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Continuing Education and Personalization of Design Methods to Improve their Acceptance in Practice – An Explorative Study

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Abstract

One possibility to establish and foster efficient method transfer from academia to industry is via the heads of professional designers and design students. The transfer and use of design methods in a sustainable way is related to the methods' acceptance by the user which is accompanied by many challenges. Educational concepts and design method adaptions have been chosen as decisive control parameters among many others in order to understand and evaluate how these can influence the acceptance of design methods in industry. An interview study to gain an understanding of the rationale of educational needs of engineers has been conducted to enrich existing literature in this area. The evaluation of feedback from academia-industry cooperation revealed specific challenges accompanied with educational concepts for modularization design methods. Based on these findings, an adaption was developed and an experiment study was conducted with students as future designers to decode variable factors in design training, gain qualitative feedback to a specific adaption and gain an understanding for the conditions and limitations of an experimental study. Joint conclusion reveals the need for improved education in method transfer and adaptions of the design methods to user-specific needs and paved the way for a series of experiments with various treatments of study participants regarding different personalized adaptions in design methods.

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1. Introduction

Although the development of design methods is a major topic in design research [1] and specific methods proved successful in case studies [2], their use in industry is still limited. In research, various reasons are discussed, for example the performance of new methods or the prototype character of developed tools. Besides, human factors play a major role in acceptance. Methods are often not adapted to typical work practice of a company or the individual needs of the users [3]. Other researchers point out, that efforts are missing to transfer methods e.g. by long lasting industry and research cooperation [4] or education, because the benefits of design method application evolve with time due to training outcomes [5]. Continuing design education is seen as an important variable to maintain and professionalize design behavior [6]. Existing literature reveals that teaching design methods have to be adapted and consider aspects of learning [7].

This paper focuses on the impact of human factors on method acceptance and aims at demonstrating that enhanced teaching concepts as well as personalization of design methods can improve design method acceptance. This explorative study will demonstrate which factors in training and how concepts in continuing education can be adapted and personalization of methods can be made to increase the acceptance of design methods.

This explorative study analyzes the method transfer through designers in industry as well as future designers in higher education, as students represent one "channel" of transfer for design methods.

This study proceeds as follows (Fig. 1). Literature findings about design method transfer from academia to industry and human factors in product development (section 2) form the

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basis for an interview study on expectations towards continuing education in mechanical engineering to explore students' as well as engineers' perspectives, especially their rationale on certain learning motivational drivers and preferences on teaching concepts (section 3). These general findings are extended with specific evaluation of feedback collected from industrial workshops and teaching product development at the university about modularization and reveal experienced challenges (section 4). Based on these challenges experienced by the method transporters, an experimental study was conducted with future designers to assess the impact of an adaption made in accordance with the users' needs and identify and enhance comprehension of influencing factors for further experimental research (section 5). Resulting implications for research and practice will be illustrated (section 6) and the conclusion of this explorative study (section 7) will form the basis for an outlook on future research.

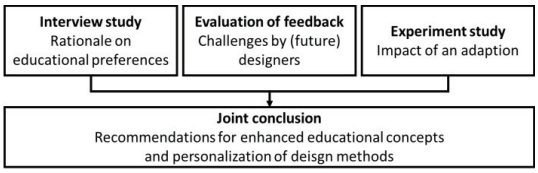

Fig. 1. Procedure of this explorative study

An understanding gained through this work with regards to the possible parameters which influence design method acceptance should finally create a basis to design a series of experiments which help to assess designers' design method acceptance. The main research question therefore is "How can teaching concepts for design methods be improved in order to enhance acceptance in industry?"

2. Background

2.1. Design method transfer from academia to industry

To bridge the gap between academia and practice and thus increase the acceptance of new methods in practice, models and approaches to support transfer projects of methods have been developed in the design research community, e.g. [8], [9] and [10]. Basis for these are e.g. ideas of change management or surveys in industry regarding shortcomings of methods and requirements on the implementation of methods into daily business. Shared success factors of the mentioned works (for detailed summary see [10]) are the need to understand the company needs, providing simple and individual fitting methods, convincing and involving people in the change process and not least suited training und provision of support during the methods implementation and its use. Within these transfer projects continuing education of the work force is needed, not only to train the methods, but to change the mindsets of the relevant designers and managers.

