KNOWLEDGE TRANSFER IN DESIGN EDUCATION: A FRAMEWORK OF CRITERIA FOR DESIGN EXERCISES

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ABSTRACT
This paper presents suggestions how to frame design educational exercises with the aim to transfer specific types of design knowledge to students, or to generate new design knowledge within students, respectively. For this purpose, the paper refers to a typology of design knowledge that differentiates between four types of design knowledge - Artefact Knowledge, Design Intuition, Design Rational, and Design Theories - as well as three interjacent transitions, in which one type of knowledge transforms to the next. It proposes specific criteria that a design exercise should incorporate, in order to teach that particular type of knowledge to students. Furthermore, it provides criteria for appropriate design exercises for each type of design knowledge. The findings are summarized in a framework. We believe that the work presented in this paper contributes to a better understanding of design knowledge and its transfer mechanisms, and it may serve as a basis for design educators to improve their teaching programs.

1 INTRODUCTION

As design educators, we constantly face the challenge to transfer our own design knowledge to students, as well as to evoke new insights within them. We come up with established and well-proven exercises, or we invent new ones. We teach them certain skills and knowledge mainly by lecturing, demonstrating, reviewing their work, or by having them read books. However, we are rarely aware of how our knowledge is actually transferred, or how new knowledge is being created by the students. The questions arise, whether certain types of design knowledge require specific exercises for being transferred, and if we can trigger certain knowledge transfer mechanisms or even create new design knowledge by applying specific exercises. This paper is structured as follows: Section 2 refers to a typology of design knowledge that differentiates between four types of design knowledge - Artefact Knowledge, Design Intuition, Design Rational, and Design Theories - as well as three interjacent transitions, in which one type of knowledge transforms to the next [1]. These seven types and transitions of design knowledge show different characteristics and therefore require different strategies in terms of transferring them to students in design education. Section 3 presents a structured analysis of these seven knowledge types and transitions in the form of a table overview. It describes the knowledge type characteristics, as well as possible artefacts, tools, and methods that a design exercise should incorporate in order to transfer that particular type of design knowledge to students. Additionally, abstracted example exercises for each knowledge type and transition are presented, to illustrate possible applications. Design educators can use this framework as an overview, to analyse their own exercises or to develop new ones that are tailored to the purpose of transferring or creating one specific type of design knowledge. We conclude by presenting a discussion and an outlook on future work.

2 DESIGN KNOWLEDGE

In the literature there are several general frameworks of knowledge and learning. The Structure of Observed Learning Outcome (SOLO) taxonomy [2] distinguishes five different phases of understanding: pre-structural (no understanding), uni-structural (only one aspect is understood), multi-structural (many independent aspects are understood), relational (the independent aspects are integrated into a structure), and extended abstract (generalized and transferred into a new context).

Dewey [3] emphasizes the importance of concrete experience in learning and proposes a three step process of learning (observation, knowledge, and judgement). Lewin [4] suggests an action-research cycle with four steps: plan, act, observe, and reflect. Kolb [5] builds on the work of Lewin [4] and Dewey [3] and suggests an experiential learning model consisting of a four-stage cycle with the following steps: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Mueller and Thoring [1] suggest a typology that focuses on design knowledge and combines experimental and academic knowledge, which is why we refer to this model. It distinguishes between four types of design knowledge: On the physical level, design artefacts are able to store information within their physical shape, which means that knowledge about a specific handling, usage or function is "frozen" in the form of an object (example: bottle opener). This concept is also mentioned by Cross [6]. On the neuronal level, knowledge is represented as tacit gut-feeling or design intuition. One just 'knows' how to design something, without being able to explain why (example: how to ride a bike). This concept is also mentioned by Polanyi [7] and Cross [6]. On the symbolic level, knowledge is represented in codified form - as text, images, rules, and instructions (example: cooking recipe). And finally, on the model level, design knowledge is represented as theories or testable models (example: ergonomic norms). New design knowledge is created in the transitions between these levels: Between the physical and the neuronal level signals are filtered or the physical information is deconstructed. In the other direction, the filters of our cognition are adjusted, or the tacit knowledge becomes manifest in physical form (such as through prototyping). Between the neuronal and the symbolic level new knowledge is generated either by externalizing the intuitive knowledge, or by internalizing the symbolic knowledge. And between the symbolic level and the model level new knowledge is developed either by theory formation based upon explicit insights, or by deriving new concepts from existing theories. See Figure 1 for an overview of the different types of design knowledge.

