INTEGRATION OF DIFFERENT COMPETENCES IN A GROUP PROJECT IN A BASIC COURSE IN MECHANICS IN MECHANICAL ENGINEERING

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ABSTRACT

The introductory course in mechanics in the first year of the Product Design Engineering Program (a three years Bachelor of Science program) at Chalmers covers the topics of statics and introduction to particle dynamics. An essential part of the course is a group project and it is this project that will be presented here. Usually a project in a course in mechanics has a tendency to focus only on analytical and numerical treatment of a system that is given in advance. In this case, however, it is a completely open problem with no specific solution. The aim of the project, which can be described as a design-implement (or design-build) project, is to present a suggestion for a bridge (pedestrians and cyclists) over one of the canals in Gothenburg. An important and unique feature, as distinguished from a fictive problem, is that the project in this way deals with a real problem since there are present plans for such bridges over the canals. The results of the project should be presented with sketches, presentation models, drawings and mechanical calculations on a simplified model. To support the working process a team of teachers from the areas of Applied Mechanics, Architecture, and Communication are working with the project, in order to integrate different competences. This integration supports the students in achieving the learning outcomes of the course, and this will be investigated in further detail here. In conclusion, the project contributes considerably in connecting learning objectives, activities and examination according to Constructive Alignment.

KEYWORDS

Engineering mechanics, Integrated competences in group project, Mathematical modelling, Standards: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

INTRODUCTION

The Product Design Engineering program at Chalmers is a relatively young program and it was launched in the academic year 2003 – 2004. The program consists of three years of full time studies, corresponding to 180 ECTS, and ends with the degree of Bachelor of Science. Already from the start the idea of introducing some form of group project in the first year basic course in mechanics was proposed and it is this project that will be discussed here. The idea was also that the project should be a completely open ended problem with no specific solution. To get a sense for the “State-of-the-art” an investigation of similar basic courses in mechanics at Chalmers shows that, if there are any projects involved, they primarily focus on analytical and numerical treatment of a system that is given in advance. However, at the graduate level it is easier to find examples of open ended problems but then it is mostly in a project course and not a pure mechanics course.

The CDIO model for engineering education states, as one of its cornerstones, that personal and interpersonal knowledge, skills and attitudes should be explicitly addressed during the education [1]. This implies that the students, during their education, should develop the ability to translate different skills into practice in the treatment of projects and real world problems. An important part, both in the work process and in the presentation of results, are different forms of visualizations and communication skills. It is in this context that the integration of different competences in the project is introduced by the participation of teachers from the Departments of Applied Mechanics, Architecture, and Communication. Another important feature in the project is the time line for the working process, which, roughly speaking, divides the work in an internal phase (research, ideas, simple sketches etc.) and an external phase (presentation model, drawings, sketches of details etc.). This creates a creative atmosphere and also establishes a connection to the future professional role in terms of the working process and delivering results in the stipulated time. The results are presented at an official exhibition where each group gets feedback from their peers and, specifically, from the architecture, communication and applied mechanics teachers. The course evaluations also indicate that the students experience the project as positive, fun and challenging. It gives a connection between mechanics and the future professional role and it illustrates how calculations on very simplified models can be used in judging whether a construction is realistic or not. The course evaluations clearly indicate what can be summarized in the quotation “Fun to apply your knowledge on a realistic project. Now I know why we study mechanics and how to use it”.

The experience from this course shows that the project work strengthens the student motivation and attainment for studying mechanics. We will return to this fact later in this paper with explanations and examples. Examples of this kind of design-build course that integrates different competences can easily be found in final-year courses in the curriculum for engineering education [2] - [7], but one unique aspect of the project presented here is that it shows that it is also quite possible to carry through a project of this kind in a first-year basic course. The conditions and possible limitations for this will also be discussed later. It should also be pointed out that the project constitutes a creative work process with creative collaboration as an essential requirement. There is a vast literature on this subject [8] - [9].

The students at the Product Design Engineering Program at Chalmers have their own design studio at campus with access to both material and equipment for producing physical and/or digital models and prototypes.