Beside the described support of transfer projects, the education of students during their studies plays a major role to change the practice on the long run. Students, well trained in new methods, take up relevant positions (e.g. designers or managers), and change companies from within [11].

2.2. Human factors in product development

The efficient use of design methods is dependent on various factors, among which the designer can be mentioned. The individual designer with his/her personality, attitudes, well-being, motivation, perception and emotions within a social environment in which a technical task needs to be solved can greatly impact the design process.

Besides personal factors such as experiences, the designers' educational background plays an important role in the design process [12]. Research into the learning process and the application of design methods has illustrated a gap which can be bridged by a consistent teaching concept adapted to the students' needs for an enhanced design method understanding [13]. Existing literature in continuing education and design method transfer as well as design method adaption is extended through this explorative study by a joint analysis of findings in these areas based on hands-on experience analysis with modularization methods and accordingly specific adaption development.

3. Interview Study

3.1. Planning and conditions

The goal of this interview study was to find out motivational factors and learning problems in general and expectations towards continuing education in engineering both for students and engineers in industry. The focus of this explorative research lies on exploring the mindset and reasons behind answers; therefore conducted qualitatively. Face-to-face interviews were conducted with 7 students studying mechanical engineering and 4 engineers in industry. Interviewees were recorded and notes were taken during the interviews. The collected data was analyzed through a content analysis.

3.2. Opinions and requirements of interviewees

Interviewees were asked about their general motivation to learn, during which activities they learn the most frequently and to reveal their opinion about the composition of the continuous education learning group – should there be shared courses of students and industry representatives or should the events be offered separately?

Interviewees mentioned that the *need to know* and the received *feedback associated with the learning process* were motivating. They have added that the need to know arises by intrinsic curiosity in the subject-matter and interest into the respective area and by relevance and usefulness of the subject-matter for professional life. This aspect was mentioned with regards to acquiring knowledge and skills which enable to solve the given tasks and was associated with regards to competitiveness towards others.

Different forms of feedback in connection with the learning process and outcomes were another motivating factor for

learning mentioned by interviewees. Personal feedback in form of regret of not having been able to perform as wanted, achievement and recognition due to successful solving of a task reflected through grades or in oral feedback were outlined to be motivating.

The *execution and application of specific tasks, context-relatedness* of these tasks and the respective *exchange with others* about the topic such as explaining certain challenges encountered as well as own *idea generation* were situations paving way to learning frequently. New tasks and research projects were mentioned beyond own research; adequate environmental conditions such as having a relaxed atmosphere for the learning process were also revealed.

Environmental aspects were also mentioned for the question. These environmental conditions include noise disturbance and distractions through social media use for instance.

Personal aspects such as physical conditions (like experienced decreasing concentration after lunch) and *organizational limitations* such as time pressure to solve a task were illustrated by interviewees. An emphasis was put on the *lack of relevance* of subject-matter which makes the learning process difficult and the *dependence on others* in case of lacking information or skills to solve the tasks.

Analysis of interviewees' opinion led to reasons for mutual education and against. The rationale behind mutual education lies in the fact that students would profit from insights into industry, different competences of students and engineers could be merged and an exchange on demanding subject-matter can help to overcome related challenges through sharing and exploring different perspectives which result in a diversity of communication.

Reasons which challenge mutual attendance of engineering education are given by different backgrounds of students and engineers in industry with regards to personal characteristics such as age and experience as well as expectations towards such continuing education and the capability to learn. It was mentioned that due to their industry experience, engineers may not consider students as equal exchange partners to discuss challenges and expand networking activities. Another aspect crucial for the interviewees was their thought that engineers may expect less research-oriented contents but more economically-driven topics to discuss, whereas students claimed this may divert the focus from their interest in fundamental science. Besides the reasons for certain preferences in continuing education, at this point it is necessary to evaluate experiences of designers from industry who have actually been part of an academia-industry cooperation. Furthermore, feedback from future designers at university who were confronted with design in education will give valuable insights into how far enhancement of teaching concepts and a method-adaption to personal needs can be developed.

