Beginning of semester 1	2	Written	Yes	Written by didactic team	Writing style
Semester 1 Team project	Project report (6 pages)	End of team project, halfway semester 1	8	Written	Yes	Written by didactic team	Writing style and content
	Revised project report (6 pages)	End of semester 1	8	Oral	Yes	No feedback	No
Semester 2 Team design project	Concept report design project (3 pages)	Beginning of semester 2	8	***Interactive lecture*** and written instructions	No	Written ***peer review*** by 8 individual students	Writing style
	Intermediate design report (12 pages)	Halfway semester 2	8	Written	Yes	Written by didactic team	Writing style and content
	Final design report (12 pages)	End of semester 2	8	Written	Yes	Oral after final design presentation	Writing style and content

2. 2. Literature assignment

In the beginning of the first semester, the staff of the scientific university library 'Campusbibliotheek Arenberg' organizes a lecture about information skills and literature search accompanied by a guided tour in the library. For the assignment, the students perform a search in literature in teams of two, starting from a clear research question. Each team hands in a short scientific report (two pages maximum). The manual of the course contains clear guidelines about technical writing style. Furthermore the assignment is accompanied by some examples of specific research questions within the technological theme of the course.

The members of the didactic team grade the literature assignments by using a checklist that summarizes the desired writing abilities (table 2). This checklist makes grading easier, because of the large number of students in the course. Furthermore the checklist ensures that all staff involved in the evaluation process uses the same evaluation norms. That way, all students receive similar written feedback on the writing style of their report. This feedback is handed to the students just before their next writing assignment.

Table 2. Checklist with desired writing abilities used for the assessment of the students' assignments and for providing feedback.

Report structure	Title	Specific
	Abstract	Summary with concrete details to arouse interest
	Introduction	Description of context and outline of the report
	Other sections	Theory, practice and results (data-driven) Logical organization and coherence
	Conclusion	Summary with concrete details and most important results
	Reference list	Reliable sources
Technical writing style	Formulations, style	Specific and concrete formulations, to the point Technical language (not colloquial)
	Figures, tables and graphs	Clarify the text Clear and complete (units) Numbered, appropriate captions with reference to in text
	Equations	Accurate and complete
	References	Complete and consistent

2. 3. Team project of the first semester

The subsequent teamwork of the first semester consists of three subsequent multidisciplinary team projects[3]. The final deliverable of one of the projects in the first semester is a written report. An example of such a project within the technological theme 'aerospace engineering' is conducting an experiment to measure the propulsive force generated by the exhaust of water and caused by a chemical reaction (figure 1). That way the students can study the generation of propulsive forces in aerospace engineering by combining elements from chemistry and thermodynamics in an experiment with elements from mechanics (conservation of momentum). Each team of eight students conducts the experiment, makes the numerical calculations and then combines these two within a technical report of 6 pages maximum.

(a) (b)

Figure 1. Students are preparing (a) and conducting (b) the experiment to measure propulsive force generated by a chemical reaction and exhaust of water.

The outline of the report is predefined by the didactic team. Furthermore the students are reminded of the feedback they received on their literature assignments and of the guidelines on writing style in the manual of the course.

The report is graded by the didactic team on the content as well as the writing style. The student teams receive feedback on both aspects. The same list of writing abilities from the previous assignment is used (table 2). Each team receives individual written feedback on a hard copy of their report.

To ensure that the students reflect upon the feedback they received, each team is encouraged to hand in a revised copy of the report. The revised report is again graded by the didactic team on the content as well as the writing style. The teams need to improve their writing for getting a higher grade based on the revised report.

2. 4. Team design project of the second semester

Design project

In the second semester, new teams of eight students are formed. Each team works on the same closed design project. An example within the technological theme 'Energy' is the designing and building of a vehicle for travelling on a railway track to a defined end-point with minimal energy-input. The vehicle starts from a height, with a certain amount of potential energy, and needs to ride up a bigger hill at the end of the track (figure 2). At an optimally chosen moment during the ride, additional energy is needed. Student teams can choose almost freely the source for this extra energy. It can be electrical, mechanical, thermodynamical by using compressed air, or a combination of these energy forms. Each team conducts an experiment to measure the friction characteristics of their vehicle and makes a numerical simulation of the ride.

