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Two years of CDIO at Hogeschool Gent: design-build projects and assessment.

Johan D'heer[1], Paul Raes[2], Christian Vandenplas[3], Patrick Van Torre[4]

1. Department INWE, Hogeschool Gent, Gent, Belgium
2. Department INWE, Hogeschool Gent, Gent, Belgium
3. Department INWE, Hogeschool Gent, Gent, Belgium
4. Department INWE, Hogeschool Gent, Gent, Belgium

ABSTRACT

Two years ago, Hogeschool Gent became a full collaborator in the CDIO organisation. As a result of this, the CDIO philosophy, as expressed in its 12 standards, was adopted by the department of engineering studies INWE as "Departemental Educational Development Plan (DOOP)". From the start, the INWE department opted for gradual introduction of the 12 standards, starting with design-build projects for all (>250) of its first year students.

The taskforce, responsible for this introduction has met with some specific difficulties: diverse student population, existing curriculum, and limited financial resources for design-build projects. In this article, we will elaborate on the way we deal with these limitations, without losing the objective of introducing and improving engineering skills, according to the CDIO standards. We will inform about our initial projects, about the test we used to form the studentgroups and the effect of this group formation on the final result of the projects. To evaluate these projects and assess the students team performance, we used a mix of assessment methods: product evaluation, peer- and self-asssesment. Examples of the criteria used in these methods will be given, together with the pitfalls and the improvements we made this year.

These projects demand new ways of teaching and learning students and teachers are not always familiar with. We will inform about the comments made by the coaches of the student groups, the plus- and min-points formulated by the students and the modifications we did accordingly this year.

As a follow-up of these first year projects, the electronics course for second year students has been adapted to the methods of teaching and evaluating suggested by the CDIO standards. Initial results and observations made by students and coaches, will be presented and compared with methods and results from pre-CDIO years.

INTRODUCTION

In 2004, Hogeschool Gent became a full member of the CDIO organisation. As a result of this, the department of engineering studies INWE adopted the CDIO philosophy, as expressed in its 12 standards, as "Departemental Educational Development Plan (DOOP)". A taskforce of three people (the first three authers) 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. Therefore, the taskforce opted for a gradual introduction, parallel with the Bachelor-Master transition, of the nescessary changes.

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 on standard 11 (CDIO skills assessment). Since these standards involve active student participation and therefore result in more visible effects, the taskforce hoped in this way to convince skeptical teaching faculty members of the value of the CDIO program and the nescessity of program 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) of the first year students. This was complicated by the fact we had to deal with an already fixed curriculum.

Since Hogeschool Gent has no entrance exams, the population of freshmans is very diverse regarding technical and scientific knowledge, motivation, social skills, etc. Furthermore, the financial resources for these activities are very limited. These factors limit the choice of feasable projects.

To overcome the problem of an already fixed curriculum, the taskforce managed to get the cooporation of collegues of 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 and this for a duration of three weeks. The total time available for completion of the project became 24 hours in this matter. In this academic year, we also got 24 hours in the second semester, but this time spreaded over 6 weeks. These hours were not taken from “normal” curriculum time, but instead allocated to C-hours. This is time a student is expected to study or do extra work for a discipline.

To carry out this type of project, the students are grouped in teams which are guided by coaces. The teams have a choice of four assignments, of which they choose one, after consultation within the team. Every team has to build a specific working model, that will be tested according to a model-specific procedure. The teams 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, in which they describe their activities and results in a non-technical and non-specialist manner.

Choice of design-build projects

To meet the demands of standard 7, a design project has to fullfil certain criteria:

- 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 stimulatie the creativity of the students.
- It has to be 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. To enhance the motivation and interest of the coaches, it is best done in dialogue them and with collegues from various disciplines, hereby safe-guarding the multidisciplinary character. The following tabel summarizes the chosen assignments and specific testing procedure.

