

THE GAP BETWEEN LEARNING AND APPLYING DESIGN METHODS

J. Jänsch and H. Birkhofer

Keywords: design education

1. Introduction

Teaching design methods [6] with the result of producing competent designers is a complex challenge. It is important to impart the aims of a design method, which consist of the effects of the design method itself and their role within the design process. Students need to understand these aspects in order to purposefully apply them. Design students should be educated with regard to these requirements to become competent in applying design methods at the university as well in industry. In order to achieve this, the relevant questions must be considered: What problems do students encounter when learning design methods? How are these problems caused? What changes have to be made to design education in order to ensure that students gain this competence?

2. Actual situation: Education and application

Design classes are often instructive and impart to the students how design methods should work. In the lecture the design methods are demonstrated with examples. The purpose of the design class is to extend and deepen the knowledge about designing, and especially the design methods. In most cases, they use design tasks in the lecture and class which fit a particular design method very well. They also show the application of the design method on an example in the lecture. The design task in the design class is very similar to the example in the lecture (Figure 1).

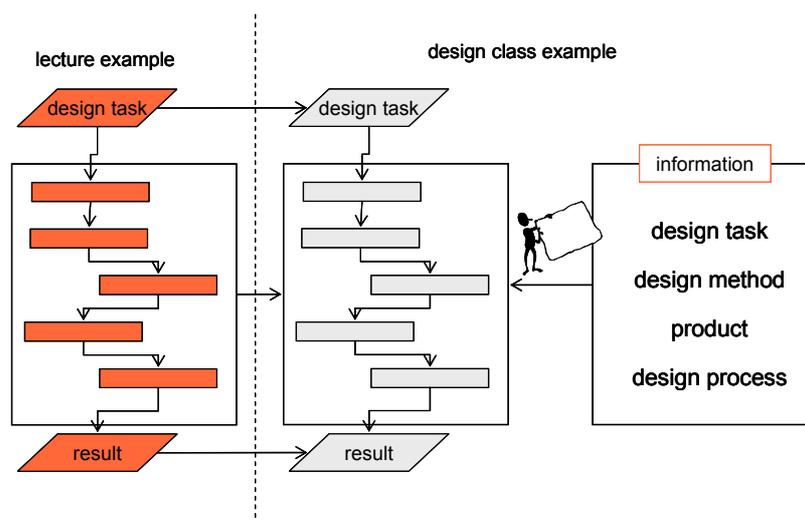


Figure 1. Actual teaching situation

The design task provides all the information which is needed to solve the task with a particular design method. The information consists of a description of the design process, the design method, a description of the design task and information about the product. So, the students have access to all this information during the design class and can additionally ask a tutor. This way of teaching guarantees the student and the teacher a successful learning process. The students feel that they have a comprehensive understanding of the design method and their application and can apply the design method in other design tasks.

However, experience shows something else: The students are in most cases not able to transfer the design method to a task which differs from the type of design task with which they learned the design method (see Figure 2). In other words, they are not able to adapt the design method to a new design task in the design class. So, they can neither find the right information that they need to apply the method nor can they structure the design process.

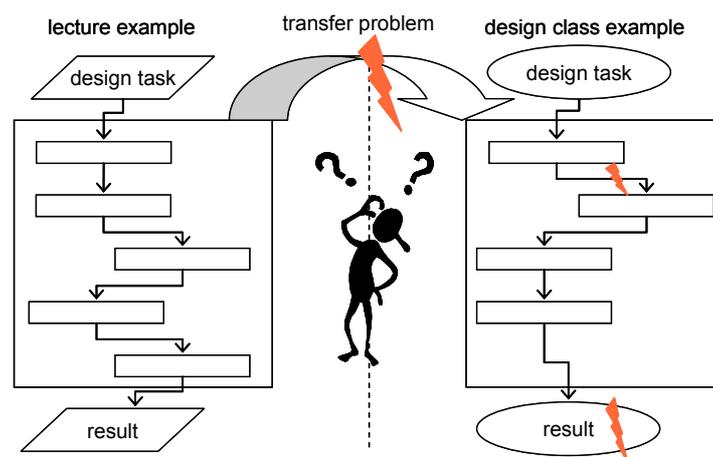


Figure 2. Transfer problem

There are apparently two reasons why they fail in using the design method. Firstly, they do not know how to proceed and end the process. Secondly, their failure is due to a wrong result. This is presumably the fault of the nature of design methods. Design methods are not like mathematical formulas or recipes, but students often try to use them in this way. They try to transfer the design method from the example from the lecture exactly to the design task in the design class. They are confused when they do not find the expected information in the expected way and at the right time. Some times they do not recognize that they completely fail the effect of the design method. This shows that they do not know what the characteristics of a design method are and why they do work. For that reason, the characteristics need to be analyzed more concrete in order to find appropriate educational instruments to impart them.