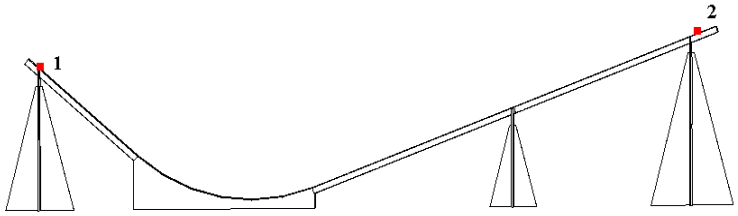

Figure 2. Sketch of a railway track with (1) the starting point and (2) the end point of the ride.

Concept report, peer review process and interactive lecture

After receiving the instructions, students follow a simple linear design process. In the second week of the project, each team hands in a concept report of their design solution (3 pages maximum). This concept report needs to describe the problem as well as the team's chosen solution. The students are reminded of the guidelines in the manual of the course and of the feedback they received on their reports in the first semester.

After handing in their concept report, each individual student makes a peer review of one concept report of another team. Peer review has been effectively used to improve student writing[4,5,6]. This peer review process was first implemented in the academic year 2008-2009.

Since 2011, an interactive lecture about technical writing style was given by a member of the didactic team prior to the peer review process. In this lecture all desired writing abilities (table 2) are discussed by means of multiple choice questions. The students are asked to

answer the multiple choice questions with individual clicking devices. That way they are actively involved during the lecture and encouraged to reflect upon writing style. After each question the lecturer shows the histogram of students' responses and the different chosen possibilities are discussed within the group. All multiple choice questions are built upon common student errors and all examples were taken from the students' own project reports of the first semester.

After the lecture, each student is asked to review the concept report written by another team and provide formative assessment that can be used to refine and improve the report. The peer reviews are double blind: the students don't know who they are reviewing, nor do they know who reviews their report. Instructions for the review are based upon the existing checklist of writing abilities (table 2). Students were asked to focus merely on the writing style of the report, more than on the analytical content.

After the peer review process, each team receives eight reviews to improve the report.

Intermediate report
Halfway the second semester, each team hands in an intermediate report (12 pages maximum), which contains not only the problem description and concept solution, but also the numerical model, performed experiments and materials that will be used in the design. Students are encouraged to build upon the concept report and improve their writing by using the peer feedback. They are again reminded of the guidelines in the manual of the course.

The intermediate report is graded by the didactic team on the analytical content as well as the writing style. The student teams receive individual written feedback on both aspects.

Final report
Based upon the feedback on the intermediate report, each team hands in a final report at the end of the design project (12 pages maximum). The guidelines contain the outline of the report and remind the students of previous feedback and guidelines.

The final report is graded by the didactic team on the content as well as the writing style. The student teams get oral feedback after the final presentation of their design project.

3. Evaluation and Discussion

Introduction
For evaluating the efficacy of the implemented technical writing program, data was obtained from students by means of surveys at the end of each semester[3]. Each semester from 2006 until 2011, all 300 to 400 students enrolled in the 'Problem Solving and Engineering Design'-course, filled out a questionnaire. Students were asked to indicate to what extent they agreed upon the statements on a 6-point Likert-type scale (1 = strongly disagree; 6 = strongly agree). The statements differed each academic year, because mostly the recent innovations were questioned. Besides these closed statements, open-ended questions were added to the questionnaire to get more insight in the ideas of the students. The writing program was then evaluated by item analysis of the closed statements, combined with the examination of the open-ended questions and interviews with the staff involved.

Literature assignment

Part of the introduction into information competencies takes place during the guided tour in the library in the beginning of the academic year. The usefulness of the tour was questioned in the first semester of the academic year 2006-2007.

Despite the literature assignment for which they immediately need to start searching for information and use the tools explained during the tour, the students are not convinced of the usefulness of this tour. 50 % of the interrogated students agreed the guided tour to be useful, overall mean is 3.36 (s.d. = 1.39; n = 381; figure 3). Students often do not see the immediate use of this library tour and they do not make the direct connection with their grades.

Additionally not all students believe they have learned how to refer to relevant sources (figure 4), the overall mean is 3.97. There is however a significant effect of the semester: the average result for the first semester is significantly higher. This can be explained by the amount of time students put in their literature assignment at the beginning of the first semester.

