Mutual Workshops enhancing Curriculum Integration

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ABSTRACT

The BSc Eng programme in architectural engineering at DTU Civil Engineering is organized in accordance with CDIO principles. We have been working with CDIO principles for 2-3 years now, and in the following we present the process and adjustments that were made, with the third semester as a case.

Every semester has a teaching team consisting of all the teachers for courses in that semester. Each semester also has its own theme and a multidisciplinary, joint project. So the most active members of the teaching team, of course, are those responsible for courses that address the theme and contribute to the joint project.

The theme of the third semester is 'structural design'. Structural design is defined as an integration of material science, statics and geometry in relation to an architectural project. Anticipating the implementation of CDIO and this theme, major changes were made to the curriculum. A course in material science was moved from the fourth to the first semester so that the project could be informed by material science. A new course in geometry was prepared and software that could facilitate an integrated design project was introduced (STAAD Pro).

The 'full package' of the new third-semester project in structural design was realized for the first time in autumn 2009. This paper presents the lessons learned from this first round along with the changes they inspired. Amongst the biggest changes made was the introduction of a successful joint workshop between the geometry course and the design course. This realized the full potential of structural design and firmly highlighted the creative potential in geometry for hesitant students. The joint workshop also showed potential as a general tool that can enhance curriculum integration.

KEYWORDS

Curriculum Integration, Architectural Engineering, Geometry, Structural Design, Design Projects

Introduction

Introduction

The principles of CDIO (conceive, design, implement, operate) have been a part of the DTU Architectural Engineering programme for several years. One of the main features of the programme is to give the students mandatory design-implement experience. This experience teaches students personal and interpersonal skills, and product, process and system design and implementation skills, and at the same time reinforces disciplinary knowledge [1].

In order to create a framework for this, the curriculum was organized in 4 semester themes, and each semester was facilitated by a teacher team, consisting simply of all the teachers for the courses of that particular semester.

1. Introduction to Architectural Engineering
2. Project management
3. Structural design
4. Indoor and energy design

DTU Architectural Engineering has a fixed curriculum with no elective subjects in the first 4 semesters. Ideally, this should allow for the implementation of that most ambitious of curriculum organization models: an integrated curriculum. In this, the teaching and learning is organized around disciplines, with skills and projects interwoven. This is the recommended organizing principle for an integrated curriculum. The model indicated in Fig. 1 shows mutually supporting disciplines, with projects and skills interwoven, serving as the organizing principle. This curriculum structure promotes the learning of subject content and allows several flexible structures for integrating project work and design-implement experience.

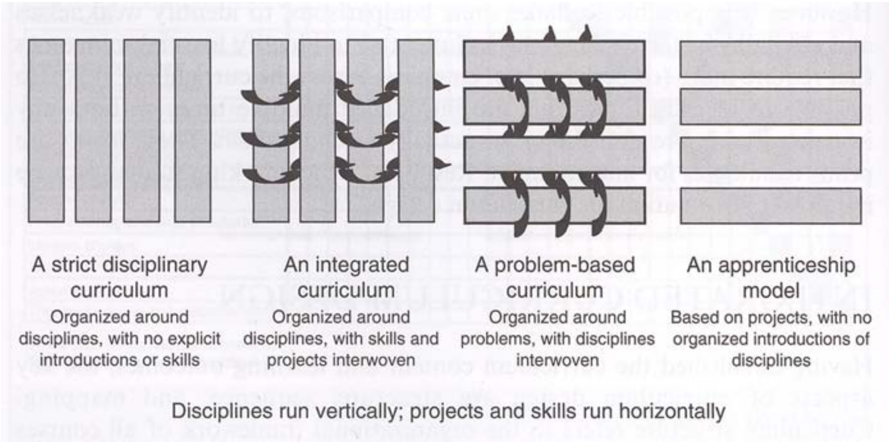

Figure 1. Diagram of an integrated curriculum compared to other alternatives [1]

Design projects and the CDIO syllabus

The semester examined in this paper is the third semester with the theme of structural design. DTU Architectural Engineering started in 2002 as an alternative to the 150-year-old civil engineering programme at DTU. The ‘classic’ engineering programme focuses on educating engineers to work as specialists in the final stages of the design phase, with documentation and certification, etc.