INTRODUCTORY COURSE IN MECHANICS

It is important to emphasize that the course we are discussing is a first year course and that it ends the first year of the program. The course covers the topics of statics and introduction to particle dynamics [10]. What skills do the students have as prerequisites when they enter the course? This is a question of great relevance to the project and to answer this question we give a brief overview of the first year of the program. The courses *Linear algebra* and *Calculus* provide the students with the necessary mathematics for the study of mechanics.

Furthermore, the courses *Computer aided design, solid and surface modelling* and *Design and communication* develop skills that are highly relevant for the project work.

The project, which will be further investigated below, can be characterized as a design-build project and apart from learning outcomes directly coupled to mechanics we state from the course plan learning outcomes which are relevant to the project work. After completion of this course, the student should be able to

- Formulate the mathematical model for a given mechanical system and carry out the analysis
- Work independently and cooperate in a group in order to solve an open technical problem
- Adopt appropriate methods in order to solve an open technical problem
- Give an oral presentation of the project and results with sketches, presentation models and drawings

Regarding the mathematical modelling it must be emphasized that it is a very rough model that only answers the question whether the construction is realistic or not. This is partly due to the fact that it is a first year course and the students have not yet studied strength of materials or materials technology. Still, our example illustrates that it is possible to carry out a project like this already in the first year of the education. We will return to this subject later on and give some examples of mathematical models based on first ideas and sketches.

It is obvious that mechanics should be taught in a CDIO program like the one we are considering here and mechanics primarily belongs to section 1 – Technical knowledge and reasoning – of the CDIO syllabus [11]. However, there are also topics from sections 2 – 4 of the CDIO syllabus that are relevant here, especially with regard to the project part of the course. This includes 2.1.1 Problem Identification and Formulation, 2.1.2 Modelling, 2.3.1 Thinking Holistically, 2.4.3 Creative Thinking, 2.4.4 Critical Thinking, 3.1.2 Team Operation, 3.2.2 Communications Structure, 4.4.1 The Design Process.

THE PROJECT – INTEGRATION OF DIFFERENT COMPETENCES

Here we give a more detailed description of the (design-build) project. The task is to present a suggestion for a bridge aimed for pedestrians and cyclists across one of the canals in Gothenburg. What makes the project unique is that it deals with a real world problem both in the sense that the bridge should be located at a specific place over one of the canals in Gothenburg (see Figure 1) and also that there are present plans for such bridges. The results, which are presented on the opening day of an official exhibition, include both the presentation of the working process and the completed presentation material. Regarding the examination of the project the calculations should be carried out and the following conditions apply for the presentations

1. First sketches of ideas and work model in optional scale
2. Situation plan in scale 1:400
3. Presentation model and drawings in scale 1:100. Explaining text, colouring and materials. Drawings of details in optional scale

To support the working process and thereby supporting the students in achieving the learning outcomes of the course, a team of teachers from the areas of Applied Mechanics, Architecture, and Communication are working with the project. In this way different competences are integrated in the project.

Figure 1: The place in Gothenburg where the bridge should be located.

The timeline for the work process shown in Figure 2 is presented for the students at the introduction of the project. The phases of the work is roughly divided into two parts consisting of internal and external work respectively. This means that the fist phase consist of work with ideas, sketches, work models and so on aiming at reaching all decisions halfway through the process so that the second half can focus on the presentation materials.