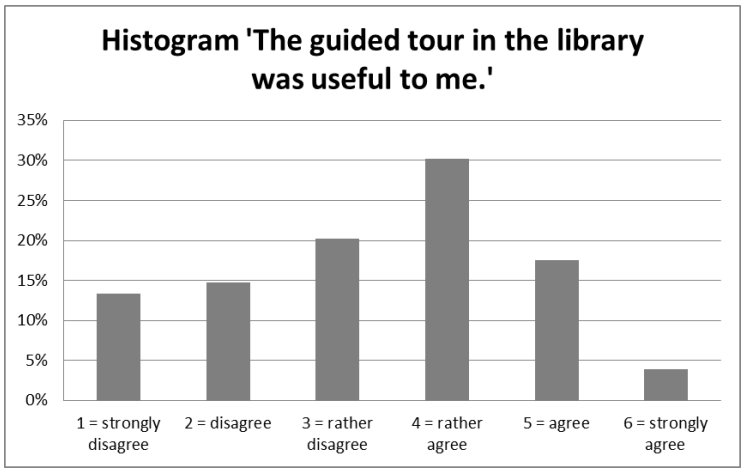

Figure 3. Histogram of the statement 'The guided tour in the library was useful to me'. Overall mean 3.36 (s.d. = 1.39; n = 381; academic year 2006-2007).

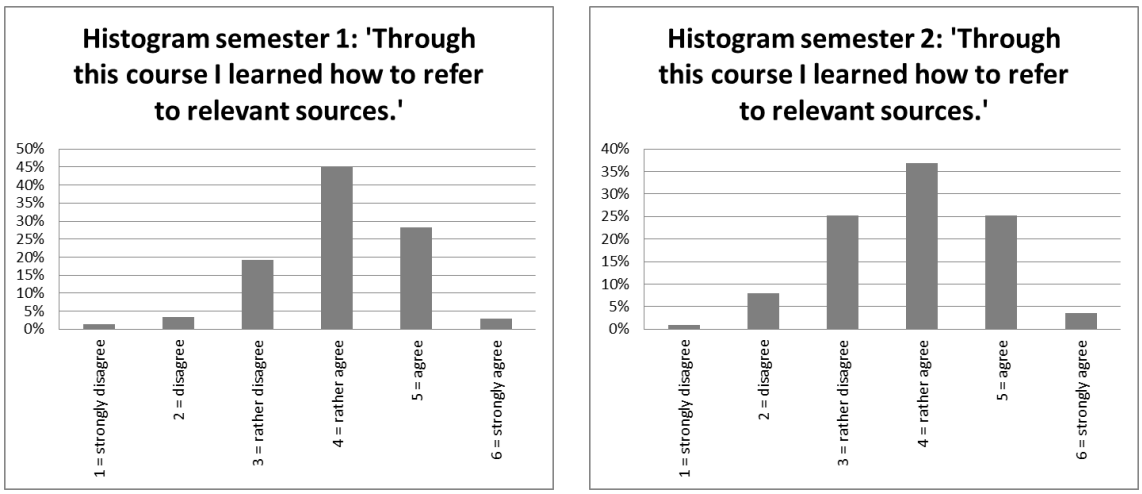

Figure 4. Histogram of the statement 'Through this course I learned how to refer to relevant sources'. Overall mean 3.97 (s.d. = 0.97; n = 709; academic year 2006-2007). There is a main effect from the semester: the mean of semester 1 (4.04; s.d. = 0.92; n = 381) is significantly higher ($p < 0.05$) than for semester 2 (3.89; s.d. = 1.01; n = 324).

Desired writing abilities

In the academic year 2006-2007 statements related to learning how to write technical reports were included in the questionnaire. These results are gathered before the peer review process was implemented.

Overall mean on the question 'The didactic staff explain the criteria for a good scientific report' is 4.11 (s.d. = 1.11; n = 709; figure 5). The average of the second semester (4.38; s.d. = 0.95; n = 324) was significantly higher than the mean value of the first semester (3.88; s.d. = 1.18; n = 381). This confirms the gradual building up of competencies: students gradually know more about writing technical reports.