In contrast, DTU Architectural Engineering was created to educate engineers who are specialists in the early design phases of a project, where engineers traditionally play no significant role, at least as far as buildings are concerned. Design projects have been a part of DTU Architectural Engineering from the very beginning and some of the design projects could be transformed into addressing the CDIO syllabus of interdisciplinary skills. In fact, one of the design project courses that will be described in this paper was ‘inherited’ from the first curriculum at DTU Architectural Engineering. For several years, this design course functioned well in the integrated curriculum organization model. Its role was that of providing a combination of temporal and parallel integration. In Fig. 2, the difference between these two concepts of integration is clearly shown. The third semester structural design course ran in extension of the statics courses of the first and second semesters, and students were expected to use this fundamental knowledge in the structural designs they made in the third semester. But parallel to this, in the same semester, another more advanced statics course was run as well as a geometry course.

It was always assumed that students should also make use of the knowledge they acquired in these two courses running parallel to the design course itself.

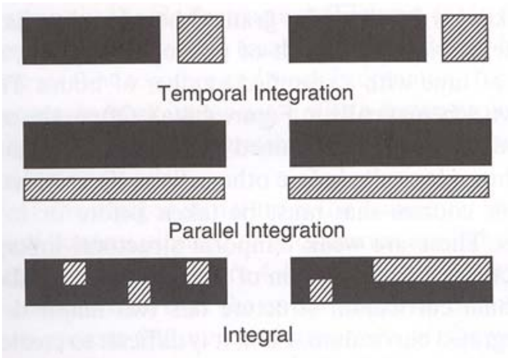

Figure 2. Before the curriculum revision, the role of the design course was that of providing a combination of temporal and parallel integration. [1]

Three years prior to the implementation of CDIO, we made an evaluation of the success of the design course as an integrated design-implement experience. The conclusion was that the design course functioned too autonomously and students could not manage to draw their engineering knowledge into the design process. Year after year, evaluations by students had constantly stated that they spent excessive amounts of time on the design course and this led to failure in some of the subject courses. So the situation was that, instead of enhancing the learning in the subject courses, the design-implement experience was disturbing the process of learning.

Although students liked the design course a lot – in spite of the above-mentioned draw-backs – the teacher team decided to work more precisely with the interface between this course with the design-implement experience and the subject courses of the semester. The discipline linkages in the semester and the curriculum were to be strengthened with a focus on achieving something more like the integral concept of Fig. 2.

The paper describes how the design course was restructured to help students integrate their previously acquired engineering knowledge in the design process as well as integrate knowledge from courses running parallel to the design project course in the third semester. This paper focuses on the integration of the design course with the geometry course, which represented a development towards a linked-merged concept (fig.3.). In the following, the two courses are first presented and then the workshop that enhanced their integration.

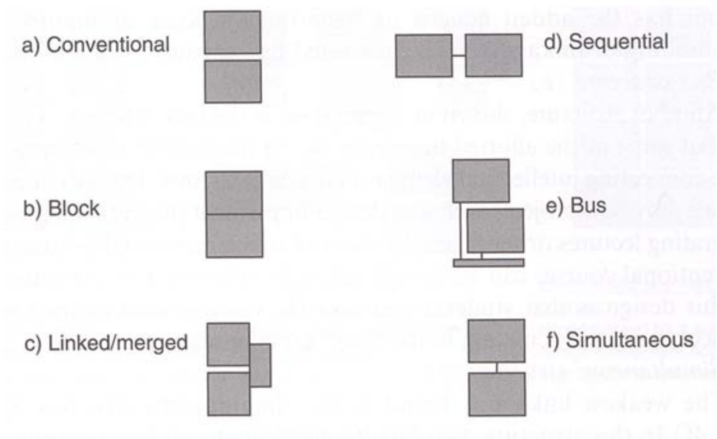

Figure 3. The integration of the design course with the geometry course, represented a development towards a linked-merged concept [1]

DESIGN PROJECT; URBAN CONTEXT AND LARGE SCALE STRUCTURES

The third semester course, “Urban context & large scale structures”, functions as the integration platform for the CDIO activities of the semester and this course hosts the design-implement experience, as mentioned above. The semester theme is structural design, and the course thus focuses on integrating knowledge from the previous and on-going statics courses.

In this course, the students are introduced to an empty place or an area of wasteland somewhere in Copenhagen. Their first task is to make a programme for a large-scale structure that will improve the place, the function of the place, and/or give new value to the place for the neighbours and the community in general.