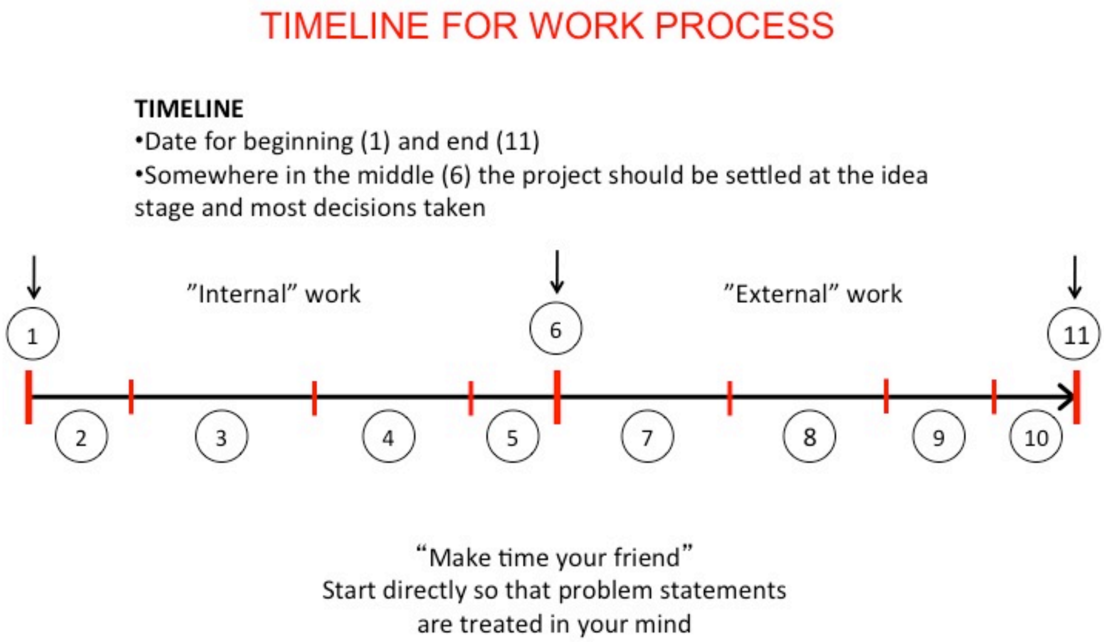

Figure 2: Timeline for work process.

The bullets in the figure are presented in more detail for the students and, in short, they stand for

1. Date for start of the project
2. Facts – Research
    - Limitations of the physical space and surroundings
    - Computer – Library – Interviews

3. Sketches
    - Let ideas flow
    - Sketch visions
    - Save the first sketches
4. Work model
    - Methods for making decisions
    - Choices – parameters – actual position – possibility to open
    - Material – colour – lighting
    - Simple work model – cut and paste
    - Think and work in three dimensions
5. Calculations
    - Decision on mathematical model and calculations
6. Decisions taken and start with presentation materials
7. Presentation model
    - Convince the principals
    - Physical model
8. Drawings
    - Construction and actual placing
    - Choice of scale
    - Plan drawings and drawings of details
9. Calculations finished
10. Oral presentation on exhibition
    - Return to the first vision – describe the process – why this choice?
    - Describe the thoughts on your idea
    - Be prepared for questions and critique

The mechanics course is scheduled for eight weeks and our experience indicates that the project preferably can be introduced at an early stage. The students will acquire the skills necessary for the calculations as the work with the project proceeds. To support the working process the following plan applies.

- End of week 1: Introduction of the project and inspirational picture show. Pictures of bridges from all around the world are shown and discussed in order to inspire the students. Basic construction ideas for bridges are presented. The timeline for the work process and deadlines are also presented.
- Week 3: Consultation and tutoring in the studio with the basic purpose to give feedback to the students on their first sketches.
- Week 6: Lecture on presentation technique and peer review.
- Week 6: Consultation and tutoring in the studio. Drawings and models are now close to be finished.
- End of week 8: Presentation of results at the opening of the exhibition with feedback from peers and from the architecture, communication and applied mechanics teachers.

THE PROJECT – EXAMPLES OF MATHEMATICAL MODELS

As mentioned above the mathematical model is very simplified and can be formulated, based on the first sketches, at an early stage in the work process. The mathematical modelling is developed in collaboration between the student group and the teacher from Applied Mechanics. This model answers the question whether the construction is realistic or not but it has its limitations due to the students lack of knowledge in strength of materials and materials technology. As the model must be analysed just with basic mechanics (i.e. only with the equations of equilibrium) this limitation also implies that the model has to be statically determinate. Furthermore, there are two ways of treating the weight of the construction. On the one hand the weight can be treated as a distributed load and the calculations then give the total values of the reactions and internal forces and moments. On the other hand the calculations can be carried out (and simplified) by only considering the applied loads thereby giving the values that should be added to the ones caused by the weight only. We give a few examples to illustrate the procedure.

