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BRINGING TOGETHER INDUSTRIAL DESIGN AND ENGINEERING DESIGN EDUCATION

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ABSTRACT
Practical experience shows that the cooperation of engineering design and industrial design within product development is strongly required for developing innovative products. However, their cooperation is often insufficient and characterized by misunderstandings. Bringing together both disciplines already during education is accepted to be of importance to solve this problem, but temporarily realized only partly at German university programs. Realized through institutes of both sides a new course on industrial design engineering has recently been set up at TU Munich to focus this white field within German university education. Within this course the different discipline specific approaches and methodologies are taught to students of both disciplines in a theory block before the students get the chance to apply this interdisciplinary method mix within common team development projects in a practical part. The concrete organisation of the course as well as experiences made within its first cycle will be presented in this paper. Upon this a resume will be given that summarizes the findings as well as the derived optimizations for the next round.

Keywords: Industrial design engineering, education, student project

1 INTRODUCTION

Although effective product development demands an interdisciplinary process [1] that requires the cooperation of design engineers and industrial designers for developing innovative products, the cooperation between the two disciplines is often insufficient and characterized by misunderstandings. Bringing together both disciplines already during their education is accepted to be of importance. However, while according interdisciplinary courses exist in various countries in and outside Europe [2] this merge is temporarily not realized significantly at German university programs.

1.1 Motivation

While students of mechanical engineering at the Technische Universitaet Muenchen (TUM) are given the opportunity to take classes in Industrial Design at the faculty of architecture for a long time and thus could build a theoretical background within this field, there has been no course implemented in the existing programs that focuses the practical collaboration of Industrial Design (ID) and Engineering Design (ED). Together with the new chair of industrial design of the faculty for architecture at TUM there was now the chance to focus this white field within the university education in Germany.

1.2 Idea / Target(s)

Based on the general problem outlined in the beginning and the opportunity of having institutes of both disciplines ID and ED at the same technical university the idea of working out an integrated course of Industrial Design Engineering (IDE) was developed. In contrast to existing complete university programs called IDE as for example in Delft (NL) that focus on a fundamental industrial design education enriched by contents of engineering and business education this IDE course should become part of the independently ongoing engineering and industrial design master programs. Regarding product development equally from the ID and the ED point of view the course focuses on two issues: On the one hand this course should aim at (1) bringing together ID and ED students in

education by letting them commonly experience a “real” development project to improve their collaboration skills. This main target can be broken down to the three sub-targets of (a) improving the students’ interdisciplinary communication skills, (b) encourage the students’ understanding of each other’s way of thinking and working and (c) foster valuation and respect of the other discipline through making the students understand each other’s competences and skills as well as each other’s limits. On the other hand the course should aim at (2) providing the students with the right “tools” to systematically develop products within an interdisciplinary context.
According to these targets the idea was to set up a course that combines the acquisition of a common theoretical background with the chance to experience a common development process of a “real” development project within an industrial context.

2 STRUCTURE

From the idea of an integrated IDE course and motivated by the above mentioned goals, a detailed structure has been jointly elaborated by the above mentioned institutes and run through in its first cycle during the winter semester 2009/10. The developed course structure comprises two main parts as shown in Figure 1. The imparting of theoretical basics and the practical training of the introduced methods through exercises take place in the “Lessons” part, whereas the “Project” part constitutes the application of the gained theoretical and methodological knowledge in a practical development project. Thus, the concept of this new IDE course reflects the great importance ascribed to the practical collaboration between students of both disciplines ID and ED.
The total quantity of students accepted for the first run was 24 representing the two disciplines in nearly similar parts. The academic staff for the realization of the IDE course consisted of two scientific assistants of the Institute of Product Development and one of the Chair of Industrial Design.

