COMPARISON AND CLASSIFICATION OF DESIGN BUILD PROJECTS IN DIFFERENT ENGINEERING BACHELOR PROGRAMS

Martin E. Vigild
Louise E. Willumsen
Egil Borchersen
Karsten Clement
Lotte Bjerregaard Jensen
Claus Kjærgaard
Peder Klit
Jens Sparsø

Technical University of Denmark

ABSTRACT

In order to find inspiration for creating novel design-build projects we have examined projects given at the B ENG program at DTU for civil, architectural, IT, electrical, chemical and mechanical engineering students. This resulted into a classification scheme which identified five different types of project work: *bucket-of-water* project, *minced-meat* project, *build-the-bridge* project, *make-it-fly* project, and *what's-up* project. At DTU it seems that the *build-the-bridge* type is predominant.

KEYWORDS

Design-build experience, bucket-of-water project, minced-meat project, build-the-bridge project, make-it-fly project, what's-up project.

INTRODUCTION AND BACKGROUND

The Technical University of Denmark educates engineers in two separate streams of education. One stream is the Bachelor of Engineering (B ENG) which is a 3½ year program that qualifies the student to go directly into industry to jobs in e.g. production units, project management or control and support functions. Another stream is The Master of Science in Engineering (MSC ENG) which is a 2 year program that follows the 3 year Bachelor of Science in Engineering Program (BSC ENG). The BSC ENG and the B ENG programs include different curriculum and are taught to different student bodies. The DTU management decided to introduce CDIO as the engineering context for all its B ENG studies, and implementation started in 2008 with the first year courses. In 2011 the process will be completed for the full B ENG program [1]. The full B ENG program include six degrees in engineering covering mechanical, chemical, civil, architectural, electrical, and IT engineering.

The introduction of CDIO philosophy to the B ENG programs at DTU serves the obvious purpose of improving the quality of the engineering education. More specifically we see the combination of CDIO and a faculty of research active professors, as a way to maintain what has always been the hallmark of B ENG studies at DTU: emphasis on applied engineering *and* an up-to-date and high level of professionalism.

The implementation process was headed by a committee lead by the Dean of Education, which included representatives from students, teachers, program coordinators and the study administration. The committee concluded its work in 2008 and set up guidelines on how DTU should adapt to CDIO and produced a detailed plan of action [1] that defined common goals and guidelines for the future CDIO-based study programs. Following this plan the program coordinators of the individual B ENG programs have implemented the necessary changes together with supporting working groups of teachers and students.

In order to support the implementation process an important step was to translate the CDIO syllabus into Danish. We translated the full syllabus, but quickly realized that a more condensed version was needed, where all skills were expressed in operational terms, and with more generic descriptions of competences (detached from mechanical engineering).

At DTU one semester equals a credit of 30 ETCS points and covers a 13 week teaching period with weekly classes, an examination period of a couple of weeks, and finally a three week period devoted to a single learning activity or course work. Traditionally, the study programs at DTU contain a very high degree of freedom for the students to compose study profiles and elective courses. Thus the emphasis on implementing CDIO into the education is focused on the first four semesters of the B ENG programs, which consist of compulsory courses and projects that provide the students with a broad basis in the specific branch of engineering. The last three semesters consist of a semester of industry internship, a number of elective and compulsory courses and the final project work, which is 20 ECTS points. The internship can be regarded as a design-build experience in itself, as it holds plentiful opportunities to design, implement and especially operate systems. However, the CDIO structure is mainly integrated in the compulsory elements of the B ENG programs during the first four semesters as indicated in Figure 1.

