Bachelor project with industrial relevance for large student groups

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INTRODUCTION

Student projects have become an important part of most modern engineering curriculum, to provide students with actual engineering experience [1-5]. Projects offer students hands-on experience to complement theoretical courses and aim to build team work and management skills. Although projects require a high effort both from students and staff, their effectiveness is higher than for traditional lectures and exercise sessions. While the effectiveness of a traditional lecture can be as low as 5-8%, because of the limits of the attention span of students, project-based education is much more effective [6-8]

At Group T, International University College Leuven in Belgium, we support this philosophy wholeheartedly by organising increasingly complex student projects throughout the three bachelor years [1,9]. The first projects focus more on building basic project skills while providing extra exercise for scientific and technical knowledge and skills. The final project for electromechanical engineers, called “Engineering Experience 5: Design of an automated machine” (EE5), however, offers students a real engineering challenge. It is an open-ended project where an industrial partner provides an actual design question. Students tackle an industrial design from the design question until the finished design on paper, containing production and assembly drawings, wiring diagrams, etc. The project runs for a full academic year and is – in contrast to in-company projects – mainly coached by college staff.

Since 2006, the number of students participating in the EE5 project has almost doubled, from 116 students [1] to 176 students in 2012-2013. Meanwhile, the amount of time staff members have available for coaching has not increased. In the previous academic year, 2011-2012, there were 154 students, which were divided in teams of 7 or 8 students. This was perceived as too large, both by the students as by the staff. It was very difficult to evaluate the individual students, and the risk of spongers was too high. Especially during the conceptual phase, it was impossible to determine the creative input of each student. Therefore, a completely new approach was desirable.

First, this new approach is explained in detail, following the different design phases. Next, the evaluation method is presented. Finally the new project approach is evaluated in a discussion and the student perception is taken into account.

1 PROJECT ORGANISATION

The idea of the project is that the students act as an engineering company working for a client, represented by both the industrial partner and the coaches. Because of organisational issues, the large group of 176 students is split in three smaller groups of about 60 students each. Each of these groups works on one industrial project and is coached by three professors. There are some organisational differences between the three groups, but the basic outline is the same. The composition of the teams is determined by the coaches, but the students can choose one partner to cooperate with throughout the project.

The project itself is divided in three phases: the orientation and analysis phase, discussed in Section 1.1; the conceptual phase, discussed in Section 1.2; and the detailed design phase, discussed in Section 1.3. Each phase has a deliverable for which the students receive a score. Since each phase of a project also has different complexity, it was decided to work with flexible team size, where team size and composition changes between phases. Table 1 summarises the timing of the phases and the deliverables.

Table 1. Time schedule of the project. The project runs for 14 weeks during the first semester and 6 weeks during the second semester. During the examination period in between there is a project week (P) organised. There are six deliverables (d1-d6), and three seminars planned: s1 about the design process, s2 about conceptual design and safety priorities, and s3 about technical drawings.

Semester	1															2					
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	P	1	2	3	4	5	6
Orientation phase	s1		d1																		
Conceptual phase			s2						d2												
Design phase														s3			d4		d5	d6	
Individual test																					

1.1 Orientation and analysis phase

Before the students can start devising solutions, they have to properly analyse and define the problem. They start from a problem description of only one single paragraph long. During the first phase, the students have to create a *quantitative* list of requirements containing all demands and wishes of the client. That way the assignment becomes concrete and any vagueness is removed.

To accomplish this, they have a discussion with a representative from the company, who answers their questions and gives them the required detailed information. The students prepare this discussion thoroughly, so they know which questions to ask and make sure they receive all the data they need.

This phase takes three weeks, during which the students work in teams of four students. The deliverable of the orientation phase (d1) consists of a detailed

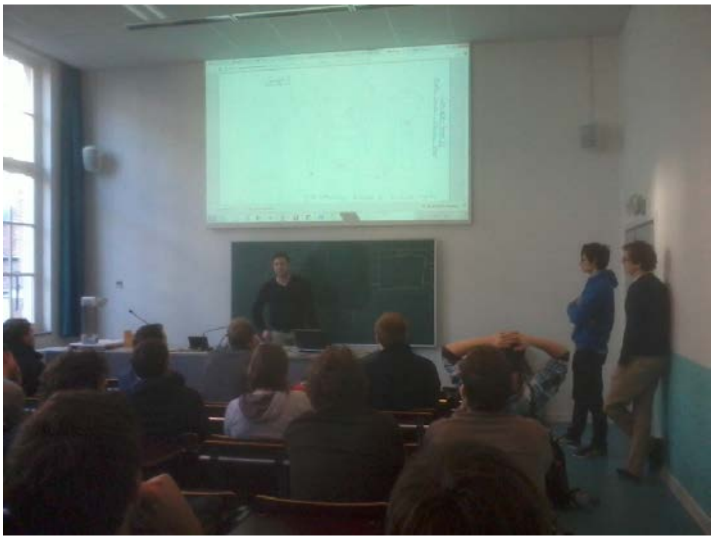

Fig. 1. Final concept discussion in group of 60 students

functional decomposition and a detailed list of requirements. Afterwards, the coaches provide the students with a good and complete functional decomposition and list of requirements to ensure that all teams start the next phase on a solid base.