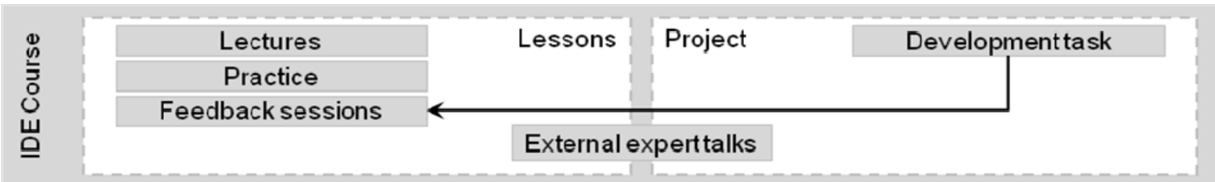

Figure 1. Structure of the integrated IDE course

2.1 Lessons

The lessons took place weekly during a period of 13 working weeks and were planned to last one complete day each. During the lectures, discipline and non-discipline specific methods (see paragraph 3.2) and their embedment into the underlying integrated phase model (presented in paragraph 3.1) were taught to the students. Both the arrangement of each lecture’s theoretical content as well as its presentation were driven as interdisciplinary as possible by the scientific assistants of the prevailing disciplines, while the preparation of their discipline specific content was taken care of by each discipline itself. In order for the students to obtain first experiences (or to consolidate existing ones) in the application of the taught methods, the latter were trained on the basis of exercises constituting the “Practice” part of the lessons. Thus, the common practical dealing with concrete tasks representing artificial situations within the development process allowed understanding the possibilities and limits of different methods and their integration as the approaches can be reflected and discussed together by both sides. The practical exercises of the methods in student teams (of varying constitution) is to provide a preparation for the methods’ application in the “Project” part of the course where they were supposed to solve similar problems independently in their respective project teams. This “Project” part is described in the following paragraph.

2.2 Project

For the “Project” part of the course, the students were divided into interdisciplinary teams of four or five members in order to handle the development of a specific product (or technical system). These projects had been set up in cooperation with industry partners (in the first run of the course, five projects had been defined with three different partners coming from the industrial fields of sports equipment, construction equipment and aviation) taking especially into consideration relevant demands coming from both disciplines ID and ED. The students were expected to commonly run

through the whole development process, from the requirements definition over conceptualization and embodiment design to the development of prototypes meeting all technical and formal requirements.
In constant exchange with the involved companies the teams had to deal with their projects independently during the week, based on the application of selected methods learnt beforehand during the lessons. Nevertheless, additional review sessions between the teams and the assistants were carried out during the weekly “Lessons”-day in order to discuss the current results and occurring problems. Besides the final presentation two intermediate presentations with the industrial partners had to be prepared by the students at the end of each phase (see Figure 2) to enable the teams to get feedback from their “clients”, to discuss their concepts and to involve them into the making of certain milestone decisions.
As a supplementary element the invitation of several external experts completed the IDE course. In the first run a methods expert from an innovation and design firm was involved providing a special training on building first product mock-ups employing various “quick ‘n dirty” prototyping methods. Furthermore, two experts of aerodynamics respectively material science had been integrated to help particular teams discuss project specific problems.

3 CONTENT AND FOCUS: METHODOLOGY

Two main tasks dominated the set-up of this new interdisciplinary IDE course; (1) Identifying the right contents of development methodology to be taught and (2) elaborating a proper framework that helps communicating this content in a structured way. Both of these tasks were realized through scientific assistants from both disciplines. The developed integrated phase model and the selection of development methods will be described in the following.

3.1 Framework: Common phase model

Phase models that focus on supporting a systematic development process are provided through from both disciplines. While a greater variety of “process or procedural models” with various focuses exist within ED [3, 4] only a few phase models are provided in the field of ID.

	Tasks	Phases	contents / methods [Engineering Design]	contents / methods [Industrial Design]
19.10.2009 Working Week 1	> Introduction > Team selection	Introduction	> Initiation, Introduction of the program, Team, development tasks and motivation > Introduction to the integrated ID&ED development phase model	
02.11.2009 Working Week 2	> Presentaion of development tast (productidea) > Task definition with the partners from the industry	Definition of Requirements	> Gradual Consistency (consistency matrix) [Practice]	Analysis of the product function from the industrial design view point
09.11.2009 Working Week 3	> Identification of requirements sources and identification of requirements to the product > Basics of requirements documentation > Structuring of requirements		> Checklists of requirement sources > Usage of diverse information sources (e.g. legislation, norms and standards, patents, market, customer, competition and diverse company sectors) > Requirements list (requirements specification) [Practice]	> KANO-Analysis [Practice]
16.11.2009 Working Week 4	> Analysis, structuring and evaluation of requirements > Documentation of requirements		> Impact network models [Practice] > QFD (correlation matrix, weighting) [Practice]	> design briefing and integration in requirement list
23.11.2009 Working Week 5	1. Presentation			
	> Analysis of product functions > Functional Modeling	Conceptual Design	> Relation oriented Functional Modeling [Practice] > zwicky box (morphological analysis) [Practice]	
30.11.2009 Working Week 6	> Develop / generate sub-solutions (concepts) for each sub-problem (--> systemic and analytic creativity methods)		> Finding solutions using physical effect catalogues > Find available solution: surveys, construction catalogues	> Systematic creativity techniques" (e.g. abstraction and transfer) [Practice] > Analogy methods [Practice]
07.12.2009 Working Week 7	> Develop / generate sub-solution (concepts) for each sub-problem (--> intuitive creativity methods		> Combination of methods (635 extended)	> Intuitive creativity techniques: drawing, Quick´n Dirty modelling, construction of volume models and mock-ups [Practice] (support from external designer)
14.12.2009 Working Week 8	> Evaluation methods and pre-selection > Consolidate action principles to concepts / verifying solutions according to the product functional models		> Develop solution concepts (compatibility of the sub-solutions) (zwicky box, reduction of solution space, etc.) [Practice] > Evaluation of concepts (pre-selecting using KO-criteria, ratings, comparison by pairs) [Practice]	
21.12.2009 Working Week 9	2. Presentation			
11.01.2010 Working Week 10	> Develop design concepts (Gestalt)	Final Design / Embodiment	> Systematic variation of design parameters using multidimensional ordering shemes	> Construction of design models: milling course, introduction to the machine shop
18.01.2010 Working Week 11			> Evaluation and selection of design alternatives > Methods for concept evaluation (linear and progressive weigthing methods, Ratings, Comparison by pairs)	> Presentation training
25.01.2010 Working Week 12	> Product validation			
01.02.2010 Working Week 13				
08.02.2010	Final presentation			

