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CROSS-FUNCTIONAL EDUCATION OF ENGINEERING SCIENCES IN INDUSTRIAL DESIGN ENGINEERING

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ABSTRACT
At Delft University of Technology, the Faculty of Industrial Design Engineering introduced a new, matrix-wise structured, course for the education of engineering sciences. Within the framework of a reorganisation of the educational program, one decided to merge four conventional first-year courses into a single course named Design Engineering 1. This paper goes into the development and implementation of this course and draws a parallel between the choice for a matrix-wise structure for the course, in the light of the advantages and disadvantages of different organisational structures.

Keywords: design engineering, multi-disciplinary, organisational structure

1 STARTING-POINT

Over the history of the faculty of Industrial Design Engineering, every ten years there was a major revision of the curriculum. The emphasis of the latest revision, which took place in the years 2000 to 2003, was on educational change of the curriculum rather than a content-related modification of the program. The recognised weaknesses of the then running curriculum (further: the existing curriculum) that are relevant for this paper are [1]:

- The existing curriculum consisted of many individual, small courses resulting in a large number of exams.
- The integration between theoretical and practical study was insufficient
- The integration between theory and practice compared to the design projects was insufficient.

A project group named CH2000 prepared the reorganisation of the educational program on faculty-level. This project group determined the constraints for the courses to develop. These constraints included, amongst other things, that the course content should not change comparing to the existing curriculum. Content is explained as the domain that the course covers as well as the depth that it reaches. Moreover, CH2000 formulated a set of goals for the reorganisation in its entirely [1]. The following goals are relevant for this paper:

- The reinforcement of 'learning to design'
- The creation of larger teaching units
- The division of knowledge into basic- and specific knowledge
- The activation of students to acquire knowledge independently.

In order to comply with the second goal, the project group CH2000 prescribed to merge four first year courses into one course named Design Engineering 1. This concerned the courses Engineering Design, Material Science, Production Technology and Technical Documentation. In order to comply with the last goal, they included a so-called "project of discipline." Important characteristics of a project of discipline are that the students carry it out autonomously and that it bridges the gap between Design Engineering 1 and the design projects. The project of discipline forces students to bring basic knowledge, which they obtained during the theoretical part of the course, into practise and to gather specific knowledge that is related to a particular product (see figure 1).

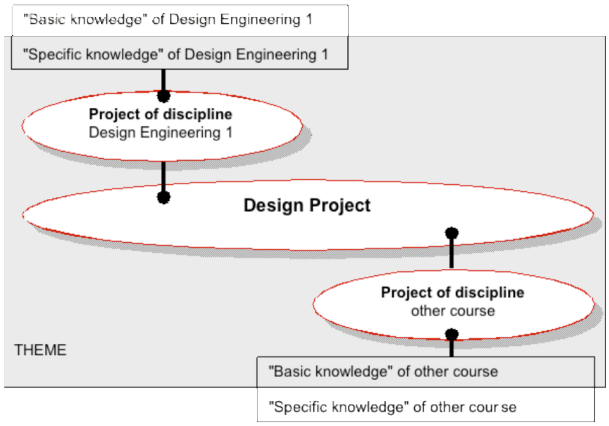

Figure 1: projects of discipline in relation with design project, according to [1]

In order to design and implement the new program on course-level, the project group Design Engineering 1 (further: DE1) was formed. This group consisted of the teachers that were already involved in the four existing curriculum courses, plus a course leader.

2 COURSE CONCEPT

2.1 Theory

It is possible to classify individuals in an organisation according to their function or according to the project they work on. This is referred to as a functional organisation structure respectively a project organisation structure. Moreover, the matrix-wise organisation structure is distinguished. This hybrid structure links individuals to others according to both their function as well as the project they work on. According to Ulrich & Eppinger [2], the choice between a functional organisation structure and a project oriented organisation structure determines the choice between (uni)disciplinary specialisation and multi-disciplinary integration.