The second task is then to design the structure. The large-scale structures proposed have been anything from large hotels, to kindergartens, road traffic plans including new bridges, pedestrian and bicycle ramps, market halls, parks, a square or a staircase, or just a wall (Fig. 4)

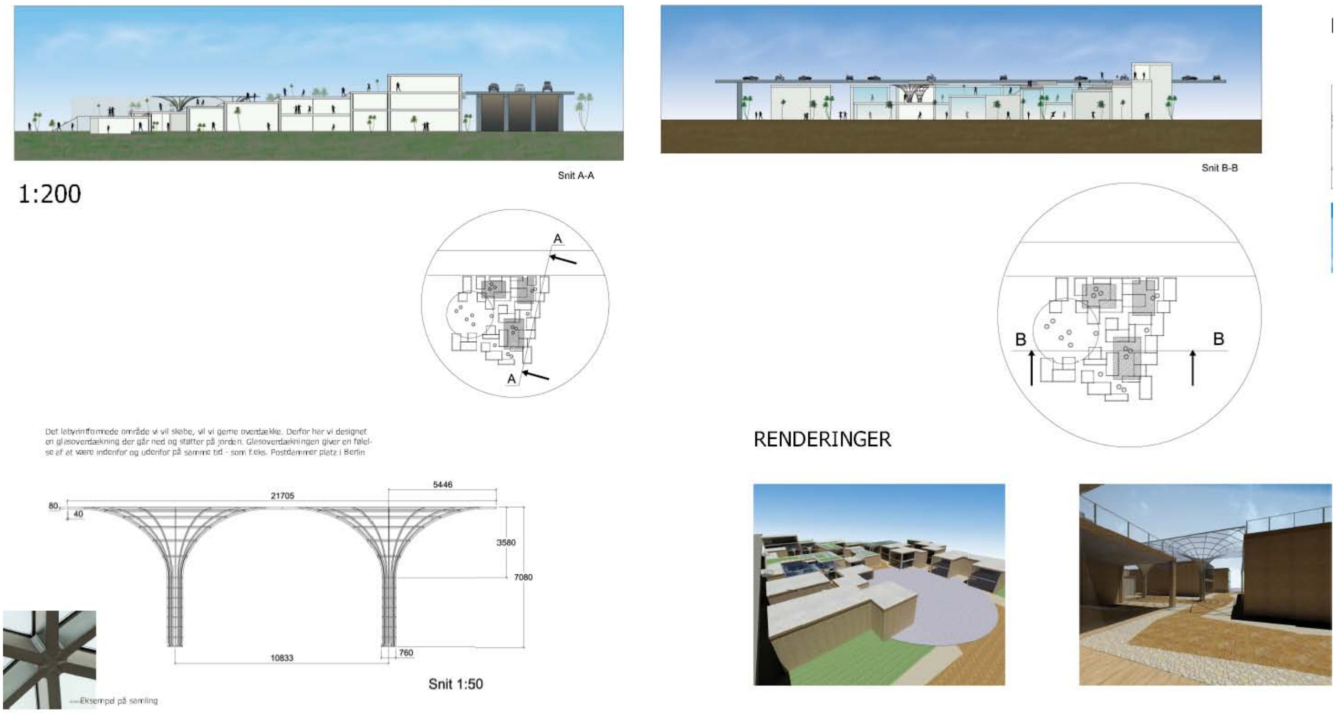

Figure 4. Student project, from the Sept-December part of the course. To the right is the existing bridge. Connecting the bridge to the run-down area below is a new shopping centre. The student project connects from existing bridge to the shunting area by means of roof gardens on a ‘Kasbah’.

The students are divided into groups. The first lecture is a short introduction to the history of the place. Then they get the most relevant documents available: maps, historic plans, etc. and they go and visit the place to register, take photos, and talk to people.

The students have to go through the process at very high speed in order to go through the learning processes that we want and achieve a result. This is done by organising the course in a series of part assignments. For each assignment, the students get a short lecture to introduce the problem area and some methods to handle it, a working period of one or two weeks and then they have to deliver. It could be a presentation, a poster, or a number of physical models.

From the semester start through to mid-October, they deliver four part assignments. Contextual analysis and narrative registration are the first two. The third assignment is the programme, and the fourth is a number of physical conceptual models illustrating the large-scale structure and some structural ideas.

After the autumn vacation, there is a two-week part assignment on conceptual structural design. The focus is on the creation of structural layouts that support the physical models and the urban context ideas behind them. The students present their concept at a workshop attended by the three teachers in urban design, structural design, and geometry in plane and space, where the final assignments for this course and the geometry course are worked out.

The groups then have three weeks to make the final proposal. In this period, they work in parallel on the geometrical assignment and the urban context large-scale structure assignment.

Structural Design

In general, structural engineering is concerned with two questions: how to form a structure to fulfil a given purpose, and how to ensure that the structure will carry the loads imposed.

Many methods have been developed for the analysis of structures and, like many other engineering schools, DTU offers a large number of courses on this issue. But in this course, the focus is on how to design or lay out the structure, and less emphasis is put on the detailed stress analysis.