Figure 2. Phase model for common development process / selected method-mix

As the main objective of the course was to provide a powerful set of development methods the framework should only give an orientation within the project and help to understand the role of these methods within the allover development task. It thus should have been kept as simple as possible and at the same time allow embedding methods of both disciplines. Furthermore, this phase model gave a fundament for scheduling the whole course. According to the employed literature of the involved institutes [3-7] a three-phase-model was elaborated which divided the development process in definition of requirements, conceptual design and final design/embodiment as can be seen in Figure 2.

3.2 Method mix: Selection of a set of development methods

The selection of development methods to be taught to the students was an intensive iterative process that built up on the set-up of the depicted phase model. Besides supporting the special development task in each phase further requirements to the method mix existed: (1) Reasonable methods of ED and ID should equally find application. However, this could mean that methods of one discipline could dominate in certain phases dependent of the focus of the given task. (2) The presented methods should be comprehensive for both sides and not necessitate any further discipline specific educational background that exceeds the knowledge of one of the involved disciplines. (3) The methods should complement each other and interlock at the best.

As both disciplines on their own normally focus a complete development process it is a matter of fact, that certain (non discipline specific) methods do find application through both disciplines. However, as result of the different focuses within a development process there are discipline specific methods for certain problems that normally are used just by one of the considered disciplines. Reasonable methods of both types should be taught for the common development process. Examples of both of these method types will be described in the following.

3.2.1 Discipline specific methods

According to the discipline specific focuses within a development project ID and ED employ different methods to cope with specific development tasks. Within the field of ED aspects of technical functions of a product prevail as well as regarding the whole life cycle of the product. One typical example of an ED method is the employment of a requirement list that has to be set up right after the definition of the development task [3, 5]. Others are different kinds of functional modelling within the early conceptual design [3, 4]. An important one which has been taught within this course is the Relation Oriented Functional Modelling that fosters a solution neutral view on the product by helping to understand in how far needed “technical” functions depend on each other but can cause negative functions as well.

ID methodology in contrast concentrates on the utilization phase of a product and has got a strong focus on the human being as user and his functional requirements. An underlying method to identify these user requirements is the analysis of product functions (which comprise more than just technical functions) [7]. This analyses points out that products correlate to rooms and other products but first and foremost they are made for and used by human beings. Teaching the students this analyses they were able to follow a user-cantered approach that relates human’s experiences to a physical, a sensual and a social layer which enables the students to design the functions of a product accordingly to the experiences they want to achieve. While aesthetical functions fulfil specifications defined by analyzing the sensual layer and emblematical product functions match the social layer’s requirements practical functions of a product meet the demands arising from the physical layer. The latter ones correlate somehow to technical functions and thus expresses the compatibility of discipline specific approaches as well as their interaction.

3.2.2 Non discipline specific methods

Besides the former mentioned discipline specific methods both disciplines apply a series of common methods within the development of a product. Examples are various interview techniques or types of questionnaires that find application in customer surveys, the great field of creativity techniques for finding solutions [9, 10] or different assessment methods [4] applied within concept selection processes. Selected methods of this field have been taught to the students as well. As they’re commonly known they won’t be further discussed here.

4 DISCUSSION (REFLECTION)

This paper deals with the development of a new IDE course that was set up to improve the collaboration competencies of industrial and engineering design students within common development tasks. The following part summarizes and discusses the experiences made in the first run of the course. Based on observations, direct feedback it will be discussed in how far the initial set up targets (see section 1.2) were reached before possible improvements will be derived.