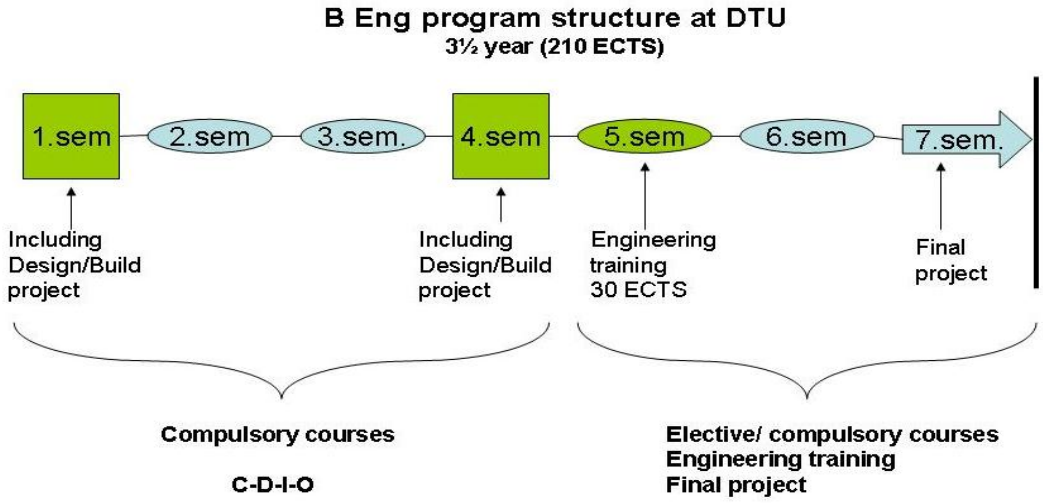

Figure 1. Outline of the study plan for the B ENG program at DTU.

Generally, we have adopted the structure of a basic level and an advanced level design-build project in the first and the fourth semesters of the study program following CDIO Standard 5. Our preliminary analysis of the structure and classification of these design-build projects are discussed in the following.

CLASSIFICATION OF DESIGN BUILD PROJECTS

During the work of developing design-build projects for the six different B ENG studies at DTU we have come across general features which distinguish different types of projects and characterise them in the CDIO context. The design-build experiences spread over the B ENG programs of mechanical, chemical, civil, architectural, electrical, and IT engineering. We would like to present the general trends in an attempt to classify project types, which hopefully will serve as inspiration to others who have to develop design-build projects. In Figure 2 we have identified – and named – different models for working processes in design-build projects which seem to work well in different walks of engineering. These are discussed below.

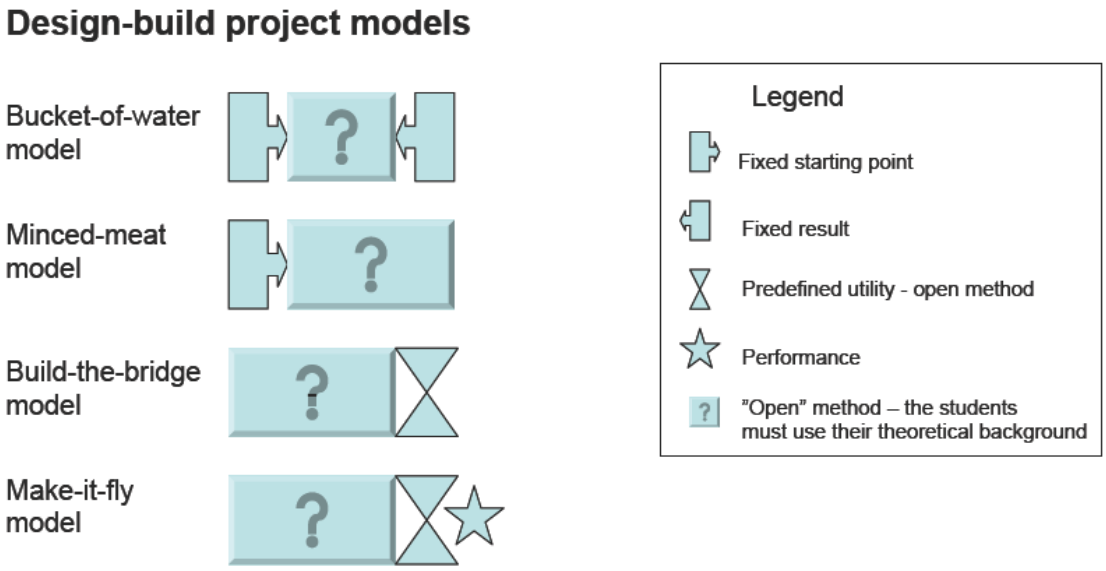

Figure 2. Four different models for design-build projects. See text for explanations.