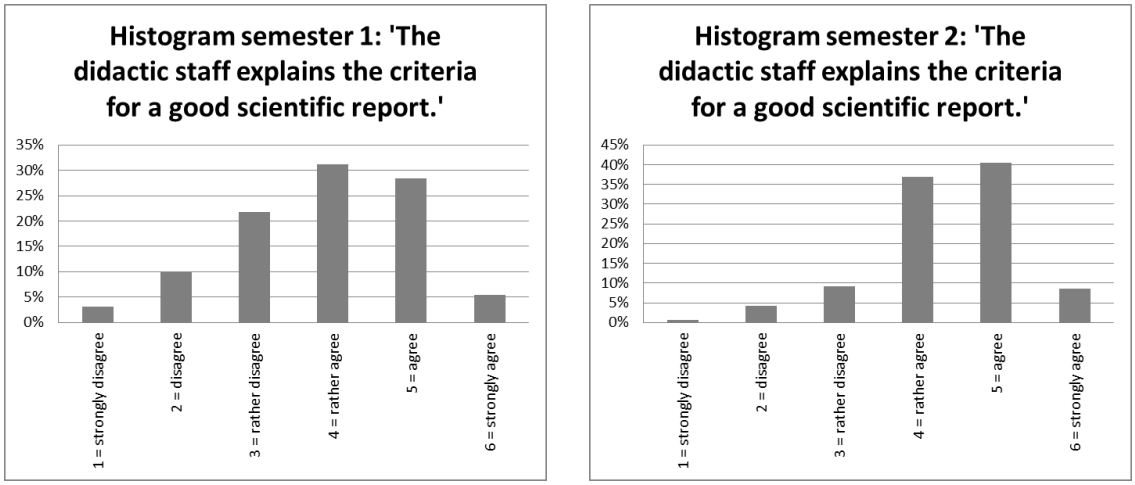

Figure 5. Histogram of the students' answers on the statement 'The didactic staff explains the criteria for a good scientific report' (academic year 2006-2007). The average of the second semester (4.38; s.d. = 0.95; n = 324) was significantly higher than the mean value of the first semester (3.88; s.d. = 1.18; n = 381).

Peer review process

The peer review process was first implemented in the academic year 2008-2009. (The interactive lecture was not part of the process yet. The lecture was first implemented in 2011.)

At the end of the second semester in 2009, 313 students filled out an online survey about the peer review process. 60 % of the interrogated students agreed to have learned more about technical writing by peer reviewing the concept report of another team (figure 6). 72 % of the students felt that this review process was useful (figure 7) and 68 % of the students thought that the feedback they got from other students helped to improve their report (figure 8).

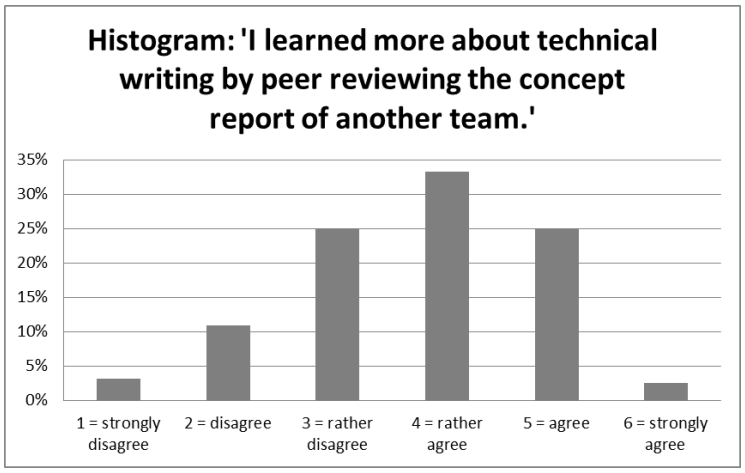

Figure 6. Histogram of the statement 'I learned more about technical writing by peer reviewing the concept report of another team.' Overall mean 3.74 (s.d. 1.12; n = 312; academic year 2008-2009).

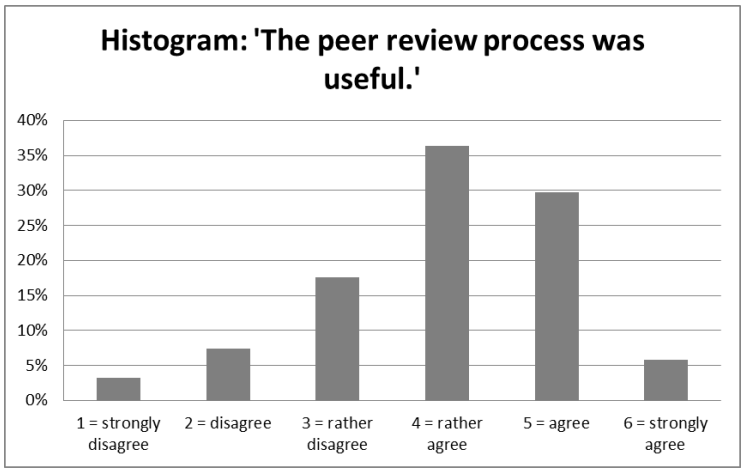

Figure 7. Histogram of the statement 'The peer review process was useful'. Overall mean 3.99 (s.d. = 1.14; n = 313; academic year 2008-2009).

