World Transactions on Engineering and Technology Education
Vol.5, No.2, 2006

Design-build projects and assessment at Hogeschool Gent

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ABSTRACT: Two years ago, Hogeschool Gent in Ghent, Belgium, became a full collaborator in the *Conceive – Design – Implement – Operate* (CDIO) organisation. The CDIO philosophy, as expressed in its 12 standards, was adopted by the Department of Engineering Studies INWE as the *Departmental Educational Development Plan* (DOOP). As part of the gradual introduction of these standards, design-build projects for all (>250) of its first year students were introduced. In the article, the elaborate on the way that some specific limitations are dealt with, such as diverse student population, existing curriculum and limited financial resources. The initial projects are described and the test used to form the student groups and the effect of this group formation on the final result of the projects are also presented. The authors also elaborate about the mix of assessment methods, namely: product evaluation, and peer and self-assessment. Examples of the criteria used in these methods are given, together with the pitfalls and improvements. Plus and minus points of these projects are discussed and the results obtained with the project in the second year electronics course are also described.

INTRODUCTION

In 2004, Hogeschool Gent became a full member of the *Conceive – Design – Implement – Operate* (CDIO) organisation [1]. As a result of this, the Department of Engineering Studies INWE adopted the CDIO philosophy, as expressed in its 12 standards, as the *Departmental Educational Development Plan* (DOOP) [2]. A taskforce of three people (the first three authors) was formed, its mission being the introduction and steering of the changes that had to be taken in order to comply with the 12 standards. At the same time, the Belgian university landscape had to make the transition from a 2-2 year structure to a 3-1 year bachelor-Master structure. As such, the taskforce opted for a gradual introduction of the necessary changes, parallel with the bachelor-Master transition.

From the start, the taskforce decided to focus on Standard 4 (introduction to engineering), Standard 5 (introduction of design-build experiences), Standard 7 (integrating learning experience) and Standard 11 (CDIO skills assessment). Since these standards involve active student participation and thus result in more visible effects, the taskforce hoped to convince sceptical teaching faculty members of the value of the CDIO programme and the necessity of programme reforms.

DESIGN-BUILD PROJECTS

In the second semester of the 2004-2005 academic year, design-build projects were for the first time introduced for all (>250) first year students. This was complicated by an already fixed curriculum. Since Hogeschool Gent has no entrance examinations, the population of freshmen is very diverse regarding technical and scientific knowledge, motivation, social skills, etc. Furthermore, the financial resources for these activities are very limited. As such, these factors limit the choice of feasible projects.

In order to overcome the problem of an already fixed curriculum, the taskforce managed to gain the cooperation of colleagues from the mathematics, physics, informatics and mechanics disciplines. The instructors of these courses agreed to replace the hours normally taken for laboratory work and theoretical exercises with a design-build project that lasted for three weeks. The total time available for the completion of the project was 24 hours. In this academic year, 24 hours in the second semester were also obtained, but this time spread over six weeks. These hours were not taken from *normal* curriculum time, but instead allocated to C-hours, which is when students are is expected to study or undertake extra work for a discipline.

To carry out this type of project, students are grouped into teams that are guided by coaches. These teams have a choice of four assignments from which they choose one after consultation within the team. Every team has to build a specific working model that has to be tested according to a model-specific procedure. Teams then present a report of their activities, describing their solution to the problem and elaborating on the technical and theoretical background of their chosen project. Every team also gives a *PowerPoint* presentation to other teams, describing their activities and results in a non-technical and non-specialist manner.

Choice of Design-Build Projects

In order to meet the demands of Standard 7, a design project has to fulfil certain criteria, as follows:

- It has to be multidisciplinary, meaning aspects of different disciplines can be found in the project;
- It has to be an *open* problem, meaning there is no fixed and unique solution to the problem;
- It has to stimulate the creativity of the students involved;
- It has to be sufficiently complex to justify teamwork.

Formulating an appropriate low-cost design-build project, suitable for first-year students with limited knowledge and experience is not an easy task. In order to enhance the motivation and interest of the coaches, this is best achieved in dialogue with them and colleagues from various disciplines, thereby safeguarding the multidisciplinary character. Table 1 summarises the chosen assignments and specific testing procedure.

Table 1: Examples of design-build projects for first-year engineering students.

