INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
4 & 5 SEPTEMBER 2014, UNIVERSITY OF TWENTE, THE NETHERLANDS

THE MINDCARD CONCEPT: INCREASING INTERACTION IN SMALL GROUP LEARNING SETTINGS

Moritz MUSSGNUG, Stefan BOËS, Bastian LEUTENECKER, Dominik NOLI and Mirko MEBOLDT
ETH Zurich, Switzerland

ABSTRACT
Learning and teaching in small groups of students with less than ten participants is a common setting in engineering design education at ETH Zurich. It can vary from class teaching and coaching sessions to study groups and project work. All learning settings usually include a platform like a whiteboard for the visualization of content and information exchange. To complement this visualization, we add magnetically attachable stiff cards (Mindcards) to the whiteboard figure of drawings and text. One can write and draw on Mindcards with common whiteboard markers. By enabling to shift the cards easily and freely, the Mindcard Concept allows to rearrange and modify the evolving whiteboard figure continuously without the effort for erasing and rewriting.
We introduce the Mindcard Concept as well as the respective physical tool and environment, and give three exemplary use cases for the concept: (1) modelling function structures, (2) structure trees, and (3) planning and organization activities. The study of teaching and learning settings for small groups of students lead to our major hypothesis: The Mindcard concept lowers the barriers of modifying and further developing whiteboard figures and this leads to increased interaction between the students and the teaching staff. Furthermore this induces an increased number of iterations of the overall whiteboard figure and also the acceleration of iteration cycles.

Keywords: Design education, visualization, Mindcard Concept, learning setting, interaction, iteration

1 INTRODUCTION

Interaction has been acknowledged early in educational research as one of the most important aspects of the learning experience [1]. The term interaction itself is used very often in education literature of all sorts [2] and is defined as "all manners of behaviour, in which individuals and groups act upon each other" [3]. This includes the essential characteristic of reciprocity in action and responses. In their work on the art of teaching, Simpson and Galbo [3] state that interaction not only enhances learning but is central to the learning process as well. In learning settings of small groups up to ten students, the frequent and intense interaction between the participants and the teaching staff is a great chance to enable a social dynamic and enrich the learning experience. Such settings usually include the use of some sort of visual support for presenting and exchanging knowledge. Visser [4] points out, that students need to be in continuous interaction with qualitative and imprecise visualizations to interact with their mental images. The requirement of visualization and continuous interaction with a qualitative representation is often fulfilled by a whiteboard, meaning a ferromagnetic surface that can be written on and the ink can be wiped away, making it reusable and modifiable.
The aim of this paper is to introduce a concept and a tool, both developed by the authors for complementing the work with whiteboards in teaching and learning environments of small groups in engineering design. All findings are deducted from qualitative observation of courses in the mechanical engineering education at ETH Zurich.
In the following, the different variations of learning settings with less than ten participants are described and classified. As a supplement of a visualization platform, in particular the whiteboard, the Mindcard Concept is introduced. First the physical properties and the concept of use are described, followed by three typical use cases for engineering design education. Finally the key success factors of the Mindcard Concept are named and analyzed.

2 LEARNING SETTINGS IN SMALL GROUPS

To get an overview of the learning settings in small groups, the different occurrences are characterized in the following. Based on that, a model for activation, the transition from one setting to another is purposed and described.

2.1 Classification of learning settings

This paragraph describes the typical sorts of learning settings for small groups of maximum ten people. Commonly, in learning settings in groups of this size, a visual support like a whiteboard to communicate content between people is used and becomes more and more a standard equipment for teaching facilities. It has the advantage of an intuitive handling and allows sharing content collaboratively by enabling multiple persons to input information simultaneously. A visual support like a whiteboard will be referred to as visualization platform. In the following, the four learning settings in small groups are described. Figure 1 visualizes all four settings with student and teacher, symbolized as empty and filled circle, and the dark bar representing the whiteboard.

- The *class teaching* describes the classical learning setting. A teacher is in front of the group and teaches the lectures content by the support of the visualization platform. This setting is characterized through a strong hierarchy between the teacher and the students.
- In a *coaching session* the teacher is more integrated in the group and acts like an expert. He has a leading function in the whole process but the creation of content is developed collaboratively.
- The *study group* is when the students have either received enough input to act without the teacher or have a different theoretical knowledge, which they can teach to each other. Here the teacher is in the background and intervenes only in situations of fundamental failure in the procedure.
- In the *project application,* students have the complete theoretical background they need and deepen their understanding of a certain method or tool by applying it to a specific task or problem. The teacher is not directly involved in the learning process, but can be contacted on the initiative of the students, if needed.