Bucket-of-water model

In the *bucket-of-water* model we operate with a specific starting point. The students can then use their theoretical background to conceive, design and implement a solution that leads to a fixed result. The example of the *bucket-of-water* project is anecdotal. [3] A professor at a university in the Netherlands ran a course in the 80s which he kicked off by giving a bucket to the group of students with the instructions to go to the canal behind the building and fill it up. When the students returned to his office with the bucket of water, he informed them that their task was to design a method to purify the water so they would drink it themselves. In this kind of project the specified starting point (the dirty water) and a desired result (drinking water) are the only direct instructions given to the students.

Minced-meat model

In the *minced-meat* model we operate with a specific starting point which the students have to analyze. The methods and the solutions are open and depend on the choice of the students during the project work. The example of the *minced-meat* project originates from the preparatory work to design a novel B ENG education in food quality control [4]. Here the focus is often on analysis and control in the food industry. Basically, a packet of minced meat is randomly collected from the fridge in a grocery store and must be subjected to proper analysis, which is not specified. In this kind of project the specified starting point (the minced

meat) is all that is given to the students. The result solely depends on the theoretical and practical knowledge of the students and their desire to innovate.

Build-the-bridge model

The *build-the-bridge* model is a rather open project model. The end result is a predefined utility, which the students can aim at using their knowledge to design and implement. Predefined constrains can be introduced, but in the pure form the only instruction is the end utility. The example of *build-the-bridge* is very simple and has been a recurring problem of mankind for all times. Basically, you stand on one side of a river – and want to cross over to the other side. The task is simply to connect the two sides. In this kind of project the specified end result (the bridge) can easily be supplemented with more specific side criteria which can guide the students in their project work, but this project form holds great potential in training the students to identify and define the problem context at hand.

Make-it-fly model

The *make-it-fly* model is rather similar to the *build-the-bridge* model. The difference is that the *make-it-fly* project contains an element of performance or competition. The goal is e.g. to create the higher, longer or faster system. The competition element is important and motivating and can result in very intense student activity. At DTU a team of students have formed *DTU Roadrunners*, which organises coursework for mechanical engineering students that leads to the construction of energy effective vehicles and propulsion systems (i.e. cars). Each year the cars participate in the annual Shell Eco-marathon event in Nogaro, France. [5] Recently the DTU students won the competition setting a world record in driving the longest distance on one litre of fuel. The inspiration for the make-it-fly name originates from a course at the KTH Royal Institute of Technology, which includes designing a lightweight structure that can fly and carry a specific weight a specific distance. [6]

What's-up model

Finally, at the end of the list it is important to mention the *what's-up* model, which basically leaves everything to the student. Nothing is specified from the teacher – apart from the total study credits that the students will receive upon completion. This kind of project is a completely open model with no predefined starting point or end utility, and obviously it carries a lot of administrative and logistic problems. However, it aims at what we want to obtain with our education: Students who can do it all by themselves. DTU has no experience with this kind of projects.

DESIGN-BUILD PROJECTS IN CIVIL, ARCHITECTURAL, IT, ELECTRICAL, CHEMICAL AND MECHANICAL ENGINEERING AT DTU

At DTU design-build projects have been developed for all the different B ENG programs. In Table 1 the characteristic features of the different design-build projects are listed. As mentioned above the projects run in the first or the fourth semester, and only the first semester projects have been completed at this time. In Table 1 the theme of both projects are given in the second line. This text does not allow for a complete description of the details of each individual project, but the following rows of Table 1 describe the projects with respect to the size of the student projects teams, the amount of credits point given for the project, the most relevant aspects of the CDIO phases addressed by the project work, and finally the most descriptive model for the project adopted from the classification introduced above. An arrow pointing from the first to the fourth semester project indicates any progression of the addressed indicators.