2.2 Choice

When structuring pieces of content in an education program, one might think in similar terms as in the case of organisational structures. Alike the designer of an organisation, the designer of an educational program confronts the choice between different approaches, from which the functional approach and the product-oriented approach are the most pronounced ones. In the case of the DE1 project group's mission, a course with a functional approach embraces a number of disciplinary sub-courses: Material Science,

Manufacturing Science, Technical Documentation and Engineering Design. Different, specialised, teachers would teach these sub-courses. The situation in the existing curriculum is a clear example of this: four disciplinary courses are offered independently at different moments in time. The product oriented approach, at the other hand, leads to a number of sub- courses that are centred around a (category of) product(s) or technical system(s) that integrate pieces of content belonging to different disciplinary sciences.
When one projects the two organisation forms characteristics on the mission of the DE1 project group, it seems to be logical to adopt a product-oriented approach. The product-oriented approach is expected to fit better to the multidisciplinary character of industrial design, which refers strongly to the first goal as formulated by the project group CH2000. Reasons to plead for a functionalistic approach also exist. Within the DE1 project group, supporters of the functionalistic approach argued that changing to a product-oriented approach will lead to loss of depth and quality in the different disciplinary sciences and therefore to loss of the academic character of the course. Supporters of the product oriented approach, at their turn, pointed out that the functionalistic approach does not lead to a good understanding of the interaction between the different disciplinary sciences in industrial design engineering. In an attempt to join the best of both approaches, the DE1 project group adopted a matrix-wise structured program. One decided to merge Engineering Design, Material science, Production Technology and Technical Documentation into one single, coherent, course. Within this course the four disciplinary sciences will be covered by four different, specialised, teachers from three faculties. A number of products, which work as a theme, link the pieces of content of these four disciplines, in order to stress the interaction between the different sciences in industrial design engineering. This leads to a matrix-wise structured course, in which the different disciplines form the rows and the product themes form the columns of the matrix (see figure 2).

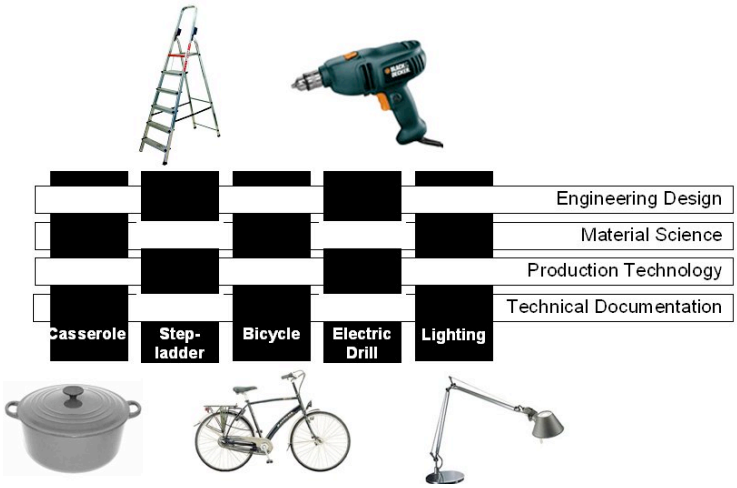

Figure 2: matrix-wise structured program (first semester)

2.3 Implementation

The matrix-wise structured program implies the need to offer the four disciplinary sciences simultaneously. The products that are treated at a particular moment, link the

specific domains of every discipline in time. Moreover, disciplinary sciences often have a preference when it comes to the order of treating the different pieces of content to be covered. This together forms a complicated puzzle. Which products are to be treated in which order, in order to link the different pieces of content that the different disciplines bring in? Although some concessions are done, in the case of Design Engineering 1 it proved possible to deal with this problem. Figure 3 shows an example of the fit between a product theme and pieces of content that belong to the four different disciplinary sciences.

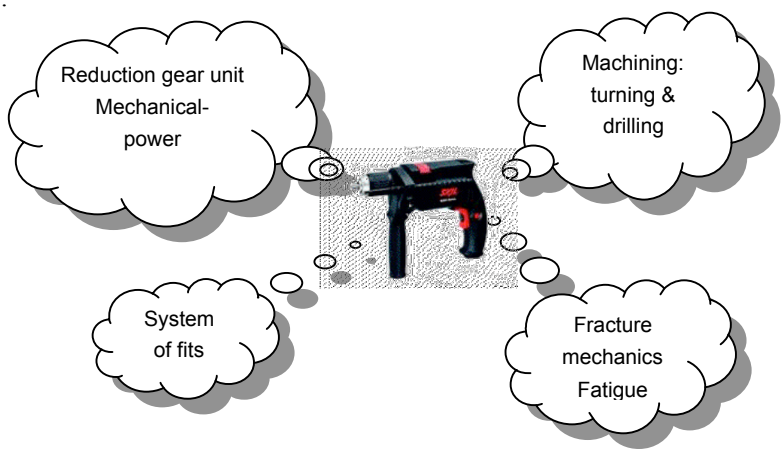

Figure 3: fit between pieces of content of every discipline and product.