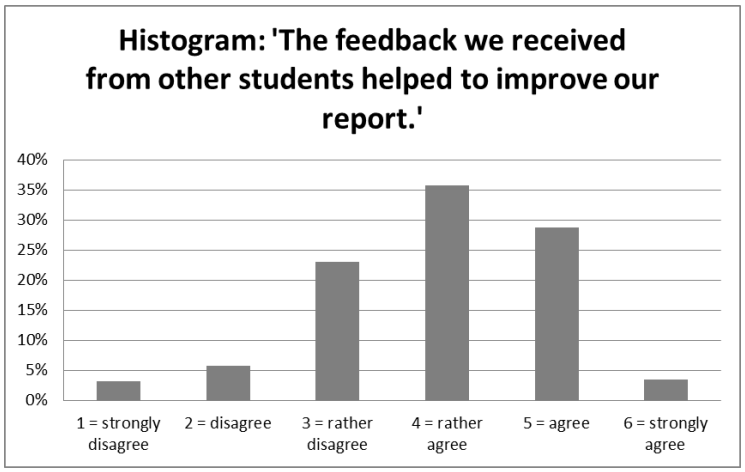

Figure 8. Histogram of the statement 'The feedback we received from other students helped to improve our report'. Overall mean 3.92 (s.d. = 1.08; n = 313; academic year 2008-2009).

Interactive lecture

The interactive lecture was first implemented in the recent academic year, 2010-2011. At the end of the second semester in 2011, all 408 students filled out a questionnaire about the lecture. Overall impression of the students was positive, 62 % of them indicated that the lecture improved their understanding of writing technical reports (figure 9). 80 % of the interrogated students appreciated that all examples were taken from their own project reports of previous semester (figure 10).

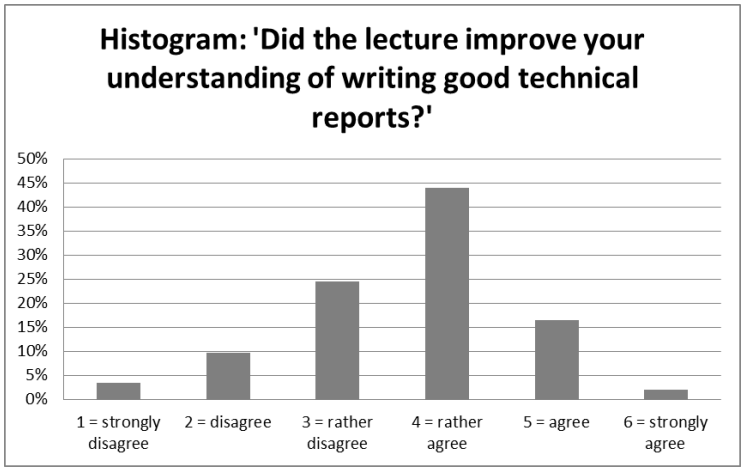

Figure 9. Histogram of the student answers on the statement 'Did the lecture improve your understanding of writing good technical reports?' Overall mean 3.66 (s.d. = 1.14; n = 405; academic year 2010-2011).

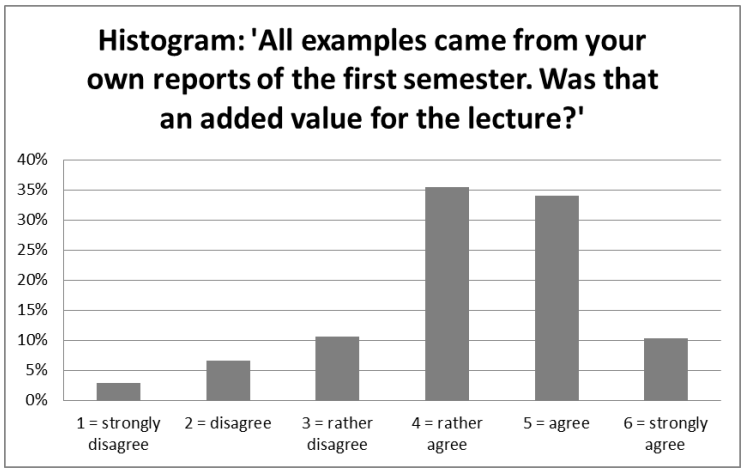

Figure 10. Histogram of the statement 'All examples came from your own reports of the first semester. Was that an added value for the lecture?' Overall mean 4.22 (s.d. = 1.16; n = 406; academic year 2010-2011).