3. Characteristics of design methods

Design methods are very flexible in their application [1]. This flexibility stems from the different adaptation possibilities depending on the design task (problem), the design situation, the design process, the product and the designer (human factors) (see figure 3). Beside this influencing factor which effects the design method from outside, the design methods have and require a flexibility in themselves. Applying design methods requires changes from abstract to concrete thinking and from partial to holistic thinking. These characteristics need to be taught and transferred to the students in order to reduce inappropriate application. With such a didactic concept, the gap between the education of design methods and their application should be reduced. This also implies transferring the right expectation to the application of a design method. So, the didactic concept has to point out the different ways in which one can apply them, the problems which might occur and the effect of the method.

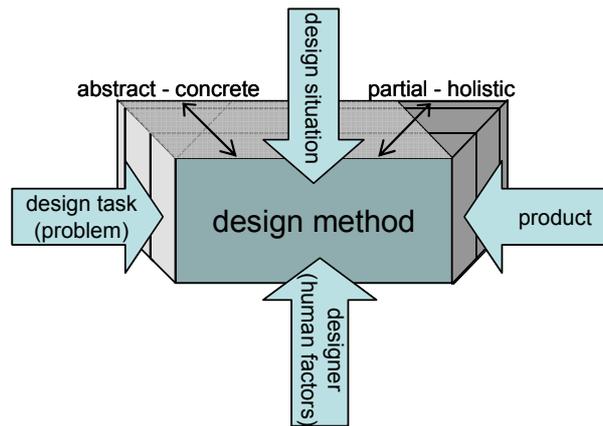


Figure 3. Characteristics of design methods

This paper aims to identify the main problems students encounter when learning design methods, how they are related to the characteristics of a design method and with which results from educational research they might be tackled.

4. Educational research

The scientific literatures on cognition, learning, development and brain are voluminous. One of the hallmarks of the new science of learning its emphasis on learning with understanding [2]. Many education methods focus on memorize rather than understanding. Research on expertise demonstrate that experts' abilities to think and solve problems depend strongly on a rich body of knowledge about subject matter [2]. However, the research also shows clearly that "usable knowledge" is not the same as a mere list of disconnected facts. Experts' knowledge is connected and organized around important concepts; it is "conditionalized" to specify the context in which it is applicable; it supports understanding and transfer (to other contexts) rather than only the ability to remember [2]. To reach a experts' knowledge a learning process is necessary which build up the knowledge step by step, based on experience and pre-existing knowledge [3]. And these requirements for learning and understanding need to be considered for design methods when building up a new didactic concept.

5. Methods: A case study

The information about the needs of students for a proper understanding of the aims and uses of design methods was obtained from a descriptive case study which shows the problems students have applying a design method. For two semesters, all questions and comments of design students in a design course were written down. Furthermore, the students were asked after two semesters of the design class what their main problems were and what helped them to solve those problems. The observations, comments and answers of the students are summarized and structured in categories. The design course, which takes up 1.5 hours/week, is scheduled in the 5th and 6th semesters for mechanical engineering and industrial engineering students. This design course belongs to the product development lecture [4]. Each product development lecture teaches one or two particular design methods. The content of the 5th semester are design methods of the conceptional design phase and the content of the 6th semester are quality management design methods. After each semester the students take an oral exam. The lecture focuses on teaching well-structured knowledge about the design method itself and the use and usability of the design method, and presents practical examples. The focus of the course is on process-oriented and methodological knowledge.

Twenty to 30 students attend the course and work together in teams of 4 to 5 students. The course is generally taught by a PhD student, who acts as consultant to the students. The structure of a course is as follows: First, there is a short recap of the design method by referring to parts of the lecture presented by the consultant. Then the students get a design task to solve using the design method. The teams discuss among themselves and with the other teams how they should begin. After reaching a

decision, they proceed to work on the task, occasionally receiving some feedback from the consultant. Each team presents their results and the class ends up discussing the problems they encountered and commenting on the results of the other teams. The slides of the presentations are published on the webpage of the department, so that the students are able to compare their results with each other.

6. Results: Questions, problems and aids

The most conspicuous results were shown by the questions, comments and behaviour of the students during the classes. The following results are independent from the design methods.