Generally, all design-build projects are organised by assigning groups of four students to each project. Very often this organisation is left to the students to manage, and the teacher only assists if an individual cannot find a team. The practical aspects of working in teams are mainly addressed as learning by doing. In such a way the students do generate their own experience, but some assisted and specifically addressed teaching elements could be of help to support the students team working skills. A few programs have build in some progression into the required team working abilities of the students by increasing the size of the team drastically in the second (fourth semester) project. This necessitates a different approach to organizing the project work and sharing the work load.

Table 1
Overview of the different themes for design-build projects in civil, architectural, IT, electrical, chemical and mechanical engineering. Data is listed for the first and fourth semester projects.

Engineering Program	Civil Eng.	Architectural	IT	Electrical	Chemical & Biotech.	Mechanical
Design-Build Project theme 1.Semester 4.Semester ⇩	Heating of houses - energy consumption ⇩ Digital building modelling	Construction design ⇩ Indoor climate/ Energy design	Implement a text based version of the game Monopoly ⇩ Not finally described	Design of a digitally operated oven ⇩ Design of an energy converting system	Combustion ⇩ Enzyme production	Design/build of a sound muffler for a lawnmover ⇩ Design/build of an automation system in Lego
Design Build Project team size	Groups of 4 ⇩ Groups of 4-5	Groups of 4 ⇩ Groups of 4	Groups of 2-4 ⇩ Groups of 4-6 (or more if collaboration between groups)	Groups of 2 ⇩ Groups of up to 10	Groups of 4-5 ⇩ Groups of 4-5	Groups of 4 ⇩ Groups of 4
Credits (ECTS points)	5 ECTS (13 weeks) ⇩ 10 ECTS (13 weeks)	2,5 ECTS (7 weeks) ⇩ 7,5 ECTS (? weeks)	10 ECTS (part of 16 weeks course) ⇩ 10 ECTS (16 weeks)	10 ECTS (16 weeks) ⇩ 10 ECTS 16 weeks)	3 ECTS (14 weeks) ⇩ 7 ECTS (16 weeks)	10 ECTS (16 weeks) ⇩ 10 ECTS (13 weeks)
C-D-I-O Phases	C-D-I-(O) ⇩ C-D-I-(O)	C-D-(I) ⇩ C-D-(I)	D-I-(O) ⇩ C-D-I-O	D-I ⇩ C-D-I-O	C-D-(I) ⇩ C-D-I	C-D-I-O ⇩ C-D-I-O
Classification of projects	Build-the bridge ⇩ Probably bucket-of-water	Minced Meat + Build-the-bridge ⇩ Build-the-bridge	Build-the-bridge ⇩ Probably Build-the-bridge	Build-the-bridge ⇩ Build-the-bridge	Bucket-of-water ⇩ Minced-meat	Build-the-bridge ⇩ Build-the-bridge

Mostly the student credits for the project work is 10 ECTS points. The design-build projects can be incorporated in the time schedule in two ways:

- The project can be integrated as a ***framework*** with contribution from several courses in the semester. This means that the project does not exist in its own right but is an integrated part of several courses in the same semester.
- The project can be carried out as a practical project in a *separate* course, which is allocated its own time in the time schedule. This can e.g. be a four hour slot in the morning or afternoon once or twice a week during the 13 week semester, or a full-time allocation during the three week interval.

Sometimes these models are combined so that the project starts as a framework but ends up as a separate course with a concentrated period of a three week interval where the students mainly *implement* or *operate* in the work spaces.