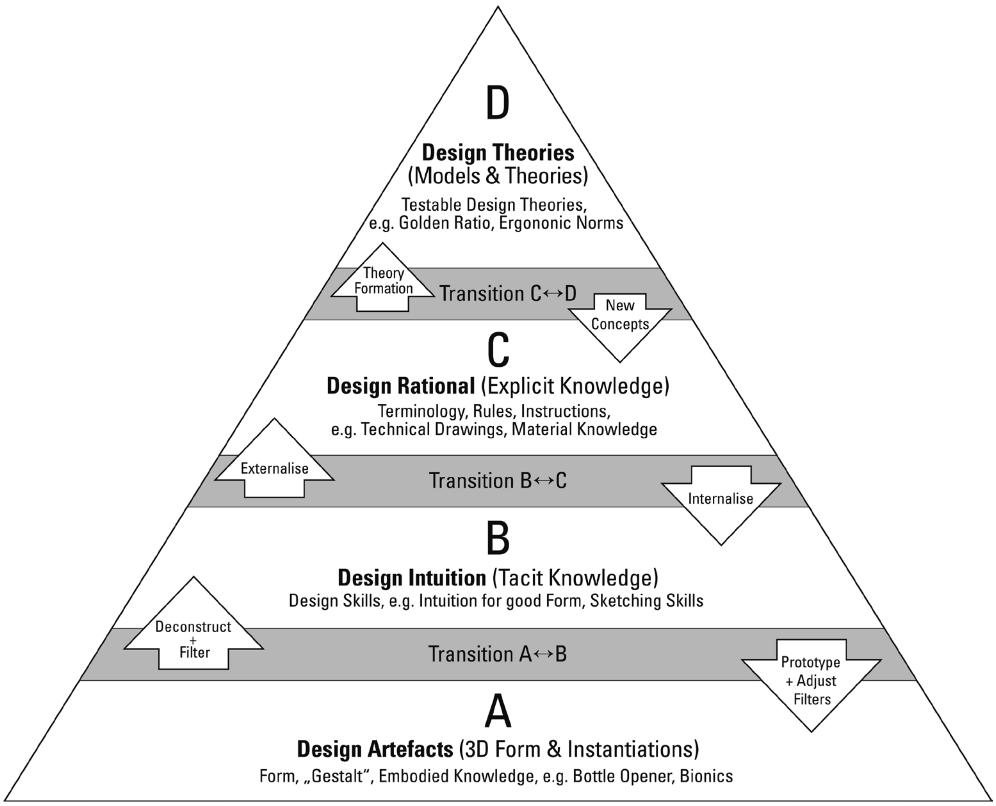

Figure 1. Typology of Design Knowledge, adapted from [1]

The four levels are materially building up on each other. That means, the design theory, which is placed on the top of our suggested knowledge pyramid, might contain all precedent levels of design knowledge, e.g. it consists of codified symbols (text). Knowledge on the lower levels, however, does not contain the knowledge types of the upper levels. The typology of design knowledge by Mueller and Thoring [1] already suggested some criteria for the transfer of these different knowledge types.

However, it does not present concrete methods or abstracted case examples how this can be systematically achieved in design education. This paper tries to fill this gap. The following section presents a structured framework of the four types of design knowledge and the three transitions, which analyses the respective knowledge transfer mechanisms and the required strategies for appropriate exercises in the context of design education.

3 KNOWLEDGE TRANSFER CRITERIA FOR DESIGN EXERCISES

The following section presents a brief description of each level and transition of the aforementioned knowledge pyramid, as well as some first ideas how these knowledge types might be addressed in design educational exercises. Table 1 provides a summary of the suggested criteria and strategies for transferring different knowledge types. We took in consideration that in a design context most exercises result in some kind of artefact, since it is the nature of design to create things. However, we differentiated between those exercises that focus on knowledge on the artefact level, and those that involve some artefacts but focus on a different level. However, there is no sharp disjunction between the levels. Some overlapping is quite possible, as well as there might be exercises that address more than one knowledge type.