6.1 Questions during the design class

A collection of the main questions which the students asked the tutor during the design class is represented by the following typical examples:

- How can we work without having this information (e.g., knowing how the connection to the other systems is defined)? This question stems from their attitude towards working with uncertain and unreliable information. The recommendations to continue the work as well as possible without the information and to see if the information could be obtained later in the process were not much accepted.
- How do we know if this step is useful in reducing the costs or if this problem is caused by that effect? They get stuck if there is no proof of the results and no evidence that they are on the right track. This becomes obvious by using design methods, like target costing and FMEA. Also, they do not want to accept repetitions: If we had known that before, we would not have to repeat that. In their eyes iterative steps imply that they made a mistake in a former step.
- A frequently asked question is: Is this the correct and complete result of this design method? The students want to get a concrete and appraisable result of a design method. They want to work under insurance, otherwise their motivation is considerably reduced. The desire to find complete and correct results shows that they hope for a straightforward design process. The aim of the students is to carry out the design method very strictly and they wish to find one approach which is always applicable and optimal.

6.2 Problems

When the students were asked what their general problems in the design class were, i.e. when they were solving a design task with a design method, the following answers came up:

Table 1. Problems

statements	problems
We did not understand the design task, we did not see the problem, so we did not know how to start	understanding design task
We did not recognize the use of the method in relation to the design task and how it might help to use it. The design method was too abstract.	relation between design task and design method
When we realized that we need to adapt the design method to the design task, we were afraid of abusing them.	adaptability of the design method
A similar problem occurred when we had to guess at information. We think our guessing is not exactly enough to get a good result.	making assumptions
We are very insecure when we have to create an abstract model, for example, a function structure. We are not sure about the level of abstraction and the level of specification.	level of specification/abstraction
We have problems to find solutions, because we are always looking for the best solution. For that reason we always try to check if this is the right solution. But we do not have a method for this and have to ask the tutor.	verifiability of the quality of the result
We do not know how the results might look. Therefore, it is very difficult to work in a goal-orientated (purposeful) way. This also leads to a lack of motivation.	impressions on the result presentation
Also we do not know what the usual process is for applying a design method to reach a result. We do not know if we get milestone results, how long it takes and when we have to stop (for example looking for solutions). We do not know how we can check milestones to ensure that we are on the right way.	ensure process quality
We can not check during the application of the design method, if we are on the right track; we also can not check the quality of the result.	ensure result quality

6.3 Aids

The next question which the students were asked was: What helped you in the design class to solve the design task with the design method? The students mentioned the following aspects:

Table 2. Aids

statements	helps for	aids
The discussions in the team were very useful to understand the design task, find a starting point and decide what the next step should be.	clear up design task	team work
Especially, the critical questions from the other team members helped to reflect the process and the understanding of the design problem.	clear up design problem	team work
Also the formulation of the critical questions to the team-members and to the tutor helped to gain a better understanding of the problems.	clear up design problem	ask questions
Further, a structured presentation of the design method and the explanations of the tutor	impression of the application and the effect of the design method	presentation of the design method
The individual tips from the tutor to the single teams helped a lot to keep the pace and have more confidence to be on track.	ensure design process	individual tips
Have the example from the lecture in mind, to compare the single steps and have an idea of a possible result.	get an impression of the result	examples
The example from the lecture showed us one possible application of the design method, but it is obvious, that there are many other applications possible, because the variety of the design task is so great. The example gives a rough idea of the use of the method.	impression of the use and application of a design method	examples
Often the example from the lecture gives us the starting point for the task in the class. But sometimes, if the example differs from the design task in the class, it is not possible for us to transfer the design method to the new task. Often the problem is caused by very little things, but we do not see them or we are not sure if it allows of changing things or facilitating them.	realize the flexibility of design methods	examples
We like very realistic examples that motivate and show the real use and application of the design methods. We also like examples showing an application failure, and then we like to analyze the failure.	impression of the characteristics and flexibility of the design methods	realistic examples

These statements give an impression of what helps students when they are learning design methods. Comparing the aids with the problems from table 1, it becomes obvious that there are still problems with no answers on how to solve them. In the actual didactic concept for design methods there is no aid for the problems of making assumptions, switching between levels of specification and abstraction and ensure quality of process and result. The existing aids for the problems understanding the design task, find the relation between design task and design method and getting an impression of the results presentation need to be improved and integrated into a new didactic concept.

7. Conclusion

The problems of students while learning design methods are multilayered and diverse. Missing goal orientation and goal analysis leads to a misunderstanding of the design task. Team work can support this understanding and clear up the design task within a discussion. Also, team work can help to find the relation between the design method and the design task.