For the first year students, the interactive lecture organized about technical writing, was the first one where they were able to use the clicking devices to answer multiple choice questions. 74 % of the students indicated that this made them think actively during the lecture (figure 11) and 72 % feels this kind of interactive lecture is an added value (figure 12).

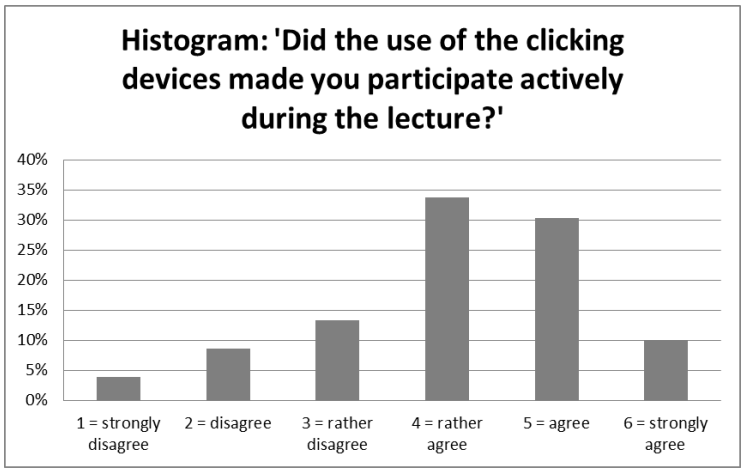

Figure 11. Histogram of the statement 'Did the use of the clicking devices made you participate actively during the lecture?' Overall mean 4.08 (s.d. = 1.24; n = 406; academic year 2010-2011).

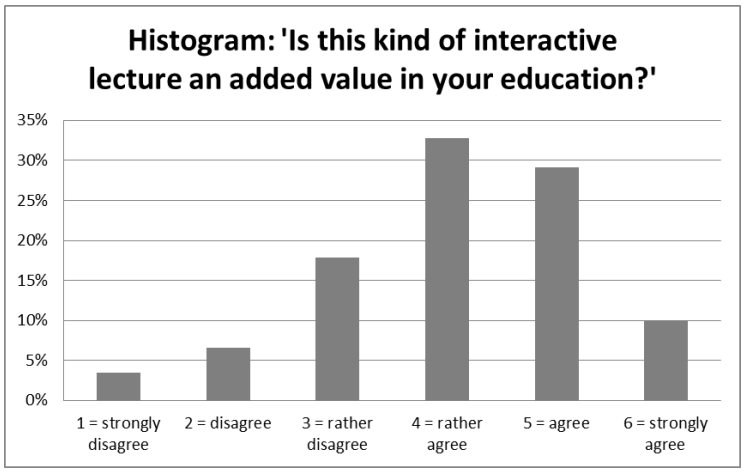

Figure 12. Histogram of the statement 'Is this kind of interactive lecture an added value in your education?' Overall mean 4.07 (s.d. = 1.20; n = 408; academic year 2010-2011).

To improve the lecture and its organization, an open-ended question was added to the survey. Students were asked what they would change to improve the interactive lecture.

Because of practical problems, not all students were able to follow this lecture prior to the peer review process. So a lot of the students commented on the timing and practical organization of the lecture. Some students even suggested to scheduling the lecture already in the first semester.

Other comments were made regarding the timing in class. Some students argued that the tempo was to slow, others discussed that there was not always time enough to thoroughly discuss all the examples. This corresponds well with the ideas of the lecturer. She had already the impression that some students took the lecture very seriously and discussed in class, while others purposely choose the wrong multiple choice answers.

4. Discussion and Future Perspectives

Overall, the didactic staff involved, as well as the students, are enthusiastic about the approach. Because of the large number of students enrolled in the course (about 400 each academic year), the staff really appreciates the use of a checklist with desired writing abilities. This checklist makes it easier to evaluate large numbers of reports. Furthermore it ensures that all different staff members use the same evaluation criteria for grading and providing feedback.