THE PROJECT – FIRST SKETCHES – EXAMPLE 1

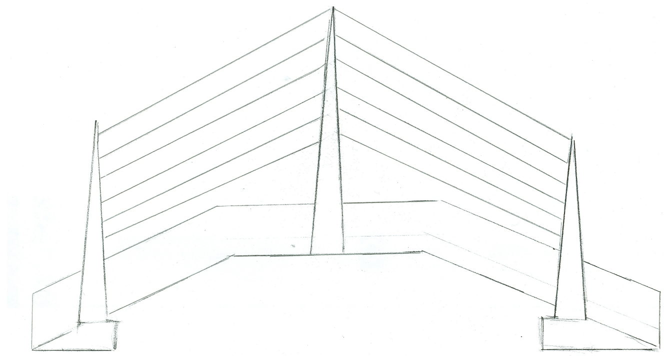

Figure 3: Simple sketch of bridge – example 1.

In the student example pictured in Figure 3 the actual footpath is the sustaining part of the bridge and the rest can be considered as “decorations”. The bridge can then be modelled as a beam according to Figure 4 where, as an example, the load is a point force 2*P* on AB, a distributed load 4*P* on BC and a point force *P* on CD. The supports at A and D makes the construction statically determined. The reactions at A and D can be determined and, after dividing the beam in sections, the internal forces and moments can be determined for each part. Diagrams can be drawn and extreme values of forces and moments can be identified.

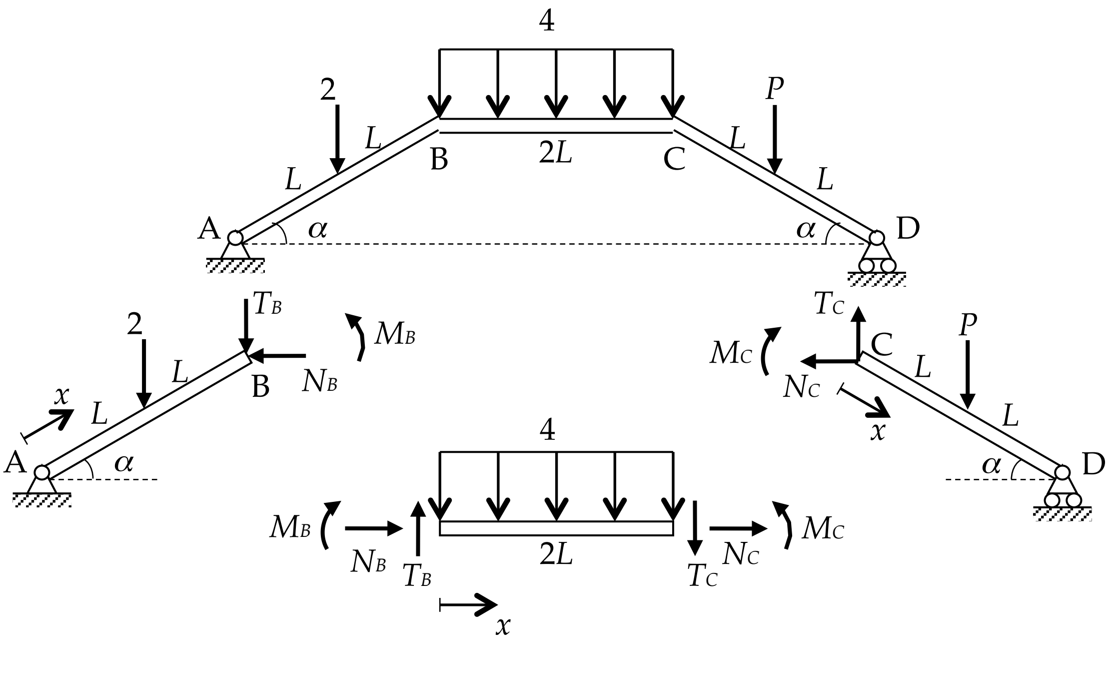

Figure 4: Mathematical model of bridge – example 1.