Assignment (2004-2205)	Testing Procedure
Construct a beam or bridge with a minimal span of 60 cm, using a maximum of 1 kg of uncooked spaghetti. The joints are to be glued.	The construction is loaded with weights until it breaks. The ratio maximal load/weight of beam has to be maximised.
Build a hot air balloon operated on a maximum of one spoon of fuel. A hair dryer is allowed for the initial lift.	The maximum height and time of flight is measured. The product of both has to be maximised.
Build a plane out of paper or cardboard with a launching pad, operated via a lever/push button.	The flight time has to be maximised.
Build a seismometer as sensitive as possible with a registration mechanism.	The smallest mass, dropped from one metre at a distance of one metre from the apparatus, is an indication of its sensitivity.
Assignment (2005-2206)	Testing procedure
Construct a bridge using A4 paper and standard paper glue. The minimum span is 50 cm and the maximum weight is 300 g.	The bridge is loaded with weight at the centre until it breaks. The ratio maximal load/weight of bridge has to be maximised.
Build a tower out of a maximum of 1 kg of uncooked spaghetti and which is able to carry a load of 20 kg.	The tower is weighted, loaded with 20 kg and its height is measured. The ratio of height/ weight has to be maximised.
Build a propeller + launching device, operated by a falling mass. No metal is allowed. The maximum falling height of the mass is 1 m.	The flight time and propeller mass are measured and the ratio of both has to be maximised.
Build a device able to launch 10 table tennis balls in 30 seconds over the net of a table. No metal springs or electrical components are allowed.	The number of balls launched within 30 seconds has to be maximised.

Although seemingly simple at first sight, most students were surprised about the complexity and difficulties that arose when building a working model that would fulfil the demands of the assignment. During the past two years, nearly all teams succeeded in their chosen assignment.

Workspaces

Apart from the low cost, these types of projects need only basic tools. In the first year, students were not given any tools at all. A dedicated workspace for building their project could not be provided either. Instead, students gathered in the physics laboratory, empty at the time of the project, and used the tools of the local workshop.

This year, some workspace was obtained that was used exclusively by the student teams and they were provided with basic equipment. From these two years, it can be concluded that the basic equipment fulfils the needs of most of the teams. Furthermore, workspace is essential and should be accessible outside *normal* work hours.

Team Formation

Since the aim is the formation of engineers who are able to work in a modern, team-based environment, the teams formed should fulfil certain criteria, which are described below.

Firstly, a team should reflect a real-life situation. Therefore, students were not allowed to form groups by themselves, but instead every student was assigned to a specific team. For organisational matters, students in each group are selected within the same discipline. Since people have to work together with different persons in the workplace, each with his/her own way of tackling a problem, it was ensured that each team was composed of members with different learning characteristics. Before the start of the project, each student was subjected to a short test designed at Hogeschool Gent [3]. This test distinguished between four learning characteristics and took only 15 minutes to complete. On the basis of the test results, students were assigned to one of the following categories: people who like to apply, people who like to do, people who like to think and people who like to observe. Each of these four learning characteristics was represented in each team. Furthermore, if possible, the teams had male and female members. In the first year, for testing purposes, a team was formed that comprised only female students, a team of only *do* students and a team of only *think* students. The female student team performed equally well as the other teams, but the *do* team and *think* team had difficulty in completing their assignment. Therefore, this year, all the teams had a mixed composition.

Secondly, a team should have a sufficient number of team members. Since the proposed projects are rather complex and the time to complete them is rather short, an average team size of seven students in the first year was targeted. This year, due to practical reasons, there were between four and seven team members. This allowed for a meaningful task of every group member. As an additional advantage, teams had the possibility to complete their projects within the allocated time schedule, even if one or two group members did not cooperate with the rest of the team. Based on the results of the previous years, it can be concluded that a team should have at least five members, but no more than seven.

To avoid any agreement between team members before the start of the project, the teams were formed during the first session in the project weeks. In this session, the team members decided on the project to be completed and they made arrangements about the different tasks for everyone.

Coaches

Every team is guided by a coach. This is a teaching assistant, normally responsible for laboratory work and theoretical exercises in the participating disciplines, ie mathematics, physics, mechanics and informatics. His/her role is to guide the different teams in their search for a solution to the chosen project, not by giving them ready-made answers, but by steering them in the right direction and giving clues where the answers might be found. It is considered that is essential in this kind of project that students find a solution themselves. No extensive technical expertise is therefore needed by a coach. Furthermore, a coach has to make sure that the team members function as a team, not as a group of individuals.