It is the experience of the didactic team that students do need to be reminded constantly of the guidelines and previous mistakes. Otherwise, even in the third semester, they tend to make the same mistakes again.

The students most appreciate the more recent developments within the program. Most students feel that the peer review process, which is implemented since 2008, is useful. Furthermore they agree that the clicking devices, used in the interactive lecture in 2011, made them think actively about their writing skills during the lecture. Overall, the students as well as the lecturer, felt that the interactive lecture was an added value to the course and the clicking devices are a good way to get the students involved in class.

Based upon the experience of this year, mainly the practical organization of the lecture will be improved. Also the examples used in class, as well as the tempo of the lecture, need some revising.

Furthermore, in the second semester, the students will be asked to formatively grade the concept report of the other team as part of the peer review process. In a previous study by L. Barosso and J.R. Morgan at Texas A&M University, this gave the students a perspective on how the grading process works[7]. Although the peer review scores were strictly formatively, students are still highly sensitive to the numbers. The students tend to evaluate harsher than didactic staff, but generally the comments and identified weaknesses were actually the same.

At the moment, only qualitative data from the staff involved and self-reported data from the students are used to evaluate the implementation of the writing assignments. The current academic year, the study will be completed by adding detailed information about the evolution of the students' grades. Because this is a direct measurement of the actual writing skills of the students, the comparison between the grades and the self-reported data will provide more insight in the efficacy of the writing program. Furthermore the students themselves will be encouraged to keep track of the evolution of their technical writing skills by summarizing received feedback in their portfolio.

5. Conclusions

Technical communication and technical writing are important skills for the daily work-life of every engineer. In the first year engineering program at KU Leuven, a technical writing program is implemented within the project based course 'Problem Solving and Engineering Design'. By embedding the technical writing program within an engineering design course, the writing assignments are meaningful for the students and the contents of the reports matter as well as the writing style.

The writing program consists of subsequent cycles of instructions, learning by doing and reflection on received feedback. In addition a peer review assignment, together with an interactive lecture using clicking devices, are incorporated within the assignments of the second semester.

Overall, the didactic staff involved, as well as the students, are enthusiastic about the approach. The current academic year the program will be fine-tuned. Mainly a grading process will be added to the peer review assignment and the practical organization of the lecture will be revised. Furthermore, the study of the efficacy of the writing program will be completed by adding detailed information about the evolution of the students' grades.

Reference list

[1] Heylen C., Smet M., Buelens H. and Vander Sloten, J., 2007, Problem Solving and Engineering Design, introducing bachelor students to engineering practice at K.U.Leuven. *European Journal of Engineering Education*, 2007, 32 (4), pages 375 – 386.

[2] Kuder, K. and Gnanapragasam, N., 2011, Implementing peer-reviews in civil engineering laboratories, *Proceedings 118th ASEE Annual Conference & Exposition*, 26th - 29th June 2011, Vancouver, Canada.

[3] Heylen, C., 2010, *Problem Solving and Engineering Design: introducing bachelor students to engineering practice.* 2010, Diss. Doct., ISBN 978-94-6018-237-2. (Available online: https://lirias.kuleuven.be/bitstream/123456789/270889/1/ doctoraat_tekst_cheylen_archief.pdf 04/04/2011)

[4] Cho, K., and Schunn, C.D., 2007, Scaffolded writing and rewriting in the discipline: A web-based reciprocal peer review system, *Computers & Education*, Vol. 48, No. 3, 2007, pp. 409-426.

[5] Shaw, D., 2008, Enhancing the Laboratory Experience Using Peer Evaluation of Group Laboratory Reports in a Fluid Mechanics Course. *American Society of Engineering Education 2008 Annual Conference*. 2008. Pittsburgh, PA.

[6] Daniell, B., et al., 2003, Learning to Write: Experiences with Technical Writing Pedagogy within a Mechanical Engineering Curriculum". *American Society of Engineering Education 2003 Annual Convention. 2003*. Nashville, TN.

[7] Barosso, L. and Morgan, J.R., 2011, Incorporating technical peer review of civil engineering student projects, *Proceedings 118th ASEE Annual Conference & Exposition*, 26th - 29th June 2011, Vancouver, Canada.