3.1 Level A - Design Artefacts

On the Artefact Level, knowledge is represented in 3-dimensional forms or signals from the environment. Students can benefit a lot from exercises that incorporate artefact knowledge, since existing objects embody knowledge about materials and construction techniques, handling and usage, but also about aesthetics.
Exercises that might serve the purpose of transferring artefact knowledge include:

- Collecting artefacts
- Recombining artefacts (ready-made design)

3.2 Transition A/B - Filtering and Adjusting Filters

In this transition, knowledge is being transformed from physical forms and signals to tacit knowledge, and vice versa. In design education, the transformation from level A to level B can be achieved either by filtering signals from the physical level, or by deconstructing artefacts in order to extract the embodied knowledge. In the other direction, knowledge can be transformed from level B to level A either by building artefacts in order to manifest knowledge within a tangible form, or by adjusting the internal filters. Students can learn a lot from embodied knowledge by re-engineering it from existing design artefacts (this means positive as well as negative design examples). Learning strategies might include the deconstruction and analysis of objects in order to understand how they were designed, the copying of the design (maybe with specific constraints, such as change of scale or change of material to focus on specific aspects of that artefact), or the derivation of a new design based on the existing design. Additionally, filtering may be addressed by reducing the complexity of a task, e.g. excluding specific parameters, such as the choice of material, or by providing other forms of support. In the other direction, tacit knowledge can be manifested into physical forms by building and prototyping, and adjusting filters may be achieved through manipulation of the students' cognition.
The following design exercises might serve the purpose of filtering signals or deconstructing physical knowledge (A>B):

- Parameter Reduction - ask the students to design a simple object, without using any colour, or by providing only one material, such as paper. Focusing on the remaining parameters may raise the awareness.
- The exact copy - re-build an object as identical as possible. The modified copy - re-build an object with some modified constraints (e.g. completely in paper, or in a large scale of 2 : 1)
- The "improve this" design - re-design an object by improving previously identified flaws.

Table 1. Framework of Design Exercises

#	Knowledge Type or Transition	Knowledge Representation (Examples)	Knowledge Transfer or Creation Mechanisms	Suggested Strategies for Design Exercises
1	Level A,	Embodied knowledge (in	Collecting, analysis,	Recombine artefacts, collect artefacts

	Artefact Knowledge	objects, 3d forms, signals from environment)	or recombination of artefacts	
2	Transition A > B	n.a.	1) Deconstruction and re-engineering 2) Filtering signals	1) Reduce exercise parameters, focus on single aspects, 2) observe signals from environment (e.g. through photography)
	Transition B > A	n.a.	1) Making things tangible 2) Adjusting filters	1) Prototyping, create mock-ups 2) Exclude specific senses, selective seeing
3	Level B Design Intuition	Tacit knowledge (intuition, skills, gut feeling)	Socialisation	Being in relevant environments, Master-Apprentice relation, trial-and error, learning-by-doing, project work, feedback by teacher or by material, observing and copying behaviour of experts
4	Transition B > C	n.a.	Externalization, articulating	Reflection, writing down, discussing, evaluating, judging existing designs
	Transition C > B	n.a.	Internalization	Skills teaching (sketching, Software etc.), frequent repetition, training
5	Level C Design Rational	Codified, symbolic knowledge (written and spoken text, images, drawings, rules, terminology)	Analysis or recombination of explicit knowledge	Teaching factual knowledge (e.g. design history, material knowledge), active argumentation pro or against a design (e.g. designerly debate club)
6	Transition C > D	n.a.	Theory formation	Synthesis, framework building, structuring, clustering and interpreting data
	Transition D > C	n.a.	Concept creation	Apply models or theories to derive new designs
7	Level D Design Theories	Models (frameworks, graphs, algorithms), and testable design theories	Analysis or recombination of models and theories	Understanding, testing, and recombining existing theories or models

- The "inspired by" design - design a new object that picks up some of the design criteria of the original object in order to make the two fit together. Bionics is another typical example of such an approach, in which specific aspects from nature are copied and then adapted and turned into a new design object.