With respect to the model types it is obvious that the *build-the-bridge* type is the mostly used. In many cases a range of limiting criteria and conditions are set up by the teachers. The other project types are used except the *what's-up* project model, which is not yet applied at DTU. In some of the study programs a combination of different project models have been

used. At the B ENG Program in Architectural Engineering a project model is used which combines the *minced-meat* and the *build-the-bridge* models. Here the students first have to analyze a concrete building in order to learn how buildings are constructed. After that they have to use the generated knowledge to design and build a bird-observation tower for themselves.

LESSONS LEARNED

The most frequently used project model at DTU at the moment is the *buid-the-bridge* model.

Today only a few B ENG programs at DTU provide teaching in team work and project management as a part of the design-build projects. The trend seems to be 'learning-by-doing'. However, in most programs the need for proper teaching in team work has recently been recognized. It is planned to develop a joint model for teaching the students team work and project management techniques.

The design-build projects need to become more complex during the semesters to ensure an appropriate progression in the programs. One way of increasing the complexity of the project work is by increasing the size of the work groups. In the B Eng program in Electrical and Electronic Engineering the group size is increased from 2 persons in the first semester to 10 persons in the fourth semester. Being 10 persons in a group force the students to split up in smaller groups and they experience the importance of proper project management, coordination, a realistic time schedule etc. when they work together towards the same overall target.

For several of the B ENG programs it has been a challenge to incorporate as many of the C-D-I-O phases as possible in the design-build projects - especially in the first semester projects where the students are just started at the university. The number of C-D-I-O phases incorporated in the fourth semester project is higher, which reflects the increased student capability. A quite general observation is that students have great difficulties in focussing on Conceiving (problem identification, clarification and limitation). Very often the teams will rush into a solution mode (Design), which is locked by (unexpressed) predefined assumptions.

Design-build projects seem to inspire the students but nevertheless they put a lot more time and energy in the project if it ends up with some kind of assessment. The students are not motivated sufficiently solely by knowing that putting a lot of effort in a project make them become better engineers. Assessment and grading is a necessary factor for motivation.

REFERENCES

[1] J. Sparsö, P. Klit, Michael May, G. Mohr and M.E. Vigild. Towards CDIO-based B. Eng studies at the Technical University of Denmark. 3rd International CDIO Conference. Can be downloaded from www.cdio.org.

[2] Danish text for the implementation of CDIO at DTU:
"CDIO på DTU's diplomingeniøruddannelser – Handlingsplan 2007-2008". DTU 2007

[3] Johannes A. Wesselingh, private communication.

[4] Associate Professor Lars Bogø Jensen, National Food Institute, DTU, Denmark.

[5] www.shell.com

[6] Ph.D. Stefan Hallström, KTH Royal Institute, Sweden.

Biographical Information
Martin E. Vigild is Dean at the Technical University of Denmark (DTU) and member of the Executive Board.

Louise Engberg Willumsen is Senior Consultant at the Department of Study Programs and Student Affairs at DTU.

Egil Borchersen is Associate Professor at DTU Civil Engineering and Program Coordinator for the B ENG program in Civil and Structural Engineering at DTU.

Karsten Clement is Associate Professor at the DTU Chemical Engineering and Program Coordinator for the B ENG program in Chemistry and Biotechnology at DTU.

Lotte Bjerregaard Jensen is Associate Professor at DTU Civil Engineering and Program Coordinator for the B ENG program in Architectural Engineering at DTU.

Claus Kjærgaard is Associate Professor at DTU Electrical Engineering and Program Coordinator for the B ENG program in Electrical and Electronic Engineering at DTU.

Peder Klit is Professor at DTU Mechanical Engineering and Program Coordinator for the B ENG program in Mechanical Engineering at DTU.

Jens Sparsø is Professor at DTU Informatics and Program Coordinator for the B ENG program in IT Engineering at DTU.

Corresponding author
Martin E. Vigild
Technical University of Denmark
DTU – Building 101A
DK-2800 Kgs. Lyngby
Denmark
+45 45251009
bachelordekan@adm.dtu.dk