Two philosophies govern the teaching. The first is that a structure can be seen as an assembly of parts and these parts can be either sub-structures or structural elements. We can call this assembly a structural system, and realize that many structural systems can meet a given requirement. Furthermore, any system and almost any structural element can be divided into sub-systems or elements; it is all a matter of scale. Nevertheless, there are a number of basic elements to which we can refer (Fig. 5).

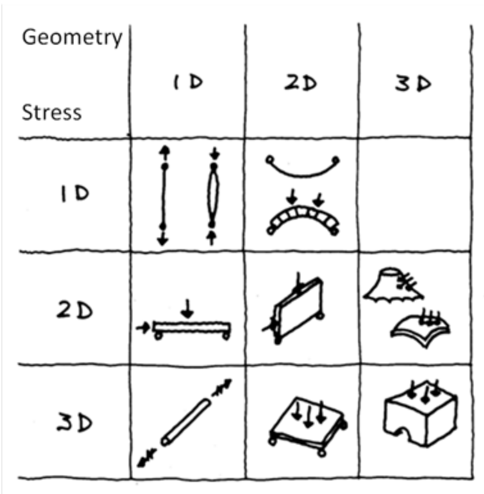

Figure 5. Structural elements.

The second philosophy is that a good design is carried by a general idea, a concept. The geometry, the elements and the structural system, the materials, and the construction process should be coherent and logical both from an architectural and an engineering viewpoint.

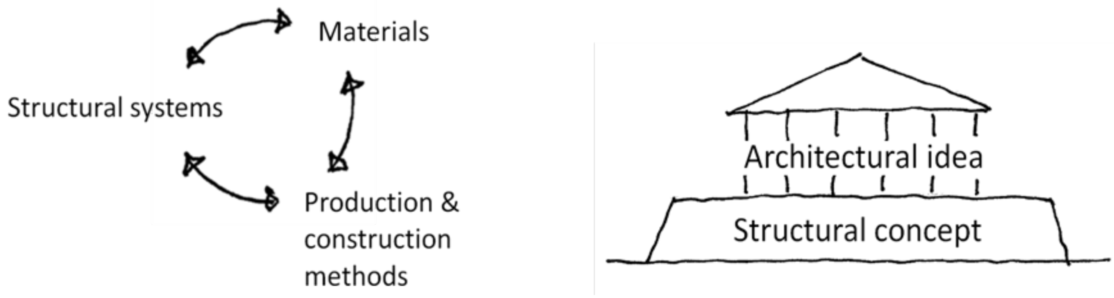

Figure 6. Structural concept.

Consequently, lectures are held on how to identify and design structural systems, how to analyse the physical properties of materials from a structural point of view, and how to develop structural concepts.

Throughout the course, emphasis is put on general design methods, such as problem-solving, intuitive or systematic generation of solutions, the use of different types of models, making experiments as well as observations, and references and other sources of information. Most of the learning is tacit because we do not teach the theory behind the methods and only briefly present the principles of the methods. The large number of part assignments simply pulls the students through the curriculum: learning by doing.

Learning objectives

Some of the learning objectives are listed below:

- To gather information about an urban situation and communicate it well
- To know basic design methods used in contemporary urban design
- To use urban design methods
- To develop and integrate concepts of building design with urban design
- To communicate graphically at a 'professional' level
- To use engineering skills for solving real-life problems
- To work conceptually on structural theory
- To use structural calculation programs in a design process
- To present structural calculations and document structural efficiency in a report

INTEGRATING THE THIRD SEMESTER COURSE IN GEOMETRY WITH THE DESIGN-IMPLEMENT PROJECT IN STRUCTURAL DESIGN.

Why a course on geometry – motivation for combining geometry and structural design

For some reason, geometry has been declining as a subject of interest for structural engineers and teaching at DTU for a number of years. This might be due to the focus on the analysis of structures. From the start, the general purpose of the Architectural Engineering programme at DTU was to produce engineers with the ability to inform the early design phases and come up with proposals for technical solutions which were relevant. In both structural and functional engineering, such solutions concern the arrangement of physical elements in space, which is why geometry should have been a fundamental teaching subject right from the beginning.

But we needed a hint from Cecil Balmond, who was interviewed by two of the authors on the occasion of the 150th anniversary of DTU BYG, to realise that we had to include a course on geometry in the curriculum. Since many of the students are more interested in the design aspects than in pure analysis, this course also has the effect that it opens the students' minds to mathematics as an interesting tool for design and not "just" a necessity for analysis.