Since none of the coaches was familiar with this kind of *teaching*, all of them were introduced during the first year to group dynamics and working with groups in a half-day course given by an external expert. This year, this was not conducted, partly because the previous course proved not to fulfil the expectations of the taskforce and partly because the coaches did not want this due to the extra workload in an already busy schedule. However, it is still felt that there is a need to train the coaches; this training should not be too demanding. This problem remains to be solved in the coming year(s).

In the first year, a coach had no fixed team to guide. None of the coaches found this a satisfying situation because they did not have a clear view of the progress made by the teams. Accordingly, this year, it was ensured that every coach was assigned to a few fixed teams. In this manner, every coach had a better view of the group dynamics in his/her teams and was able to intervene more quickly if necessary.

ASSESSMENT

Since the goal is not only to give students a taste of what it is to be an engineer by letting them build something, but also to introduce them to teamwork, not only the completed product was assessed, but also the functioning of every student in a team.

Product Assessment

In order to obtain a full evaluation of every product, the following procedure was utilised:

- Every finished product was graded with respect to the specific criteria for the chosen project. These tests were performed in the presence of an external audience. This generated extra motivation for the students. Some sceptical colleagues were surprised by students' inventiveness and the ingenuity of the presented models, and afterwards expressed a more positive view of the whole CDIO project;
- The written report was evaluated regarding clarity of style and presentation. Also, the technical content was checked for errors against relevant physical or mathematical theory. Since all of coaches have a solid technical and/or scientific background, this posed no problem;
- The *PowerPoint* presentation was graded with respect to the fluency of the oral presentation, and the overall structure and creativity of the presentation. The initial scale led to too high grades according to the coaches. Therefore, a scale was used this year that provides the possibility of giving negative grades.

These three evaluations are carried out by the coaches themselves. Furthermore, every member of a team obtains the same grades. Therefore, the team has to reach an agreement about the content of the written report and presentation.

Peer and Self-Assessment

Peer assessment and self-assessment was utilised in order to assess the group dynamics of a team and the individual performance of every team member. This meant that every member grades the other team members against a few specified criteria (peer assessment) and grades himself/herself (self-assessment). The criteria used includes active participation, taking responsibility, time-management, listening to other members, being creative, and separating essentials and inessentials [4]. The same remark can be made about the scale for the product evaluation. Students felt it was important to be able to punish non-cooperative team members. This could be achieved by allowing for negative grades. Also important is to make sure that one does not have to evaluate against too many criteria. The initial form contained 16 different criteria. This year, it was reduced to 10 criteria, making the completion of the forms more accessible and the interpretation of the results more transparent.

To ensure that no arrangements about grading are made between the team members, it is not explained beforehand how every team is to be evaluated with respect to its functioning as a team. It is only during the last session of the teams where the teams learn about this method of assessment. In this last session, students are asked to honestly grade each other and themselves by filling in a form with the mentioned criteria. It is also emphasised to students that no member of a team will see the results of the other team members. It is thought that this aspect is very important in order to obtain a reliable peer assessment. For the final grade of every member, the mean of the grades attributed by the other members is taken, excluding the grade obtained via self-assessment. Self-assessment is only used to evaluate the method of peer assessment.

The overall result of every student is a weighted mean of the grades obtained for the product, report, presentation and peer evaluation. Since one of the goals is fostering the better functioning of a student in a group, greater weight is accorded to peer assessment with the following weighting coefficients being utilised: 20% product, 20% report, 20% presentation and 40% peer assessment.

After a careful examination of the peer and self-assessment results, the following observations can be made:

- With a few exceptions, the grades obtained via peer assessment did not differ significantly from the grades obtained via self-assessment, indicating that most students were honest about their contribution to the teamwork and could make reasonably good judgements about their achievements in the group;
- Some groups scored low in peer assessment, while others scored very high, indicating that in the first groups, the group dynamics was very bad, but in the second groups, there was an excellent functioning of the teams. After consulting with the coaches, this conclusion could indeed be validated.

It is thought that these observations are a result of the fact that it was promised that the results of the peer assessment would not be made public, and that it would not be revealed if students did not like particular members in a team who were not productive enough or, even worse, were counter-productive.

EVALUATION OF TWO YEARS OF FIRST YEAR DESIGN-BUILD EXPERIENCES

To have an idea how coaches and students experienced the whole project, informal talks were held with the coaches and some students in which they could freely give their opinion. The whole group of first-year students was given a form with assertions about project work, group work, the formation of teams, the role of coaches, acquired skills, workspaces, etc, on which they had to indicate their degree of agreement with the statements. They could also give their own written comments and suggestions. The following conclusions were reached, including the authors' comments and suggested solutions.