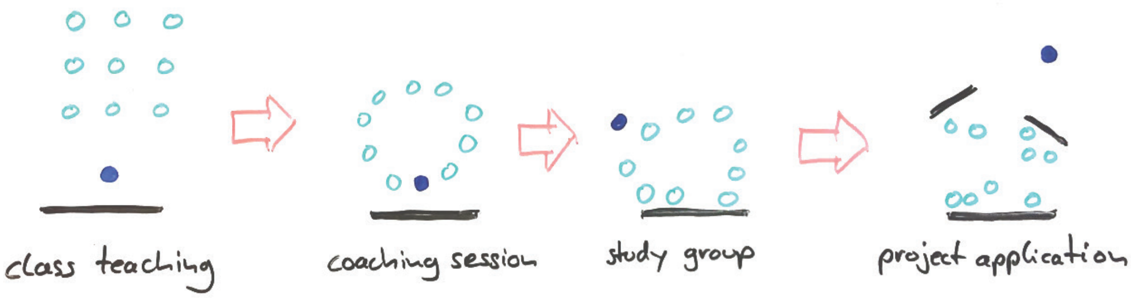

Figure 1. Learning settings with small groups

2.2 Activation process

In the application of the described learning settings both of the following patterns exist: a single setting can be constant over a whole lecture as well as the setting can be transformed within one lecture, once or multiple times. Typically, the transformation is performed from class teaching, to coaching session and study group to project application (in Figure 1 from left to right). The aim is to have a high level of interaction between the students, which deepens the understanding of a certain method or tool. The highest interaction rate is reached when learning in a student project. Hence we focus on reaching the right side of Figure 1 in the context of small group learning. The transformation from the left to the right learning setting we call "activation", as it activates the students towards more involvement and participation.

3 MINDCARD CONCEPT AND USE CASES

This section introduces the Mindcard Concept for teaching and learning in small groups of engineering design students. The central aim is to support interactivity in team processes. Furthermore the concept aims to support each of the described learning settings as well as the transformation from the mere class teaching method to a more interactive setting.

3.1 Physical properties

The Mindcard Concept is based on flat cards (Mindcards), which have the size of a third of an A4 format and are made out of polymethyl metacrylate (PMMA). The user can write on the Mindcards with standard whiteboard marker, and can clean them with a whiteboard wiper. Hence the surface can be re-written like a whiteboard surface. It can be easily written onto the card while holding it in the hands because of the stiff structure of the card. As illustrated in Figure 2 the card itself is equipped with two Neodyn magnets that allow the attachment to any ferromagnetic surface as whiteboards, blackboards or sheet metals. Hence the Mindcard acts like "a small whiteboard on the main whiteboard". The material of the card can be both colourful and transparent. This concludes in two effects. First, the colourfulness in combination with the cards plasticity and an acoustic click effect, caused by the magnets pulling the card tight when adding it to a whiteboard, creates high attention of the audience to the listener when using a Mindcard. Second, the transparency of the Mindcard allows visualizing contents in three layers: the surface of the whiteboard, the backside of the card and the front side of the card, which is directed to the user (see right side of Figure 2).

Figure 2. Mindcards attached to a whiteboard

3.2 Concept of use

The Mindcards are used on ferromagnetic visualization platforms, as whiteboards. To write on the card there are different possibilities: they can be placed horizontally on the table, they can be hold in the hand and they can be labelled already attached to the visualization platform. Once placed on the board the cards can be shifted and rearranged easily to create clusters or describe dependencies. In addition to that, the content written on the card can be added, changed, or erased during the usage. Hence both, the content that is written on the card and the position of the card on the platform can be modified, which allows evolving the content dynamically (see Figure 3 from left to right).

Furthermore, during the usage it is possible to remove cards, which are not relevant to the model any more, or should be attached to another platform. The transparent characteristic of the card gives an additional concept of use. A basic visualization that is fixed during the usage can be added to the back side of the card or onto the main board (for example a coordinate system or a defined basic shape of an electrical resistor). The variable content can be written on the front side (e.g. elements of the coordinate system or the values of the resistor). This allows changing the variable content, without erasing the basic visualization.