This is of special importance in structural design because of the very close relationship between the geometry of a structure or structural element, and the loads, section forces and stresses it can bear. The fact that you design the structural system and the section forces, and hence the volume of the structure, when you lay out its geometrical form is important information for the structural engineer and requires an interest in geometry and a basic toolbox to handle it.

The geometry course

Geometry is a natural facilitator and tool for constructive design and for structural analysis in general. In this 5-ECTS-point course, the main focus is on the design aspects – inspired and motivated by e.g. [5]. The course is essentially concerned with very basic geometric deformations of triangles and tetrahedra. The associated mappings are controlled by matrices, i.e. affine maps in plane and space, and their geometric properties are analysed using the linear algebra that the students have studied in an earlier mandatory calculus course. The design assets are enhanced further by introducing the basic geometry of space curves and by controlling the triangular and tetrahedral deformations via the Frenet-Serret basis (i.e. curvature and torsion) along the curves, see [4], [3].
So far, the course has been given twice. In 2010 it was attended by 40 students from DTU Architectural Engineering and 40 students from DTU Mechanics.

The workshop

Every student in the geometry course is offered a final credit-giving project exercise from a very general list of about 20 suggestions, see [3]. The main aim of the 4-hour workshop, which takes place just before work on the projects begins, is to focus upon, pinpoint, and perhaps also adjust a relevant choice of project for each student or group of students.
Essentially, this is facilitated in two significant ways. The DTU Architectural Engineering students are already well prepared with detailed ideas and suggestions from their previous work on their semester design project. Moreover, a number of the suggestions listed have already been exposed as appetizers during the course from the first week.
At the workshop, there are a total of 5 teachers present to guide the final choices – essentially by sheer brainstorming.
Some projects turn out to be more popular than others. Several mechanics students chose a classical roller-coaster construction problem. Some students chose to work on largely open projects, such as the Windstalks project. So far, this particular project is only a (nice) idea, see [6]. Not much is yet known about either its technological implementation or its feasibility. It is nevertheless a highly relevant case for the geometry course. It was chosen by one of the DTU Architectural Engineering groups as an integral part of their project for the design studio course and it will surely be developed further as a case study in geometry. In this way, the students are actually introducing a frontrunner resource into the future development of the course.
Another project of the same type (and with the same momentum for engaging the students as a resource) is concerned with the application of a specific piece of free software for the optimization of geometric structures, see [2].
Out of the 42 Architectural Engineering students who participated in the course during the autumn of 2010, all except 8 chose a geometry project which was a direct spin-off from their Semester design project. The 8 chose a roller-coaster construction project and a tall building construction project, respectively, both of course related to architectural engineering, but not directly related to their specific design projects projects.
The workload of the teachers involved in the workshop, therefore, is mainly to take an active part in the workshop and to act afterwards as consultants for the students in those cases where they have specific questions concerning the topics of the teachers' expertise. Each consultancy window (of typically 1 hour a few days per week during three weeks) was

divided into blocks of 15 minutes, which could then be 'booked' by the students via e-mail. It was also possible to ask more technical questions (typically related to the application of Maple) via e-mail with attached worksheets containing the problem pointed out and formulated as clearly as possible. This functions very well – not least because of the precise, focused, and well-prepared communication which is necessary because of the limited time available for each consultancy block.

A general evaluation comment by students

"The collaboration between the geometry project and Design Studio Course was really great. It gives a feeling for the possible applications of geometry in architectural design – which is very useful, for example, if I get employment at a drawing office."

CONCLUSION

The goal of realizing an integrated curriculum and having a design-implement experience integrated in the semester was, if not totally achieved, then at least significantly approached by means of the almost banal 'tool' of a 4-hour joint workshop.

The linked or merged structures are when two faculty members start the term teaching independently, and at some point the two courses flow together and work in common. [91] Students cannot manage to integrate their technical scientific knowledge in the design project at this early stage in their studies by themselves. The joint workshop helped both teachers and students in realizing the design potential of the geometry course.

Linkages within a curriculum place demands on faculty staff because they require substantial cooperation and adjustment in course content in order to achieve the desired connections. The 4-hour joint workshop proved to be a very efficient way for faculty staff to achieve these linkages.

Although the curriculum is fixed for the first 4 semesters in this programme, there are always students who need individual curricula. The 4-hour joint workshops enable us to maintain flexibility in the elective curriculum. If the students do not have the geometry course, they do not need to attend the workshop and will not integrate geometry aspects in their design projects. And if they do not attend the design course, the geometry teacher has report themes they can choose that are independent of the design course.

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