Positive remarks included the following:

- Students wanted more project-based assignments where they not only have to tackle a problem theoretically, but also experimentally. General science courses and especially engineering courses, such as mechanics and electronics, should be modified accordingly. The electronics course has already a great deal of project-based work and the laboratory component of the physics course for first and second year students has been adapted this year to facilitate more intense project-based assignments;
- Students appreciated the fact that they were pre-assigned to a team because they had the opportunity to get to know different people and were confronted with various opinions and different points of view;
- Students commented that they worked harder and believed that they had learnt more. The coaches agreed with the first statement, but whether or not the second remark is true remains to be examined;
- After completing their project, students wished to learn more about the theoretical background. It seems that starting with practical experiences stimulates the acquirement of theoretical knowledge, and not the other way around. This forms a strong argument for project-based teaching and learning in regular engineering courses;
- The coaches were enthusiastic about their role. They had a more intense level of contact with the different teams and they appreciated the fact that they did not have to *teach* in the usual sense. Most of the coaches also mentioned the high level of enthusiasm displayed by the students during the team gatherings and the active participation of the team members;
- Students spontaneously searched for information in the library and mainly on the Internet to find the appropriate books for solving a particular problem or question they find difficult.

Negative remarks included the following:

- Students wanted more time for completing the project and to experiment with the constructed models;
- The design-build experience should be spread over a longer period of time. Students tended to spend most of their time thinking and focusing on the chosen assignment, thereby neglecting other courses and tasks. This indicates that they are interested and enthusiastic about their project. Although the total time spent on the project this year is the same as last year; the use of hours outside the *regular* hours allowed for more effective time for the project without neglecting other tasks and courses;
- Students expected more help from the coaches since most of them were not trained to search for answers and pose questions by themselves. Nevertheless, with the exception of a few groups, all teams managed to finish their project and presented a workable model. Therefore, the method of not giving technical information to teams will be continued.

DESIGN-BUILD EXPERIENCE FOR SECOND YEAR STUDENTS

This year, a design-build experience was also introduced in the electronics course for the second bachelor year.

The Project

This project involves aspects of electronic design, software development, as well as mechanical engineering. The objective is to design and build *a mechanical scanned LED display which is capable of showing useful information*. The prototype has to be demonstrated, accompanied by a presentation and a written report, mentioning the activity of every team member and a technical explanation of the proposed solution. A total of 90 hours of project work is planned in the laboratory, spread out over one complete semester.

Team Formation

Students are subjected first to the same learning style test as the freshmen. Teams of seven students are then formed, taking care that every learning style is represented. Every team member has a specific function within the team. The different *jobs* are presented in an introductory session. There are people responsible for the hardware, software, CAD and mechanical aspects. The team decides about the function of every team member.

Role of Coaches

This time, the coaches give technical feedback to the students. The teams present their ideas about the technical implementation of the project and gain feedback about the feasibility of their proposal. This aspect is very important: creativity is stimulated, but the specifics of the implementation are never determined without approval from the coaches.

Furthermore, since students do not have enough engineering experience, and given the complexity of the assignment, a couple of introductory technical sessions are organised to cover some important topics directly related to the project.

Observations

Students showed a high level of enthusiasm, but had the tendency to underestimate the complexity of the project. This led to stress among students, but not to a decrease in motivation. In fact, students spent more time in the laboratory than usual. Students agreed that they had learnt a lot more compared to the more traditional methods. Coaches appreciated the motivation of students, but remarked about the large workload associated with this activity. Therefore, projects of this proportion should not be planned more than once a year in the curriculum.

CONCLUSION

Introducing CDIO into an *existing* curriculum can be a tedious process. It is felt that the approach described here, with a gradual introduction of the reforms, is the best way to achieve the goals set by the 12 CDIO Standards.

REFERENCES

1. The CDIO Initiative (2006), http://www.cdio.org
2. The CDIO Standards, http://www.cdio.org/tools/cdio_standards.html
3. GPB – Vakdidactiek, Leerstijltest. Gent: Hogeschool Gent.
4. Gielen, S., Struyven, K., Dochy, F., Beijer, L., Centrum voor Opleidingsdidactiek (2004), http://ppw.kuleuven.be/cod