Figure 3. Ideation process

3.3 Use cases

The Mindcard Concept can be applied in different learning settings and for different contents and topics. In order to show the exemplary integration of Mindcards in design education the three following models are described below: user cases function structure, structure trees and state-gate model.

3.3.1 Function structure

A basic model in engineering design is a function structure as defined by Ropohl [5], where a collection of connected sub-functions represent the system as a whole. The functions are connected by the flows on which they operate. After a black box model with system input and output is created in implicit or explicit form, we start using the MindCards. On that basis function chains for each, in- and the output, are created to further aggregate them towards a functional model [6].

As an example shown in Figure 4, a coffee machine is modelled as the system of interest. The task on student's side is to model the function structure of a coffee machine and learn about the definition of a function, the notation of a function structure and the execution of a functional analysis.

During the process of modelling different behaviours between the use of a whiteboard with or without Mindcards were observed. First of all, the individual sub-functions can be collected on cards and put on the whiteboard. Compared to whiteboard without Mindcards, they do not have to be written down again in the correct position but instead can be moved around or replaced until the final order is achieved. Also the functional chains that were modelled after the collection of sub-functions could be moved around easily and connected among other function chains. The arrows and connections on the whiteboard are drawn at the later stage of this process but can be, wiped away and be redrawn easily.

The individual learning challenges were first of all formulating a function, then modelling a function structure according to the notation and finally the application of functional analysis and decomposition.

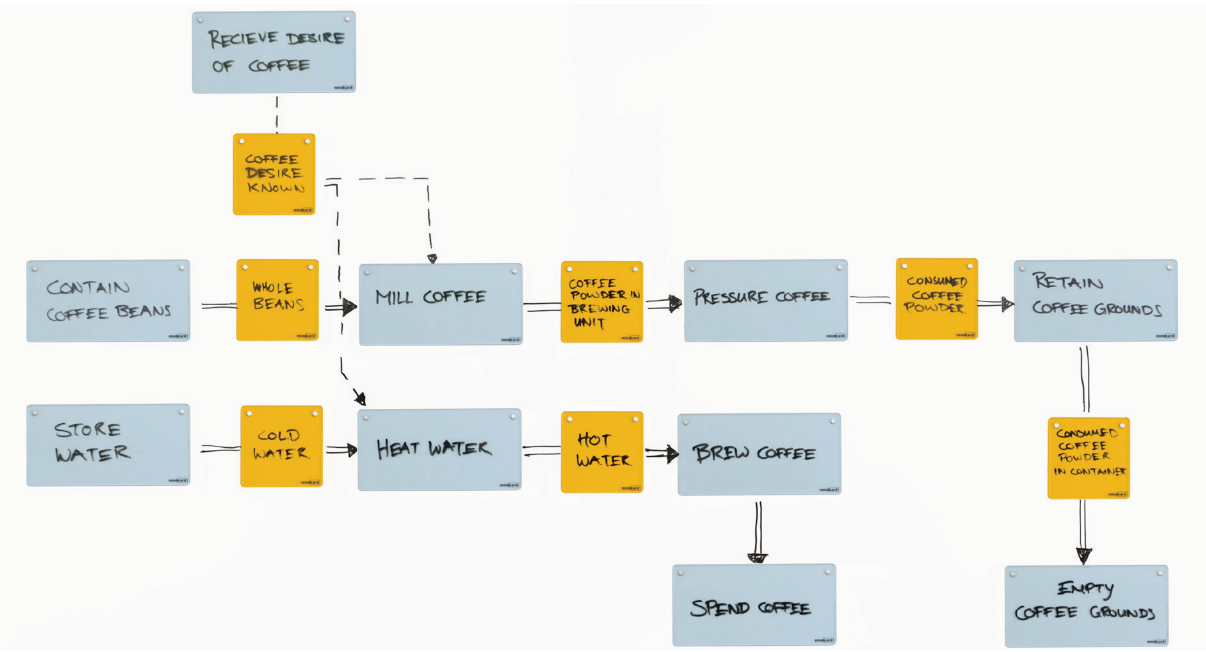

Figure 4. Function structure

3.3.2 Structure trees

For the task of showing hierarchical relations a structure tree is a very common visualization form in a variety of different applications. Some examples are fault tree analysis [7] or system decomposition [8]. The example used for this use case is a need hierarchy based on the need finding theories [9], which is important for deriving the underlying requirements of a person. It consists of the needs of a person on different levels of generality. Going up the hierarchy the "why" question is asked, going down the "how" question is focused upon.