THE PROJECT – FIRST SKETCHES – EXAMPLE 2

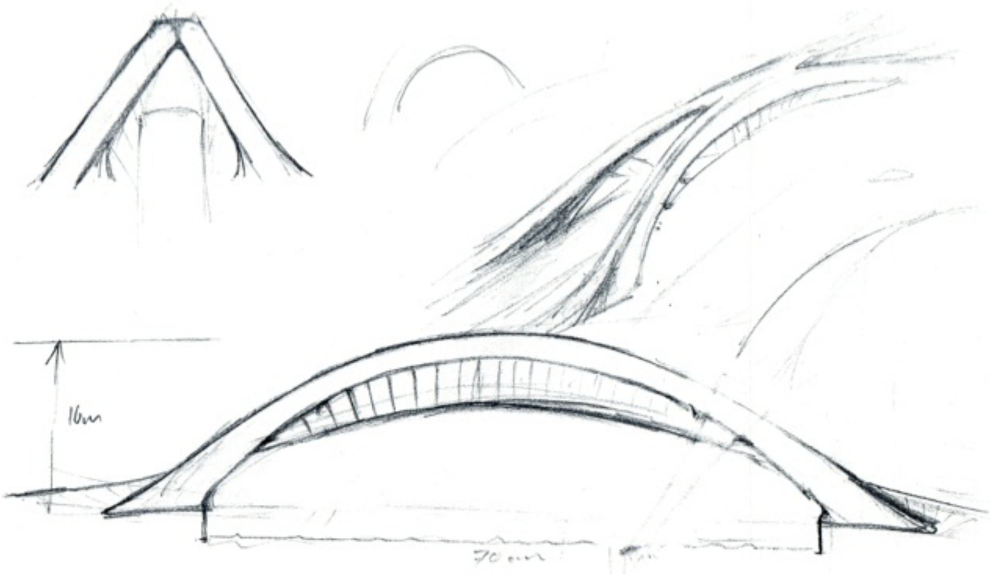

Figure 5: Simple sketch of bridge – example 2.

Figure 5 shows a student example of a curved bridge, which in turn is suspended in a curved beam. A simplified model of the beam, neglecting the weight, is illustrated in Figure 6. In order to make the system statically determined, the supports at A and B are modelled as shown. As an example of load three point loads *P* are chosen. The radius of curvature *R* and the angles θ_0 and θ_1 can be extracted from drawings and calculations of internal forces and moments (defined according to the right figure) can be carried out.

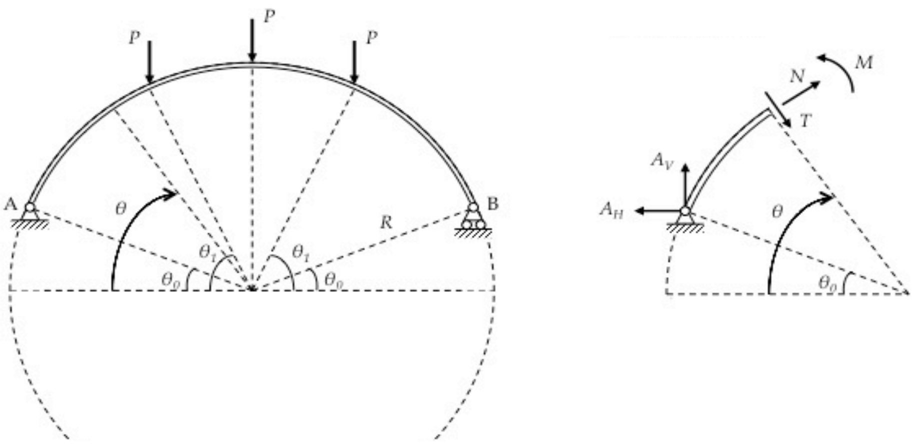

Figure 6: Mathematical model of bridge – example 2.

THE PROJECT WORK – EXAMPLES FROM THE EXHIBITION

It is of great importance to create a realistic situation at the exhibition and especially at the opening of the exhibition. Therefore the exhibition is held in one of the public spaces at Chalmers, the entrance hall in a creative building called "Kuggen", a meeting point for innovation and entrepreneurship at Chalmers campus Lindholmen, situated in close vicinity to Lindholmen Science Park. The sketches and models remain in the building for another week after the project presentations, forming an exhibition open to the public.

