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DESIGN MAPPING: SUPPORTING COLLABORATIVE ADVANCED DESIGN PROJECTS WITH MAPPING TECHNIQUES

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ABSTRACT (250 WORDS MAX)
This paper presents the idea of “design mapping”, an approach in which mapping techniques (e.g. concept mapping or mind mapping) are used in early stages of the product development process, visualizing both the process information and product features. It originates in the “collaborative Advanced Design Projects” (collaborative ADP or cADP) at Technische Universität Darmstadt (TUD), which are also described in regard to concept, organisation and experiences.

Keywords: Engineering and Industrial Design Education, Team Cooperation, collaborative Advanced Design Project (cADP), Mapping Techniques, Design Mapping

1 INTRODUCTION TO CADP

Product development is a collaborative and (above all) communicative process between often differently educated participants [1]. Aiming at preparing students for industry-like team projects, the faculty of Mechanical Engineering at Technische Universität Darmstadt (TUD) has introduced the Advanced Design Project (ADP) for the final courses of the Master programme in Mechanical and Process Engineering. In it, four to eight students collaborate in a mostly self-defined design project within a timeframe of originally about 80 hours (excluding documentation, extended by recent reforms of the Master programme). Whereas “normal” ADPs are usually offered by a single department within the Faculty of Mechanical Engineering, the “collaborative ADP” (cADP) aims to go beyond department and faculty borders. It originates in a co-operation of three mechanical engineering departments, namely

- Computer-integrated Design (Datenverarbeitung in d. Konstruktion, Prof. Anderl),
- Product Development and Machine Elements (Produktentwicklung und Maschinenelemente, Prof. Birkhofer)
- Ergonomics (Institut für Arbeitswissenschaft, Prof. Bruder)

with the Faculty of Design of Darmstadt University of Applied Sciences (h_da).

Thanks to that combination, the cADP boasts a highly interdisciplinary team composition, with aesthetic and mechanical design, ergonomics and computer integration duly represented. Since the first iteration in winter term 2005/2006, four cADPs with a total of 45 participants have taken place. Each course has shown a noticeable improvement with regard to organisation; while the first cADP in winter term 2005/2006 was restricted to a blog-like collaboration platform for file and information exchange, the second iteration in ST 2006 introduced a (now fully established) mapping-based collaboration platform, implemented with IHMC's CmapTools [2] client-server application. Each time, students were familiarised more extensively with the tools put at their disposal, as well as with their roles and responsibilities as members of a design team.

2 CADP COURSE DESIGN

Due to their interdisciplinarity, cADPs face characteristic challenges: Participants' different courses of study imply not only differing views on the design process, but also significantly different competencies and different interests in the outcome of the project, as well as (at times very) different temporal availability. To "build common ground" in the setup phase, a two-step approach was chosen.

2.1 Setting up, conceptual step: Defining competency aspects to focus on

Looking at research in team cooperation, it shows that Cannon-Bowers offers a suitable matrix to classify team competencies (Figure 1) [3]. While the goal of a cADP is undoubtedly to build as much "transportable" competency as possible, the necessity for context-driven competencies cannot be ignored and has to be dealt with on the operational level, including both team and task elements.

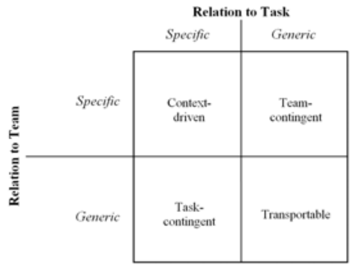

Figure 1 Two-dimensional approach to team competencies, introduced in [3]

Cannon-Bowers further defines Knowledge, Attitude and Skill as the key attributes of team competency. In the particular case of cADP, sufficient knowledge about design is assumed to be present, since all participants (including Industrial Designers) are at the end of their studies. Attitude is equally assumed to be present, since participants are provided with a self-defined, motivating task and team environment in an elective course. Therefore, the educational focus of the project lies in the skill attribute.

Skill has, according to Cannon-Bowers, the following dimensions: Adaptability, shared situational awareness, performance monitoring & feedback, leadership/team management, interpersonal relations, coordination, communication and decision making. Early results of the interdisciplinary BEMAP project, a collaboration of TUD engineers and psychologists of Bamberg University, add another dimension: Reflection. As described in [4], reflection supports all other dimensions (e.g. in situational or processual analysis) and is indispensable for successful teamwork. All of these dimensions of teamwork have to be considered to master the design process. Building a common understanding of product and process is achieved by developing "shared mental models", as described in [5]. This, in turn, can be facilitated by the proper use of methods, tools and media put at the participants' disposal.