4. Feedback from design education events

Feedback from design education during continuing education in the form of modularization workshops for engineers in industry conducted by the research institute were collected and analyzed to collect specific experiences. Besides design engineers, students are valuable design method transporters from academia to industry and hence define another target group who's acceptance play an important role in this transfer. Therefore, another study was conducted to further explore students' learning habits to find possibilities to strengthen the transfer through potential design method users. Feedback from engineering design students from a product development lecture serve as a preliminary needs analysis for possible adaptions in education concepts in design and design method adaption.

4.1. Description of modularization workshops

In order to enhance method transfer from academia to industry, the research institute has conducted 5 modularization workshops. Fundamentals such as definitions, strategies, potentials of modularization and their impact onto product development will be demonstrated. In order to enhance the industry exchange and improve understanding through practical examples participants are motivated to talk about current challenges. Different modularization methods, their strengths and weaknesses in application and the modularization method developed by the research institute, the integrated PKT-approach [14] which is a method for developing modular product families is trained intensively in lectures and interactive exercises.

4.2. Feedback of engineers from modularization workshops

Feedback on workshop contents reveals that learning new, basic modularization principles and different approaches were appreciated. The gained overview and the possibilities to evaluate modular structures received positive resonance. The exploration of challenges in the practical implementation of methods during practical examples and case-studies were considered to be useful. The reflection on the methodical procedure applied and effective exchange with participants who were from different companies was mentioned to be positive.

Participants expressed their desire to have seen more practical implementations of the design methods and their use areas and their organizational as well as process setup frame need to be cleared. Potential conflicting situations thereby need to be specified. Given use-cases can be detailed further.

Feedback on the training concept has shown that practice was put in focus through practical examples of the method, implementation of the method, product examples, industry use-cases and a good mix of theory and practice. Participants especially liked the presentation and implementation of various methods in an interactive training concept with various opportunities to communicate with others. The competences of the trainers were appreciated. It was mentioned that feelings about a good product structure could become transparent and objectivized.

Improvements for the future with regards to the didactical concept refer to easier explanations of the methods, more precise tasks to solve with boundary conditions and an

overview of methods with their advantages and disadvantages.

4.3. Description of the product development course

The integrated PKT-approach was taken for an adaption to user-specific needs. Due to the fact that students of the advanced product development lecture of the research institute have a comparable background in product development and are potential users or transporters of design methods into practice, these students were chosen for a needs survey due to their first impression with the design method. This first impression is assumed to be an important variable for the methods' long-term application in industry. The conditions of limited amount of time, group work and required skill to learn quickly to solve the design task provide a high psychological fidelity to the situation of engineers in industry. The research question was operationalized and transformed to qualitative as well as quantitative questions in the paper-and-pencil survey represented as free space answer questions, multiple choice and ranking questions. The following main survey categories proved reasonable after a pre-study with 3 research assistants and are listed as follows:

- Naming and explaining difficulties during the application of the design method (Q1)
- Possible adaptions to facilitate application of the design method (Q2)
- Personal experiences with specific parts of the integrated PKT-approach (e.g. easiness to understand, the most difficult aspect of this part etc.) (Q3)

The goal of this survey was to find out specific difficulties of the integrated PKT-approach, which also shed light on general influences on method understanding and their efficient use in product development (Q1), to generate comfortable adaptions as solutions which fit the target groups' needs (Q2), to collect and analyze individual tools' perceived benefits and disadvantages to be able to compare the tools via certain criteria and identify the area of most urgent need for improvement (Q3).

29 students were provided with the survey immediately after the modularization group exercise to ensure that memories and experiences are fresh.

4.4. Feedback of the product development course

The difficulties mentioned by the students during the modularization process with the integrated PKT-approach can be categorized in three categories.

User-dependent difficulties are due to lacking previous knowledge and experience with design which ultimately led to not knowing how to start.

Method-related difficulties arised through lack of understanding for the method technique and the corresponding interrelations. In this regard, the required mapping procedure and criteria were not clear. The fact that there is no unique structure gives choice in developing modular structures and posed a challenge to students.