3 COURSE DESIGN

3.1 Theoretical part

The matrix-wise structured program is carried through in the course schedule. The product themes determine the schedule's time-axis. The different disciplines offer their lectures parallel in time. In practise, the schedule is divided in two-week chunks. Product themes take one or multiple chucks. Within one chunk, every discipline covers one two-hour lecture. Textbooks are disciplinary, partly for practical reasons, partly in order to maintain the course's academic character. In the first part of the course, a hands-on part in 3D Computer Aided Design accompanies the lectures. The course includes two written exams, which are equally structured. Each of them consists of ten questions with a disciplinary character. Analogous the lectures, three product themes form the basis of each exam. Individual questions are clustered and linked to one of the products themes, in order to stress the relation between the different disciplines.

3.2 Projects of discipline

The project of discipline is a project with a focus on reverse engineering. The students carry out the projects in groups of four or five students. Each group investigates a small consumer product. Examples of such products are an electrical toothbrush, a solar powered torch and an electrical alarm clock. Although the groups carry out the project autonomously, a 20-minute meeting with a coach on a weekly basis is obligatory. A process for the carrying out of the project (see figure 4) is prescribed in a project manual.

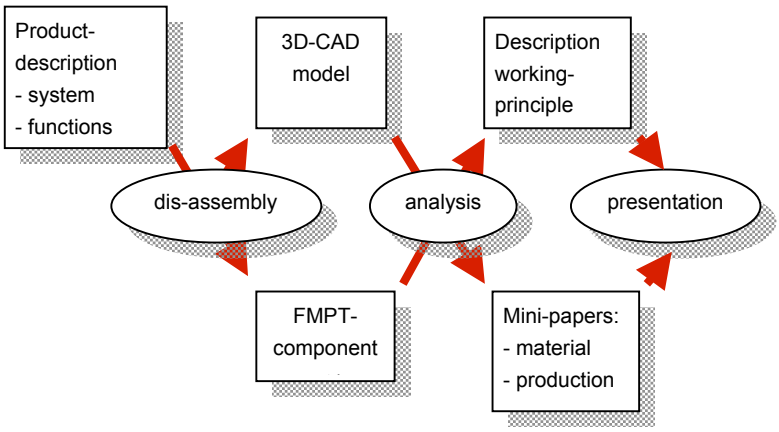

Figure 4: project of discipline - process

Roughly, this process consists of three phases: a descriptive phase on product level, a descriptive phase on component level and an explanatory phase in which the groups explain the product's working principle as well as some design decisions in terms of material- and production technology. The groups present the project in a report and a short oral presentation.

3.3 E-learning environment

An e-learning environment that aims at the students who are following the course, as well as to the teachers who teach the four disciplinary sciences, supports the course. In this way, the participating teachers are able to keep track on the lectures of their colleagues. The e-learning environment provides the students with practical information on the course, as well as additional information related to the course content.

4 EXPERIENCES

The Design Engineering 1 course started for the first time in the academic year 2000/2001. Over the following three years, participating students and teachers evaluated it by means of questionnaires and group discussions. The following observations are relevant for this paper.

- Students indicate that the matrix-wise structure of the course provides a good insight in the relations between the disciplinary sciences. Students mention the structure of the exam explicitly in this context.
- Students as well as the teachers who act as coach in the disciplinary projects indicate that the theoretical part provides a sound basis for the disciplinary project, which itself has a clear multi-disciplinary character.
- The implementation of the course did not lead to loss of depth of knowledge, when comparing to the level that was reached in the four disciplinary courses in the existing curriculum. This observation is based on the fact that exam-questions in the Design Engineering 1 program were fundamentally the same as the ones used in the existing curriculum courses.
- After the DE1 project group reached consensus on the course concept, its further development went surprisingly fast.

- The course is little time consuming for the different disciplinary teachers. This enables the employment of highly qualified teachers.
- Time-consuming issues for the course leader are the co-ordination of lectures and exams, keeping the pressure on the teachers to link their content to the product themes and providing a maximum of transparency concerning the course structure towards the students. This means that course-leadership is not limited to administrative tasks and requires a sound insight in the course content.

5 CONCLUDING REMARKS

Matrix organisations, being hybrid, have the potential to exhibit some of the characteristics of both functional organisations as well as project organisations [2]. The aim of applying a matrix-wise structure in an engineering science course is to combine the following characteristics:

- depth and quality in the different disciplinary sciences
- focus on the interrelations between the different disciplinary sciences in engineering design.
- speed of development of the course.

The different evaluations indicate that the course meets this goal, what makes us to believe that its matrix-wise structure provides a good basis for an engineering science course for industrial design engineers. A condition for successful application of the matrix-wise structure is the assignment of a strong course leader who understands both the structure as well as the content of the course.

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