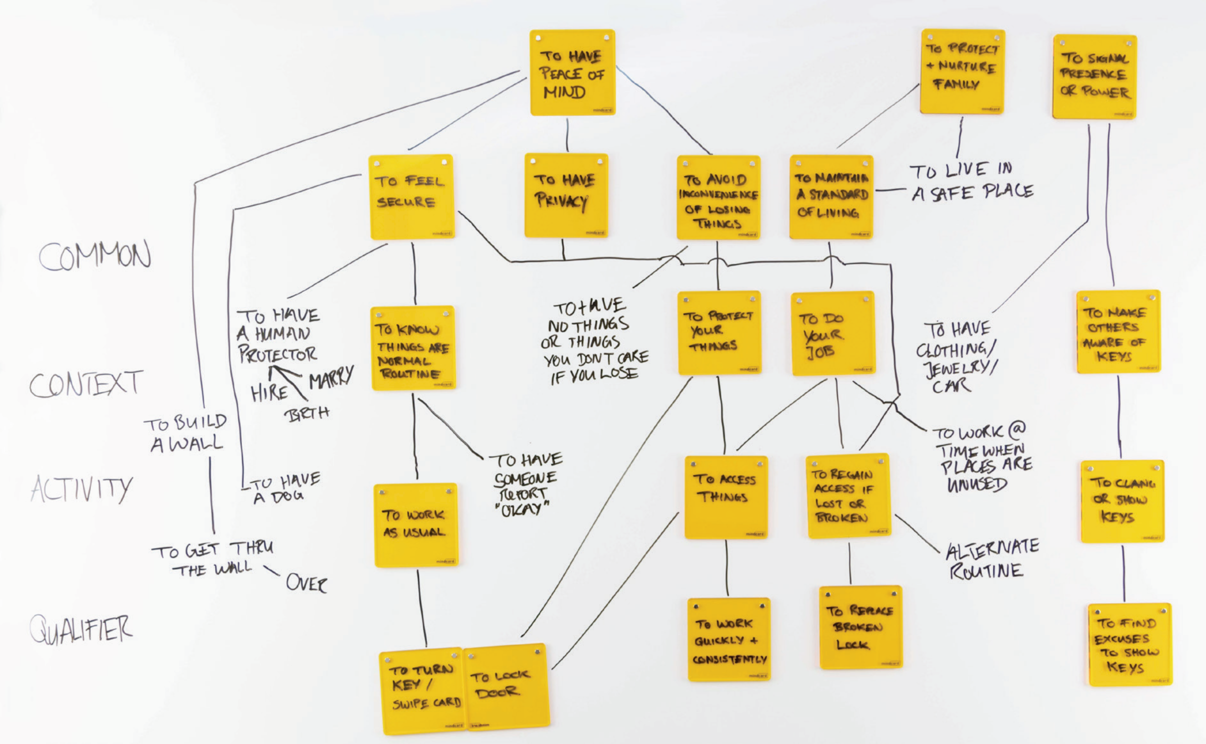

Figure 5. Need hierarchy

The task was to map the needs of a user utilizing a mechanical key and lock system. The results are shown in Figure 5. One Mindcard is used for one need, making it easy to collect them first and then put them into hierarchical order. The main learning effect, despite the concept of need hierarchies, is the application of the MECE rule: Create mutually exclusive (ME) entries on the same level and collectively exhaustive (CE) hierarchy branches.

3.3.3 Stage-gate-model

Incorporating project-based learning in design education, project management topics form an important part of the curriculum, ideally by applying it in student projects. Often the stage-gate-model [10] is taught as a famous process model for product development. An important aspect is breaking down the development goal in smaller goals called gates that constitute the completion of the respective development stage.

This aspect shall be learned and internalized by the students. Therefore the task is to model the different stages, sub-stages and gates of a development project. This begins with brainstorming the gates and the content for each stage, bringing sub-stages into order and arranging everything along the time axis. A part of the results can be seen in Figure 6, where three stages are modelled.

A big benefit of the use of Mindcards is the option to move the whole stage around along the time axis without rewriting everything. New stages can easily be fit in between and existing stages can be detailed with new sub-stages.