2.2 Setting up, operational step: Organising interdisciplinary collaboration

2.2.1 Team-specific and task-specific preparations

To make sure that existing competencies were balanced as well as possible, teams were pre-defined by supervisors, drawing on previous experience and signup questionnaire

data. With the assumption of “specialist roles” enforced (mechanical design, computer support, ergonomics, aesthetic design, project management, team leadership), participants were required to know about and reflect on their strengths and weaknesses.
In the latest, conceivably optimal approach to task definition (applied during 3rd and 4th cADP), students were asked to develop a product of their choice within a pre-defined application area or “scenario”. Choosing one out of several (presumably) suitable scenarios was left to participants, in order to make sure they could identify themselves with the product. Previous approaches with a completely "free" product choice (1st cADP) had proven ineffective and ended up in eternal discussions among participants. Similarly bad results were given by the almost completely pre-defined product of the 2nd cADP (electronic tape measure with a bonus feature of choice), which had proven to be somewhat demotivating in terms of creativity and product identification.
Product complexity, however, was kept reasonably restricted throughout all cADP instances, in order to prevent both “black-box design” (considered too conceptual) and pure subassembly development (considered too technical).

2.2.2 Getting and keeping students “on track”: Kick-off event and project control

To allow for a maximum of flexibility, compulsory attendance of all participants (including supervisors) was limited to the kick-off event at the beginning of the course, and a final presentation at the end. To maintain control in-between these key dates, participants had to show up at least occasionally in order to deliver three self-scheduled milestone presentations. Given the occasional ad-hoc character of these sessions, not everyone had to be present at every time.
However flexible the course was designed, the kick-off event focussed on organisation just as much as on knowledge sharing and team building. In its beginning, participants were introduced to the task at hand, as well as to the rest of the team, including supervisors. After that, and after a series of knowledge-sharing presentation introducing everyone to the disciplines involved, they had to define their product within the chosen scenario. Once the participants had convincingly presented the chosen product and the associated project plan to the supervisors, they were given free choice in their further time planning, under condition of meeting the (mostly) self-defined project milestones.

2.2.3 Supporting design skill management: Collaboration tools

From the beginning, supervisors expected a highly self-organised project, strongly based on shared responsibilities, well-defined interfaces and process-to-product coordination. To facilitate this complex task, it was clear that a common collaboration platform had to be provided. During the 1st cADP, an improvised, blog-like web platform with file attachment capabilities was provided. Postings were always in reverse chronological order, and no cross-referencing was possible. Obviously, this solution was unsatisfactory for further cADP iterations. From the 2nd cADP onwards, collaboration was therefore shifted to the CmapTools Collaboration platform [2]. In retrospect, this is the moment in which the “design mapping” approach started to take shape.

3 IMPLEMENTING THE DESIGN MAPPING METHODOLOGY

CmapTools is based on a mapping technique (MT) called concept mapping [6], which is originally used in pedagogical contexts. MTs use diagrams as a simplified visual model of an entity, composed of graphical elements annotated with text fragments or symbols. These diagrams facilitate the gathering, sharing and exploration of information. MTs are powerful and easy-to-use methods to portray complex information, supporting knowledge visualization (e.g. concept mapping) [7], argumentation visualization (e.g. dialogue mapping) [8] and creativity (e.g. mind mapping) [10]. Figure 2 shows a simple concept map, originally implemented in the CmapTools software.

Figure 2 A simple concept map, illustrating a student's view on design interaction

MTs act as a "cognitive prosthesis", aiming to support the limited cognitive system of human beings, drawing both on the visual and the spatial working memory system. Compared to a linear textual description of information, a MT may allow users to avoid having to explicitly compute information, enabling them to extract information 'at a glance'. "Helping students to organize their knowledge is as important as the knowledge itself, since knowledge organization is likely to affect student's intellectual performance" [8]. Furthermore, MTs facilitate to trace 'design rationale' [9] as an explanation of why a designed artefact is the way it is.