Table 1: 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 maximum 1 kg spaghetti. The joints are to	The construction is loaded with weights until it breaks. The ratio maximal load/weight of beam has to be

glued.	maximalized.
Build a hot air balloon. The maximal volume of fuel that can be used is one spoon. A hair dryer is allowed for the inital lift.	The maximal height and time of flight is measured. The product of both has to be maximalized.
Build a plan out of paper or cardboard with launching pad, operated via a lever or push button.	Time of flight has to be maximal.
Build a seismometer, as sensitive as possible, with registration mechanism.	The smallest mass, dropped from one meter at a distance of one meter from the apparatus, is an indication of its sensivity.
Assignment (2005-2206)	*Testing procedure*
Construct a bridge using A4 paper and standard paper glue. The minimal span is 50 cm and the maximal weight is 300 g.	The bridge is loaded with weight at the center until it breaks. The ratio maximal load/weight of bridge has to be maximalized.
Build a tower out of max. 1 kg spaghetti, able to carry a load of 20 kg.	The tower is weighted, loaded with 20 kg and its height is measured. The ratio height/weight tower has to be maximalized.
Build a propeller + launching device, operated by a falling mass. No metal is allowed. The maximum falling height of the mass is 1 m.	Time of flight and mass of propeller are measured and the ratio both has to be maximalized.
Build a device able to launch 10 tabel tennis balls in 30 sec over the net of the table. No metal springs or electrical components are allowed.	The number of balls launched within 30 sec has to be maximalized.

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

Workspaces

Apart from the low cost, this type of projects needs only basic tools. The first year; students weren't given any tools at all. We also could not give them a dedicated workspace were they could meet and build their project. Instead they gathered in the physics lab, empty at the time of the projcect, and used the tools of the local workshop. This year, we got some workspace, exclusively used by the student teams and we provided them with basic equipment. From these two years we can conclude that basic equipment fullfils the need of most of the teams, workspace is essential and should be accessible outside "normal" work hours.

Team formation

Since we aim at forming engineers, able to work in modern, team-based environment, the formed teams should fulfil some criteria.

First, a team should reflect a real life situation. Therefore, we do not allow students to form groups by themselves, but instead assign every student to a specific team. For organisatorial reasons, the students in each group are selected within the same discipline. Since on the workfloor, one has to work together with different persons, each one with his or her own way of tackling a problem, we make sure each team is composed of members with different learning charateristics. Before the start of the project, each student is subjected to a short test, designed at Hogeschool Gent. This test allows for discriminating between four learning characteristis and takes only 15 minutes to complete. On basis of the results of this test, one can place a student in one of the following categories: people who like to apply, people who like to do, people who like to think, people who like to observe. We make sure these four learning characteristics are represented in each team. Furthermore, if possible, we also make sure the teams have male and female members. The first year, for testing purposes, we formed a team of 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 our teams had a mixed composition.

Second, 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, we opted for an average teamsize of 7 students in the first year. This year, due to practical reasons, we had between 4 and 7 team members. This allows for a meaningful task of every group member. As an additional advantage, the team has the possibility to complete its project within the allocated timeschedule, even if one or two group members do not cooperate with the rest of the team. Based on the results of the previous years, we can conclude a team should have at least 5 members and no more than 7.

To avoid any agreement between team members before the start of the project, the teams are formed during the first session in the project weeks. In this session, the team members decide which project they will complete, and they make arrangements about the different tasks for everyone.

Coaches

Every team is guided by a coach. This is a teaching assistent, normally responsible for laboratory work and theoretical exercises in the participating disciplines, i.e. mathematics, physics, mechanics and informatics. His or 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. We feel it is essential in this kind of project that the students find a solution for themselves. No extensive technical expertise is therefore needed by a coach. Furthermore, a coach has to make sure the team members function as a team, not as a group of individuals.

Since neither of our coaches is familiar with this kind of 'teaching', we introduced during the first year all of them to groupdynamics and working with groups in a half-day course, given by an external expert. This year, we did not do this, partly because the previous course proved not to fullfil the expectations of the taskforce, partly because the coaches themselves did not want this because of the extra workload in an allready busy shedule. However, we still feel there is a need for training of the coaches; a training that should not be to demanding. This problem remains to be solved in the coming year(s).