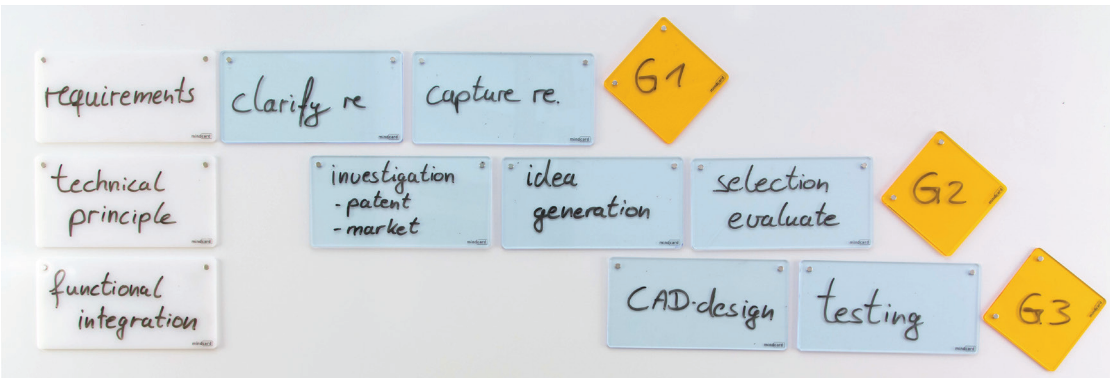

Figure 6. Stage-gate-model

4 INTERACTION AND ITERATION AS KEY SUCESS FACTORS

The Mindcard Concept was applied to small group learning settings at the Product Development Group Zürich in different lectures. The observations that have been made are subdivided into interaction, iteration and derived learning effects.

4.1 Interaction

Making use of the Mindcard Concept speeds up the activation process within a lecture, see Section 2.2. In our understanding this is caused by the flexibility of the created model. The cards allow bringing ones input to the visualization platform and update the current model easily. Hence, the barrier of modifying an existing model is smaller compared to conventional working styles on visualization platforms. The same reasons lead to the assumption that the interactivity rises by the implementation of the Mindcard Concept. Every participant can see that the current status of the model on the visualization platform is not fixed and one can bring in his ideas into that dynamic process.

4.2 Iterations

"Fail often to succeed sooner" is a famous phrase of Tom Kelly, the general manager of IDEO [11]. This philosophy does not only apply in the product development of companies but also in the teaching process of engineering design. When students apply a new method or try to shape the learning content they are very likely to make some mistakes during the first few tries. Looking at the process creating the final output it can be seen that the implementation of the Mindcard Concept leads to a high number of iterations on the way to the final result. The students use the high flexibility of the model and change it permanently by bringing in new input, by rearrange the existing content or by removing parts after agreeing with the other team members. High interactivity and a high number of iterations lead to creative ideas on solving a problem, which supports the learning effect as well because of the relevance of the results.

4.3 Learning effects

Regarding the results of group learning processes under the implementation of the Mindcard Concept, it can be found that the students are quicker in understanding and internalizing the learning content than without the use of Mindcards. This is attributed to the high attention given to the content by the students listening and watching. We assume that this is caused by physical appearance of the card, the method of use and the high interaction rate during the lectures. The usage of the Mindcard Concept enables the students to achieve a common understanding of a task and the problem. Additionally the collectively generated results are accepted and acknowledged by all participants. The high number of iterations led to an increased number of (sub)ideas and at the same time to a higher quality of the end result.

5 CONCLUSION

This paper introduces the Mindcard Concept as physical tool and a method of use in small group learning settings with visual support. The implementation of the Mindcard Concept supports each individual learning setting as well as the activation process, which is the transformation from one setting to a more interactive setting, based on three aspects. First, the use of Mindcards leads to an increasing attention towards the content by the students. This is caused by the plasticity, the colourfulness and the acoustic effect when adding a card on a whiteboard. Second, the Mindcard Concept supports the interactivity between teaching stuff and students, which is particularly beneficial for small group learning settings. The concept allows people to bring input by adding new cards or to change the actual content by repositioning the cards or modifying the written elements on the cards. Third, the usage of the Mindcard Concept results in an increasing number of iterations. The flexibility of the cards leads to a dynamic model evolving the content, which increases the number of (sub)ideas and the quality of the overall result.

6 OUTLOOK

As the reuse of content created with the Mindcard Concept is limited to the used visualization platform, further research will be put into developing an interface for digitalizing figures created with Mindcards, so that a software based reuse and transfer of content will be possible.

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