For modelling processes and product information, a basic "design mapping" methodology was introduced in the cADP kick-off instructions. It is based on recommendations for various mapping techniques, such as mind mapping [10], concept mapping [11]) and general problem solving strategies [12]. The methodology comprises five simple steps:

1. Formulate a contextualizing "Focus Question".
2. Collect relevant information in the form of different objects (text or pictures), either by using the team's creativity in brainstorming or by individually adding to it.
3. Sort, rank, and/or organize the collected information by positioning the objects relative to one another (e.g. by grouping similar elements).
4. Select the main objects and start connecting them with named relations.
5. Format and structure the objects and their relations by the use of colours, text formats, etc. and repeat steps 2 to 5 if necessary.

This method could be easily used with the CmapTools client. Furthermore, simple formatting guidelines for highlighting responsibility (role or person), status (new, in progress, finished) or importance (low or high) of the objects and relations were suggested. Adopting these organisational rules was recommended to the students, rather than imposed on them. Working with the CmapTools client software, teams could easily define networked structures to represent the interdependencies of product and process features, as well as organise and store their data and discuss open points in the integrated forum.

4 RESULT ORIENTATION: ADDING PROCESS MONITORING

4.1 Early cADP results, experiences and conclusions

Judging from a purely product-oriented point of view, the results of the cADP collaboration efforts have always been highly satisfactory, both in regard to the technical and the aesthetic solutions provided by the teams. Figure 3 depicts products designed in the 3rd and 4th cADP respectively.

Figure 3 Product results of the 3rd cADP (left) and the 4th cADP (right)

In comparison, the documentation left much to be desired in terms of displaying process insight, regardless of the ever-high weighting factors given to the “process” part of grading, and the noticeably improving process quality. However, the application of the CmapTools software has proven from the beginning not only to support the participants in the design process, but also the supervisors in tracking the project progress. That could be achieved by simply watching the product “evolve” in its Cmap representation. The decision for future cADPs was easily taken: Mapping techniques were continued to be applied as a “universal method” with low entrance barriers and high expressiveness.

Additionally, with process curiosity further stimulated, it was decided to establish an “externalised” monitoring of the process to acquire additional data. The following sections will give help on implementing and present results of the monitoring activities.

4.2 Adding process monitoring: Implementation and results

The idea behind process monitoring was, first of all, to acquire additional data about the process, while keeping it completely independent from grading. To that end, the monitoring task was “outsourced” to interested graduate students as a thesis topic. Judging from our experience, it is advisable to rely on carefully selected, empathetic and markedly interdisciplinary students – participants are obviously not keen to be treated like guinea pigs or “test setups”. By completely anonymising data, and by carefully building mutual trust, valuable information can be gathered.

For cADP, participants were asked to keep standardised logs of their activities and fill out several questionnaires at kick-off and milestone meetings, aside from accepting unobtrusive observations. Results of the first process monitoring, covering a total of 114 questionnaires and logs, show that reliable quantitative data can be acquired, indicated by the blatant honesty of students’ work logs. One student’s entries amounted to a (realistic) work sum of less than 20 hours, in a course in which 80+ were expected.

Figure 4 shows software usage share and communication channel results, indicating the central role of CmapTools for project work. Asking about its usefulness at each milestone, it was rated “useful” in 81 % of the cases (vs. 6 % “not useful”, 13 % “no reply”).

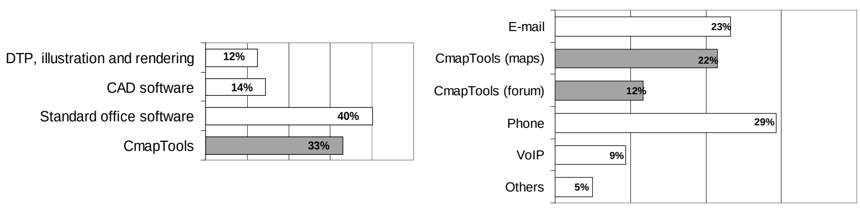

Figure 4 Software tool usage shares (left) and communication channels (right)

Regrettably, newer monitoring results (4th cADP; end Feb 08) could not yet be included.

5 CONCLUSIONS

Across its iterations, the cADP has shown steady improvements, while proving to be a suitable environment for observations of the collaborative product development process between engineering and industrial design students.

With "design mapping", a methodology has been developed, introduced and tested, which could fulfil the need for flexibly usable methods, tools and media for the early and "fuzzy" phases of the product development process. cADP results indicate that design mapping allows to quickly organise the often fuzzy, incomplete and dynamically evolving information in the early stages of the product design process.

All in all, results warrant further work in cADP and design mapping. Aside from continuing the cADPs, some still-recurrent deficiencies of the CmapTools software suggest that the development of a tool specific to design mapping might prove to be of interest.

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