The first year, a coach had not a fixed team to guide. None of the coaches found this a satisfying situation, because neither of the coaches had clear view of the progress made by the teams. Accordingly, we made sure this year every coach was assigned to a few fixed teams. This way, every coach has a better view of the groupdynamics in his or her teams and is able to intervene more quickly if necessary.

ASSESEMENT

Since our 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, we assess not only the completed product but also the functioning of every student in a team.

Product assessment

To get a full evaluation of every product, we use the following procedure:

- Every finished product is graded with respect to the specific criteria for the chosen project. These test are performed in precense of an extern audience. This forms an extra motivation for the students. Some of our sceptical colleagues were surprised by the inventivity of the students and ingenuity of the presented models and afterwards, expressed a more positive view against the whole CDIO project.
- The written report is evaluated against clarity of style and presentation. Also, the technical content is checked for errors against relevant physical or mathematical theory. Since all of our coaches have a solid technical and/or scientific background this poses no problem.
- The powerpoint presentation is graded with respect to the fluency of the oral presentation, the overall structure and creativity of the presentation. Our initial scale lead

to too high grades according to the coaches. Therefore, this year we use a scale that gives the possibility of giving negative grades.

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

Peer- and self-assessment.

To assess the groupdynamics in a team and the individual performance of every team member, we use peer-assessment and self-assessment; meaning every member grades the other team members against a few specified criteria (peer-assessment) and grades itself (self-assessment). A few of the criteria used are: active participation, taking responsability, time-management, listen to other members, being creative, separating essentials and inessentials. The same remark can be made about the scale as for the product evaluation. Students feel it important to be able to punish non-cooparative team members. This can be done by allowing for negative grades. Also important is to make sure one has to evaluate against not too many criteria. Our initial form contained 16 different criteria. This year we reduced this to 10 criteria, making the working up of the forms more accessible and the interpretation of the results more transparant.

To make sure no arrangments about grading are made between the team members, we do not explain beforehand how every team will be evaluated with respect to its functioning as a team. Only during the last session of the teams, they learn about these methods of assessment. In this last session we ask the students to honestly grade each other and him- or herself by filling in a form with the mentioned criteria. We also emphasize the fact that no member of a team will see the results of the other team members. We think this last one is very important to get a reliable peer-assessment. For the final grade of every member, we take the mean of the grades attributed by the other members, excluding the grade obtained via self-assessment. This last one is only used for assessing the method peer-assessment itself.

The overall result of every student is a weighted mean of the grades obtained for the product, the report, the presentation and the peer-evaluation. Since one of our goals is getting better functioning of a student in a group, we give more weight to the peer-assessment and use the following weighting-coëfficients: 20% product, 20% report, 20 % presentation and 40% peer-assesment.

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

- With a few exceptions, the grades obtained via peer-assessment do not differ significantly from the grades obtained via self-assessment, meaning most students are honest about their contribution to the teamwork and can make reasonably good judments about their achievements in the group.
- Some groups score low in peer-assessment, others score very high, indicating that in the first groups, the groupdynamics was very bad, and in the second ones, there was an excellent functioning of the team. After consulting with the coaches, we could indeed validate this conclusion.

We think these observations are owing, part of it, to the fact we promised to make the results of the peer-assessment not public, and, part of it, to the fact students do not like members in a team who aren't productive enough, or even worse, who are counter-productive.

EVALUATION OF TWO YEARS OF FIRST-YEAR DESIGN-BUILD EXPERIENCES.

To have an idea how coaches and students experienced the whole project, we had informal talks 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 projectwork, groupwork, formation of teams, the role of coaches, acquired skills, workspaces, etc. On this form, students had to indicate their degree of agreement with the assertions and could also give their own written comments and suggestions. We reach the following conclusions, followed by our comments and probable solutions.

Positive remarks

Students want more project based assignments where not only they have to tackle a problem theoretically, but also experimentally. They also want to design and build things. Given the fact we are training students who want to become engineers, this is no surprise. But this also implicates we have to take into account these specific needs when modifying a curriculum. General science courses, such as physics, mathematics, chemistry, informatics and especially engineering courses, such as mechanics and electronics, should be modified accordingly. The electronics courses for second-, third- and fourth-year students has already a great deal of project based work and the laboratory part of the physics course for first- and second-year students has been adapted this year for more intense project-based assignments.