Didactical concept arrangements such as the specification of the task boundaries revealed improvement potential and the time schedule allocated was considered to be a challenge.

To generate ideas for adaptions in the method and the educational concept, students' opinions on how to facilitate application were collected. With regards to the method application, students demanded procedural instructions for modularization and an enhanced visual representation. In order to improve the didactical concept, the reduction of the extent of the exercise example, clarification of the interaction of the methods individual steps, clearer instructions on what to do in every group and the explanation of specific examples in the preceding lecture in more detail and a clearer design was demanded.

Individual tools' and procedural method steps of the integrated PKT-approach revealed students' personal experiences and therefore variable factors in the following areas:

Required pre-knowledge, conceptual understanding, active generation of single steps of the tools, visualization of the method, (holistic) overview, degree of detail, clarity and simplicity, abstractness, easiness to understand, easiness to apply, easiness to remember/reproduce, easiness to develop, complexity, difficulties in the distinction of the levels, problems with synthesis and unclear instructions, putting oneself into the role of others. The results of the interview study helped to find out what lies behind designers' learning perspective and the evaluation of feedback helped to gain an overview on the specific gaps. This basis helped to develop an adaption of the integrated PKT-approach and evaluate it in an experiment.

5. Experiment Study

5.1. Preliminary needs analysis with a survey

Various parameters which can be adapted in the design method or the design method transfer process have been identified (section 4). In order to develop new concepts on the most promising parameter, a case-specific adaption was required. The target group needs to be well-defined in order to allow for a concise search and development of required adaption solutions. The most pressing needs were identified through the survey among students of the lecture advanced product development (section 4.4).

Through this survey, an idea generation workshop for possible adaptions to enhance the application of the design method with students and researchers and a final survey among experienced students and researchers finally led to the development of additional supporting material (Fig. 2) for facilitation of the module synthesis process during modularization with the help of a developed tool. The independent variable of the experiments was therefore the *additional supporting material* to guide the user with instructions and additional information through the modularization process.

Development of the user-specific method adaption required that the additional supporting material was designed in

accordance with following criteria to motivate its use in between many other material distributed to students working on the design task. It should provide useful contents, have a good layout to support structuring and be aesthetically appealing.

Finally, the additional supporting material included in the front side a step-by-step-general instruction and overview of the method steps via a practical example with the goal of each steps' and hints. On the backside, the potential benefits of modular product structures with regards to each life phase and an overview of motivational backgrounds for modularization in a graphical representation with the most important buzz words and reasons as well as more detailed explanations to each buzz word in a table were provided. A more detailed step-by-step instruction based on the first page is given in written form and illustrated via a practical example.

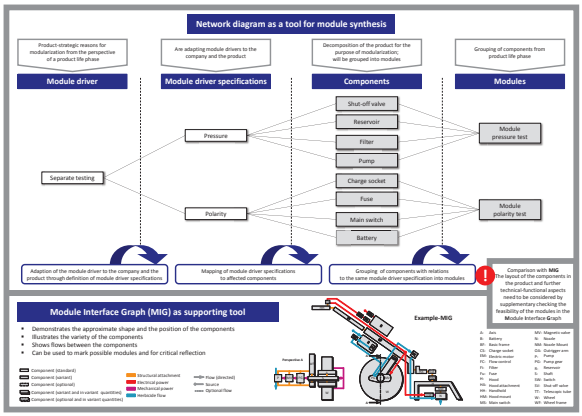

Fig. 2. Additional supporting material as method aid

5.1 Conduction of the experiments

The independent variable was therefore the method aid provided and the dependent variable the groups' performance. Based on this, the following conditions were present during the experiments with one control group of 4 students and two experiment groups with each 4 students in a between-subject design (Table 1).

Table 1. Conditions for the different experiments

Provided material	Control group (1 group with 4 members)	2 experiment groups (2 teams with 4 members each)
Additional supporting material	Not provided	Provided

All experiment groups were informed about the study's details and asked for consent. The below mentioned relevant groups (more experiments were conducted but served a different research question) received an introduction into the topic modularization followed by a design group exercise (Fig. 3) on modularization. The groups presented their results at the end of the designated time period. Written and oral feedback was collected from the study participants in general and in specific. The problem-solving process, the use of the material provided to solve the task and their satisfaction with their solution was reflected and discussed. Space for additional commentaries was provided to pick up additional hints such as with regards to the study setup.