The problem of not knowing how to proceed shows the lack of a holistic understanding [5] of the process-orientation and the awareness of the characteristics of design methods. The students are not able to adapt methods and act according to the situation. They do not see them as an aid which can be flexibly applied, and that the majority of the work when designing is strongly influenced by the personal skills and characteristics of the designer in using creativity to solve problems. Therefore, it is important to impart the meaning of design methods in the design process and the characteristics of design methods to the students. There is a need to give the student a deep understanding of the design method in order to use them flexible to the situation. The problem with making assumptions is related to the problem of ensure process quality. This problem need to be considered while building a new didactic concept for design methods.

The students are not flexible in what they are doing, neither in the process and their thinking (concrete vs. abstract) nor in the content (part-problem vs. comprehensive-problem). Their problems start mostly during the goal analysis [1]. They are not able to carry out a comprehensive goal analysis and do not take the time to do it properly. This problem is related to craving the perfect way and result. They do not expect iterations during a good design process with a good result. They have not realized that an

iterative step takes them to a higher level of information. They always force a perfect way and the result of their design process and method application. This stops them from going back and rethinking their course. They are not able to reflect upon their procedure to solve the problems they have. This might help to get a better impression what the design process looks like. Individual tips from a tutor can help to ensure the proceeding when solving the design task. But in long term there is a requirement for a didactic concept which helps to overcome especially the problems of making assumptions, switching between levels of specification and abstraction and ensure quality of process and result.

Another point which became obvious during the design classes concerns the factual knowledge of students. The students do have not enough methodological and factual knowledge, and the existing knowledge is poorly structured. Furthermore, the students are tempted to rely on the use of the design methods. They think as long they use a design method they are on the right way to a good result. They still mix them up with mathematical formulas and recipes. It is also significant for the education of design methods to integrate the factual knowledge which is needed to apply a method and to present a sensible structure of the knowledge (facts, design methods) in order to support the composition of an appropriate mental model of designing. There is much to be said for a didactic concept for teaching design methods, which includes and integrates the use of factual and basic knowledge about methodological proceeding [1] in teaching design methods. This knowledge would it make it easier for the students to understand the core of the design methods. The students would not have to learn everything by the same time and would be able to adapt their expectations of design methods.

8. Key conclusion

This descriptive study identifies the main problems of the students when applying a design method for the first time. It also shows that we have aids to support the student when learning design methods but the study also shows that the students have problems like “the impression of the result”, “be not able to decide and act when insecure” and “ensure result quality” and “process quality” which are not easily to solve and we do not know what kind of didactic concepts and instruments might help to overcome them. This study discloses the gap between learning design methods and applying them. The paper gives an impression of the main problems when students learn design methods and what aid they like. It also point out learning problems which are not effortlessly to overcome by a new teaching concept. Therefore, it is necessary to adapt the didactic concept of a design course in order to overcome these problems. A special focus should lie on the still unsolved problems and the difference between the abstraction of a design method and the accompanying flexibility in its application. Also, the iterative parts and uncertainties of a design process must be considered and taught.

References

- [1] Pahl G, Beitz W, *Engineering Design*, Springer, London, 1996
- [2] Bransford J, Brown A, Cocking R: *How People Learn: Brain, Mind, Experience, and School*. National Academy Press, Washington, D.C. 2000
- [3] Kolb D, *Experiential learning: Experience as a source of learning and development*,. Prentice Hall, 1984
- [4] Birkhofer H, Kloberdanz H, *Skript zur Übung Produktentwicklung II*, 2003
- [5] Birkhofer H, Kloberdanz H, Sauer T, Berger B, *Why methods don't work and how to get them to work Engineering Design in Integrated Product Development. Design Methods that work*. Ryszard Rohatynski, Julian Jakubowski (Ed.): *Proceedings of the 3rd Internat. Seminar and Workshop*. 10.-12.10.2002. Zielona Gora, Lagow, Poland. S.29 - 36
- [6] Jänsch J, Sauer, T, Walter, S. and Birkhofer, H.: *The Transfer of user-suitable Design Methods” ICED 2003 “International Conference on Engineering Design, Stockholm, August 2003.*

Judith Jänsch

Product development and machine elements, Darmstadt University of Technology

Magdalenenstrasse 4, 64289 Darmstadt, Germany

Telephone: +49 (0) 6151 / 16 30 55, Telefax: +49 (0) 6151 / 16 33 55

E-mail: jaensch@pmd.tu-darmstadt.de