4.1 Experiences: Observations, Feedback and Results

While the observation of the accomplishment of the IDE course comprised regarding the students working/interacting and presenting over the complete semester feedback included direct response from attending students as well as from professors and the involved cooperation partners and was gathered particularly in feedback meetings after the course. The discussion of observations, feedback and results happens on the basis of the earlier mentioned two aspects, the structure of the course (section 2) and its methodological content and focus (section 3).

4.1.1 Structure (participants, lessons and project)

As the main targets were (1) bringing together the students of ID and ED to let them commonly experience a “real” development project within an industrial context and (2) providing the students with the right “tools” to systematically develop products within an interdisciplinary context, the discussion concentrates on the interaction of the students as well as on the set-up two component structure of the course.

Summarizing the feedback of the students the course gave the exceptional opportunity to gain important experience in interdisciplinary collaboration as well as an insight in the other discipline’s way of working and thinking which helped realizing the importance and relevance of the other side’s work. Apart from this the interaction of the students as well as their results differed a lot among the different teams. While some teams found efficient ways of working, taking into account the team members various skills and capabilities and sharing their work (according to their discipline specific capabilities or not) other teams had great problems running a productive development through the whole project. One possible reason for this is seen in a lack of canalizing the very heterogenic skills of the ID master students which results in their various backgrounds[1]. Supporting the students in taking advantage of these differences within a common team project wasn’t focused enough in this first run. Another reason for the partly unproductive team work is seen in the method mix taught as it gave a mutual basis but neither focused enough on the different existing (discipline specific) personal skills. The latter aspect will be discussed in 4.1.2. Communicational problems resulting from different or ambiguous definitions of the same vocabulary haven’t been observed as a great problem within the course. They probably have been compensated by the intensive collaboration of the students. The structure of the course in general worked well. The students generally stated the support by methodological approach given through the lessons as very helpful to work systematically on their development project. However, the rigid structure of the lesson within the course was criticized by the students. As it concerns the content it will be discussed in the following.

4.1.2 Content and Focus

Getting a methodological support through a common phase model and a harmonized set of development methods was generally judged as very important by the students as well as by the industry partners. Especially students who weren’t familiar with a methodological approach estimated this theoretical support as very helpful despite their difficulties in the method application in the beginning. However, giving the students a fix set of methods brought two difficulties: First, the necessity of methods to support a development process differs strongly with the given task. While certain methods could give great support for one team at one point, its application can be needed at another point in time or never at all for the task of another team. Instructing students to employ a set of methods at fixed points in time consequently leads to difficulties. Second, as consequence of the

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[1] While the graduated ED students had more or less learned the same basics within their engineering classes the ID students were in their first semester of a common master program. Their educational backgrounds reached from engineering design over architecture to graphic design and product design, their approaches from systematical and method based to unstructured and experimental.

different educational backgrounds the capability to apply methods brought to the students from the different disciplines differed a lot. While most of the ID students had great problems in the application of abstract methods as for example the Relation Orientated Modelling of Functions (see 3.2.1) ED students had trouble in developing more concrete presentations of product solutions in form of drawings but particularly in the construction of prototypes. However, these difficulties fostered the exchange within the teams and furthermore enhanced the respect for the other discipline's competences. In how far the impartment of a common set of methods is anyways favourable remains an open question. On the one hand it delivers a basic for a common development and important discussions between ID and ED students. On the other hand it forces to start the methodological support from almost zero. Thus different discipline specific backgrounds and skills can barely be taken into account which often leads to teaching students already known methods again and thus lowers the motivation of the students. Both these issues have been realized as main problems and will be addressed in the improvements suggested in the following section.

4.2 Conclusion and Outlook (Improvements)

Summarizing the discussed experiences the set-up of the course was successful concerning the set targets. Especially the confrontation with other disciplines (or personalities) way of thinking within a common development process was an experience that almost all students judged as exceptional and very important. However, helping the students in taking advantage of the various skills of such heterogenic teams wasn't considered enough beforehand and needs to be improved.

Concerning the impartment of methods two issues have to be (re-)considered:

(1) Although the provision of a harmonized set of methods for an interdisciplinary product development as second goal was reached the observations questioned this goal itself. The common learning process of a mutual method pool didn't take sufficiently into account personal and discipline specific skills and competencies of the different team members. Starting from almost zero was time consuming and partly frustrating for the students. Another option which will be discussed would be to send the students to already existing classes that cover contents they haven't learned so far before bringing the students of both disciplines together in a common development project.

(1) As the development tasks of the different teams differed in their need of methodical support according to the involvement of industrial partners from different branches with very different products the provision of methods has to happen more flexible while a mandatory application has to be questioned in general.

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