1.2 Conceptual phase

Once the assignment is properly defined, the conceptual phase is devoted to the generation of ideas. Concept generation should contain two steps: *divergent* in which alternative concepts are generated, and *convergent* in which these are evaluated and selected. Ideally, this happens in several iterations [10], and the conceptual phase of this project was organised as such.

During the conceptual phase, the students have to develop detailed concepts in teams of two for six weeks. The advantage of working with small teams is that the ideas of all students get a chance to surface and that it is easier to evaluate the students. The first divergent step is done by each of those teams at the start, where they have to come up with concepts for each of the functions described in the functional decomposition. This is followed by the first convergent step, during which the most promising partial concepts are selected function by function. Next, each team combines their partial concepts into various complete concepts, another divergent step. Finally, they make an argumented selection of three of their concepts which are elaborated further. By the end of this phase, the students should prove that their concepts are feasible, safe, producible and economically viable and that they provide a solution for each function and requirement. They already make simple calculations to check e.g. major dimensions or power requirements. The deliverable (d2) consists of the partial concepts, three elaborated concepts and a discussion to compare them and select the best. This deliverable should primarily consist of sketches with some clarifications.

At the end of this phase, in a major divergent step, the 30 teams of two students each deliver one or two concepts in one big pool for review by their peers. The teams get one week to study all concepts and score them. At the end of the week all individual scores are combined to create a preliminary ranking of concepts, starting the final convergent step. The students then have a group discussion to clarify some concepts and come to a final ranking (Fig. 1).

Afterwards, the students had to fill in a short one page survey about the process; 165 surveys were completed. All except 3 students prepared the concept selection in advance, but they only spend on average a couple of hours to study all 30-60 concepts of their project. 51 students or 31% did not expect the preliminary ranking to change, however after the selection, 89 students or 54% of the students agreed that the final ranking was the best. 21% thought the preliminary ranking was best, and 19% were most convinced of their own ranking; 7 students left this question blank.

The final convergent step in the concept selection was different for the three groups.

Group 1: In the first group, the coaches organised a one hour speed dating activity, just before the concept selection session, allowing the students to gain additional information on competing concepts. This activity was immediately followed by the plenary selection session. During this session the students were asked to decide on a final ranking of concepts, thus selecting the ten best concepts. From this moment on, the coaches no longer interfered. In this group, after about half an hour of chaos, the students decided to first form teams themselves and than each team decided on a concept. The coaches and the company had very limited influence on the concepts chosen. In this group, only 29% of the students agreed that the final ranking was best, 67% could defend their opinion and 52% had the impression everyone was listened to.

Group 2: In the second group, the coaches asked the students to hand in their reports a week earlier, so they could give feedback and the final concepts would be more according to expectations. The students had to score all 60 concepts on both occasions, so the first time they also got feedback about how the other teams rated their concepts. The entire group entered then in a four hour long group discussion without the presence of the coaches. Meanwhile the coaches did the same together with the company representative. There was a good correlation between the ranking of the students and the concepts. In this group, 58% of the students agreed that the final ranking was best, 80% could defend their opinion and 53% had the impression everyone was listened to.

Group 3: The third group first organised the students in four subgroups of 15 students. These teams were left to their own with minimal instructions to attain a top ten ranking of concepts. All of the groups decided to review and clarify the concepts one by one and discuss their value. After two hours, all 60 students gather in a bigger room without instructions about how to proceed. A few students quickly took the lead to start the discussion. The four rankings were combined and everyone got the chance to bring new arguments or ask for clarification. Based on this ranking, the professors together with the company select ten concepts for the students to develop further. In order to diversify, some adaptations were made to the concepts to make sure all interesting partial concepts are elaborated. The team of professors also divide the teams for the next phase, making sure that the students who created the selected concepts get to work on their own ideas. In this group, 73% of the students agreed that the final ranking was best. 69% found it useful to first have discussions in smaller groups. 96% could defend their opinion in the small groups, while only 50% could do so in the large group. Moreover, 96% had the impression everyone was listened to in the small groups, against only 34% in the large group.

1.3 Detailed design phase

During the last phase, the students make a detailed design in ten groups of six for seven weeks. The end result is a technical report (d5) comprising two parts. The first part contains the *design motivation*: the design of the machine is presented together with the detailed calculations of all parts, the choice of components and the materials selection. Each design decision has to be justified.

The second part contains the *design* itself: everything required to produce the parts and assemble the machine, such as technical drawings and electric schemes. The set of technical drawings contains the assembly drawing, bill of materials, and drawings of the subparts indicating material, dimensions, tolerances and roughness. Electric schemes include the wiring diagrams, control logic and a list of components.