Each group has a table and a notice board at their disposal for arranging their presentation material. To furthermore resemble a real situation the opening starts with some snacks and mingle where everyone can walk around and look at all the presentations. Then each group presents their work and gets feedback from their peers and, specifically, from the architecture, communication and applied mechanics teachers, and from anyone else present. Figure 7 shows some photos taken at the exhibition.

Figure 7: Photos from the opening of the exhibition.

EVALUATION AND CONCLUDING REMARKS

Examples can be found where certain special competences are integrated in the curriculum for an engineering program [12] - [13]. However, here we have focused on integration of several different competences in one specific course, which in this case is a first-year basic course in mechanics. What have the students learned? It is clear that integrating language and communication, and specifically *communicating to learn* activities strengthens the students learning within the course. Communication is not only an important aspect of the final presentations but also a valuable part of the whole (learning) process of creating and developing a bridge model. Furthermore the communication feature forms a continuation of a previous writing course on the program, and later writing and communication activities, and is hence part of the communication profile on this specific engineering program.

Our experience is that the project has very much contributed to the attainment and of the learning outcomes for the students. The learning outcomes, which are relevant to the project work, were stated earlier and the description of the project, given in this paper, clearly indicates how learning outcomes, activities and examination are connected in accordance with Constructive Alignment. The mathematical model has its limitations in that it must be handled with only basic mechanics since the students have not yet studied Strength of Materials and Science of Materials. Thus the calculations give no “exact” answers but they can indicate whether the construction is realistic or not, in the sense that they give an estimation of the magnitude of forces and reactions due to a certain load. However, this fact has the positive consequence that it strengthens the motivation among the students for further studies in these subjects.

The examination is divided between the project presentation and a written exam on problem solution in mechanics. The number of students that pass the course is very high and with only very few individual exceptions all students have passed the course each year. Numerical examples from the latest years are presented in Table 1, which should be compared with a corresponding course without any project work. For instance, in the Mechanical Engineering program (Bachelor of Science) at Chalmers, where there is only a written examination, the number of students that pass the course lies at approximately 70% during the same years.

Table 1
Examination results from the latest years

Year	Number of students participating in the course	Number of students that pass the project presentation	Number of students that pass the written examination
2013	32	32 (100%)	30 (94%)
2012	31	31 (100%)	31 (100%)
2011	29	29 (100%)	26 (90%)
2010	32	32 (100%)	28 (88%)

The course is evaluated using the standard Chalmers system and is carried out in cooperation between the program management, the students and the teachers. There are thirty students in the course and four student representatives are randomly selected as a reference group and meets the teachers tree times. The third and final course meeting, where the student representatives, the teachers and the head of the program (or the program coordinator) are present, takes place after the course has been completed. The results from a web-based questionnaire, that has been distributed to the students and answered anonymously, are discussed at this meeting. At the end of the questionnaire there are some summarizing questions and specifically the students are asked to give their overall impression of the course on a scale from 1 (bad) to 5 (very good). During the five last years the result on this question has been between 4.5 and 4.7 which shows that the students are very satisfied with the course. Another summarizing question is “What should above all be preserved till next year?” and a frequently appearing answer is “The bridge project”. Other quotations from the answers to this question are “The bridge project – great fun”, “Great fun with bridges and to apply your skills on calculations on a realistic problem”, “Because of the bridge project I know why we study mechanics and how to use it”.

In a sense the Product Design Engineering Program is special when it comes to developing skills in sketching, drawing and using computer based tools for presentations of concepts in the product design process. However, we are fully convinced that it is quite possible to adopt this project model (maybe with some minor modifications) to other engineering programs as well.

Finally, this example proves that it is quite possible to carry out a project of this kind in a first year course in a basic subject.

Future development opens up by the fact that the basic courses in mathematics (situated before the mechanics course in the program curriculum) in the program at Chalmers are being reformed and will contain numerical treatment by the use of Matlab. This implies great possibilities for numerical treatment in the modelling and calculations.

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