Students appreciate the fact they were pre-assigned to a team. This is a surprise, since in the previous term, they had already done laboratory work in smaller groups, assembled by themselves. When questioned about this, they say they like the fact they got to know different people and were confronted with various opinions and points of view.

Students say they work better and more and have the feeling they learn more. The coaches agree with the first, but whether or not the second remark is true remains to be examined.

Students like to learn more theoretical background about the different projects. It seems starting from practical experiences stimulates the acquirement of theoretical knowledge, and not the other way around. This has profound consequences for the way first-year courses should be presented to students. This forms a strong argument for project-based teaching and learning in regular engineering courses.

The coaches themselves are enthousiastic about their job as coach. Most of them are used to help students during regular laboratory work or hold sessions in which theoretical exercises are solved. As a coach they feel they have a more intense contact with the different teams and they appreciate the fact they don’t have to ‘teach’ in the usual sense, but instead they have to guide students in finding a solution. Most of the coaches also mention the great enthousiasm of the students during the team gatherings and the active participation of the team members.

Students spontaniously search for information in the library and on internet. This remark is made by various coaches and by the library personnel. Especially the internet is a popular medium for obtaining information. Students are less used to search in books and have trouble finding the appropriate books for solving a particular problem or question.

Negative remarks

Coaches and students have the following negative remarks and make the following suggestions for improvement:

A great majority of students wants more time for completing the project. Once started, most teams find, taken the complexity of the assignments, the total time officially allocated to the project, barely sufficient to design, build and test the chosen product. They also want extra time to do more experiments for improving the constructed models.

The design-build experience should be spread over a longer period in time. This is a remark made in the first year by both the coaches and the students. During the three weeks given in the first year for completion of the project, students tended to spend most of their time thinking and focussing on the chosen assignment, hereby neglecting other courses and tasks. This indicates students are really interested and enthousiastic about what they are doing. But we must not forget a design-build experience is only part of the curriculum and therfore other tasks and courses should not be neglected. This year, the 6 weeks foreseen for the design-build experience, proved to be a good solution. Although officially the total time spend to the project remains the same, the fact that we use hours outside the hours spend for traditional teaching and learning allows for more effective time for the project and thus comes to meet with the demands of the coaches and the students.

Students expect more help from the coaches. This can be expected from first-year students, since practically all of them have no previous experience with a design-build project and most of them are not trained in searching answers and posing questions by themselves. However, given the fact that, with exception of a few groups, all teams during these two years of design-build projects, finished their project and could present a workable model, we will continue to not giving technical information to teams.

DESIGN-BUILD EXPERIENCE FOR SECOND-YEAR STUDENTS

As a result of the gradual introduction of CDIO at Hogeschool Gent and the successful results obtained in the first year, a desing-build experience was introduced in the electronics course for second bachelor year.

The project

This projects 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 lab, spread over one complete semester.

Team formation

As in the first year, students subjected first to the same test in order to identify their learning style. Teams of 7 students are then formed, taking care 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 hardware, software, CAD and mechanical aspects. The team decides about the function of every team member.

Role of coaches

Contrary to the role of the coaches in the first year, this time the coaches give technical feedback to the students. The teams present their ideas about the technical implementation of the project to the coaches and get 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 by the coaches.

Furthermore, since the students have not 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.

First observations

Since this project is not fully completed at the moment this article is written, we can give only partial results.

- As in the first year, students show large enthusiasm but have the tendency to underestimate the complexity of the project. This leads to stress amongst the students but not to a decrease of motivation. On the contrary, students start to spend more time in the lab than usual.
- Students are very pleased with this kind of teaching and learning and agree they learn a lot more compared to more traditional methods.

- Coaches appriciate the motivation of the students but have remarks 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 in an existing curriculum can be a tedious proces. We feel our approach, gradual introduction of the reforms, is the best way to achieve the goals set by the 12 standards.