5.2 Documentation and results

The experiments were analyzed through real-time observation and its documentation of the students during the problem-solving, collecting feedback from participants (oral and written) and analyzing the researchers' impressions and evaluation of modularization results from the students.

Quantitative data gathered through the student survey after the experiments was analyzed by calculation of the number of votes for each answer and the respective mean value resulting from the individual answers. Multiple choice questions were weighted with a scale from 1 to 4 points. Qualitative answers were summarized and categorized. The participants were also asked to provide oral feedback. The analysis of this data base gives the following insights.

The students used the additional material less than expected; therefore it is difficult to clearly assess the impact of the additional supporting material. Nevertheless, positive quantitative and qualitative feedback underlines that the additional supporting material can support the user. When students were asked after the experiment to assess the usefulness of the additional material they said that it is useful. They claimed that if they had regarded it more carefully in the beginning, several of their problems and questions could have been solved. It was also mentioned that the task could have been solved with just the additional material without the introduction on modularization principles if more time to dedicate to the additional material was provided. Reasons why they did not use it that much included

- team dynamics, such as the overmotivation to accomplish the task such that a direct and intuitive working on the task without focusing on additional reading was done,
- the example given came from a different life phase than the one they were supposed to do in the group exercise and therefore transfer difficulties arised
- visual aspects such as too much text.

In this context, it is important to note that the adaption did not deteriorate the modularization process. Useful hints on how to improve were collected from the participants and serve as a data basis for upcoming experiments. In general, it can be concluded from this study that the additional method aid can support the designer and should be adapted to the users' needs with regards to the material itself as well as the educational concept behind it.

Fig. 3. Impression of the group exercise on modularization

6. Implications

For an improved acceptance of design methods in practice, the design education concept and the design method can be adapted to the user. The design methods' potential in general and their specific use to the designer with regards to current problems in the specific context should be emphasized. The relevance to the user can be increased through combining the task with the designers' daily problems. The creation of space for various kinds of oral and written feedback by various stakeholders such as academia representatives and industry representatives is necessary for the designers' confidence, enhancing exchange and creating new knowledge. (Future) Designers should be given the chance to reflect upon their procedure and be provided with assessment tools. During instructions, the role of the trainer plays an important role. In the next step, additional supporting material should be considered during training and after training. The contents as well as visual representation of this additional supporting material need to be further specified. In how far students' and industry representatives' needs are coherent and results acquired from studies with students are applicable to engineers remains an open question for further research. Qualitative findings can be extended to quantitative studies to collect statistically reliable data in the future.

Limitations of this study include that during the interview study, although everything was done to make the participants feel comfortable, interviewees may have retained some of their comments because of the abstractness of the topic and social desirability effects on a personal topic such as learning experiences. The results of the experiment study need to be statistically assessed as the positive outcomes in the experiment group with the specific adaption yielded insignificantly higher performance results. Not least, it will still be an open question in how far the user-specific desires for adaption comply with organizational constraints, didactical principles and methodical fundamentals.

7. Conclusion

The starting point for this research was the transfer of methods which also happens through continuing education for professional and potential designers in training – the design students. During this transfer, various challenges occur and can be user-dependent, method-related or related to the educational concept. This paper has given insights into the needs of potential designers (students) and engineers in industry with regards to these areas and depicted their implications on the enhancement of educational concepts and design method adaption. Besides the adaption of training concepts to cognitive principles and design-specific conditions, the need for a user-specific adaption – personalization – of the design method has been shown via an identification of various influencing parameters and the rationale between variations in them. Experiments have proved a good validation procedure in testing adaptions to design methods and design method education, though influencing factors such as group dynamics need to be considered in the future. Although more influencing parameters in design method transfer from academia to industry exist, this work has helped to gain an understanding of experiment conditions and will form the basis for further experimental studies for personalization.

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