Once during this phase, at a time chosen by the team of students, an intermediate report can be handed in (d3). The professors can check this to provide feedback. Contrary to the expectations of the coaches, almost no teams made use of this possibility. Two weeks before the final report (d5), the students hand in a preliminary version (d4), after which the coaches provide the last and thorough feedback.

Finally, the students present their work to the company representative, both with the final report and in an oral session, allowing for questions and discussion (d6).

2 EVALUATION

The students are evaluated on the different deliverables according to Table 2. The scores on the deliverables are team scores, and the 'Process and results' score is partially individual.

2.1 Individual evaluation tools

Due to the large amount of students it is impossible for the team of professors to know each student personally or to properly judge his or her individual contribution. In order to evaluate the students individually, students complete two peer assessments. An individual test at the end of the project allows the coaches to identify spongers. This test consists of basic questions based on their own report. If students fail the test, they cannot earn a credit for the project. The tests are designed in such a way that students who participated fully in every aspect of the project, should have no problem with it.

For most students, the score is simply calculated as given in Table 2. For the 'Process and results' part, the student receives the team score, unless the team of professors perceived a difference in contribution between team members and this perception is confirmed by the peer assessment. The total score is also individualised by the fact that the students receive three team scores from being in three different teams.

For about 5% of the students there was deviated from this table. In each case, it was a combination of an unacceptable individual test, a very low score on the peer assessment, and a negative perception of the coaches.

Table 2. Evaluation of the students

Evaluation element	**Team/individual**	**Score**	**Weight**
Functional decomposition and list of requirements (d1)	Team of 4	(0-20)	3
Concepts (d2)	Team of 2	(0-20)	5
Process and results (d5)	Team of 6/individual	(0-20)	12

Test	Individual	Pass/fail	
Presentation and report (d5-d6)	Team of 6	Bonus/malus ±2 on total score	±2
Total *(not necessarily the numerical weighted sum of the above scores)*			**20**

3 DISCUSSION AND CONCLUSION

Overall, the experience from the staff members involved was that the presented approach works and allows to handle the large amount of students while still being able to give them an individual score with confidence. Flexible team size allowed to optimise each phase separately. The main issues rose from insufficient communication towards the students. Compared to the earlier projects in their curriculum, the students are required to work much more independently, which was not always according to their expectations. They complained about the uncertainty of the assignment, while that is inherent to unsolved industrial problems.

In previous projects, the students learned about project management: how to make and follow a planning, how to divide tasks and how to communicate within the team. In this project, it was left mostly to themselves to decide how they handled the project. At the end of the project, after the individual test, 137 students completed another one page survey about this. In group 1, the coaches obliged the teams to make a planning. 51% found their planning useful, 41% found it a bit useful and 8% found it useless. In the other two groups, which did not oblige a planning, only 14 students or 16% indicated that they did not make a planning, and 9 of those thought their results would have been better if they had made a planning. Of those that made a planning spontaneously, 55% found it useful and 36% found it a bit useful. Overall, this indicates that they learned the usefulness of a planning in the earlier projects.

The most important innovation of the approach presented here was the concept selection. Three different methods were used with varying success. In the first group, the students did not spontaneously engage in a group discussion and instead chose to first divide themselves into smaller teams, mostly consisting of friends. As a result, not the best concepts were selected, but rather did the students choose their own concepts. This is reflected in the fact that only a minority thought the final concepts were the best. Language issues or cultural difference might have played a role in group 1, since half the students were of a different nationality and English was the language of the discussion, while the other groups were exclusively Belgian. In group 2, the final discussion in a large group was perceived as too chaotic and too short by the students. The fact that they reached the same conclusions as the professors, however, indicates that the method worked well enough. The method used in group 3 was best received by the students, and that group had the highest acceptance of the final ranking. The level of participation greatly decreased between the group sizes of 15 and 60. It should be noted that the objective quality of the concepts is not considered here, only the quality as perceived by the students. Overall, the concept selection was perceived as too subjective, as the concepts of the most vocal students got higher ranks.

In a general remark about the project, the students judged the conceptual phase too long, and the design phase too short. This probably stems from the fact that it was insufficiently clear to the student what was expected from their final concepts. As a result, they did not put a sufficient amount of work in the concepts and those concepts were not as detailed as they should have been. Thus, some conceptual work still needed to be done in the detailed design phase. Better communication and more feedback at the start of the project is the proposed solution.

A last frequent comment from the students is that they think the individual test is not the right way to identify spongers, and the peer assessment or a group discussion should be used instead. 13% thinks the test was a good method, and 43% thinks it was no good at all. All except one student do agree that spongers do not deserve the same score as the other team members, and 43% thinks that spongers should even fail the course.

To conclude, a flexible team composition allowed for individual evaluation but a well structured organisation and a clear communication with the students remains vital.

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