All of these exercises also involve the creation of new artefacts. However, we place them not on the transition from B>A, since this is not the focus of the exercises. (This applies also to some of the following exercise examples.) As mentioned earlier, most design exercises involve the creation of new artefacts because this is the nature of design, but in the cases described above, the focus was a different one - namely to extract the knowledge being embedded in existing objects, or to filter the signals from our environment.

The following design exercises might serve the purpose of adjusting filters or making knowledge tangible (B>A):

- Selective cognition - focus the students' perception by excluding one sense (e.g. touching an object blindfolded, and then sketching it afterwards).
- Selective photographing - guiding the students' attention towards specific aspects, e.g. by having them collect pictures of only red objects in their surroundings.
- Discovering codes - photographing in an unfamiliar surrounding (i.e. foreign country) to break accustomed seeing habits.
- Embodiment of concepts in a physical (tangible) form - that means all sorts of prototyping exercises, or building quick mock-ups.

3.3 Level B - Design Intuition

On this level knowledge is represented in tacit or implicit form. This is relatively difficult to transfer, because the knowledge is not codified, yet [7]. Intuition can mainly be built through experience, trial-and-error, observing experts, or by just being in relevant environments [8].

The following design exercises might serve the purpose of building design intuition:

- Project work - Learning-by-Doing or Trial-and-Error
- Feedback by teacher - experimenting and receiving feedback from the teacher
- Feedback by material - experimenting and receiving feedback from the material (which e.g. breaks at a certain treatment)
- Internships or Master classes - being in relevant environments

3.4 Transition B/C—Internalization and Externalization

In this transition knowledge is being transformed from internalized, tacit forms to externalized, explicit forms, and vice versa. Internalization means that codified knowledge (text, rules, etc.) are being stored holistically, so that it can be recalled intuitively [9]. Internalization can be achieved by frequent application (training) and repetition. Externalization means that intuition and tacit knowledge are put to words and symbols [9]. This process is either characterized by learning specific skills (such as drawing or modelmaking) or design terminologies, and can be supported by reflecting, verbalizing, and discussing [10].

The following design exercises might serve the purpose of internalizing knowledge:

- Any traditional skills teaching - sketching classes, CAD and other software teaching.
- Any exercises involving secondary research - reading books, doing online research etc.

The following design exercises might serve the purpose of externalizing knowledge:

- Agreement on design terminology - e.g. describing objects based on a geometrical terminology.
- Developing design terminology - creating a visual grammar, e.g. based upon semantics of form.
- Any exercise involving critical reflection of intuitive decisions - evaluating, discussing, and judging existing designs.

3.5 Level C - Design Rational

On this level knowledge is represented in codified or symbolic form. This is relatively easy to transfer. Students may just read books, watch movies, or listen to the teacher's argumentation.

The following design exercises might serve the purpose of recombining codified knowledge [9]:

- Teaching factual knowledge - e.g. classes in design history, material knowledge, etc.
- Any exercise involving active argumentation - like a designerly debate club or debate battle.

3.6 Transition C/D - Theory Building and Concept Formation

In this transition knowledge is being transformed from codified forms into structured and testable models, or existing theories are interpreted and applied in order to create new concepts (designs).

The following design exercises might serve the purpose of concept formation D>C (applying existing theories):

- Designing according to aesthetic theories - e.g. form development following the golden ratio.
- Application of design rules, heuristics, or ergonomic norms - e.g. an ergonomic workspace optimization.

The following design exercises might serve the purpose of theory building C>D (develop new theories):

- Exercises focusing on design synthesis - framework building to derive new models [11].
- Any practical design project that results in a design theory [12] - e.g. material experiments with derived guidelines how to work with that material.
- Any research-focused design project that results in theories about users' needs or customers' problems - e.g. personas or other frameworks

3.7 Level D - Design Models and Theories

Models and Theories provide explicit design knowledge in a highly abstracted and structured form. Such models and theories can be used in design exercises in various forms.

The following design exercises might incorporate existing design models and theories:

- Any exercise that tries to understand existing theories - such as a design theory class.
- Any exercise aiming at testing existing theories or models - e.g. testing ergonomic norms.
- Recombining existing models in order to create something new - e.g. combining different patents.

4 DISCUSSION AND CONCLUSION

This paper presents a framework of different types of design knowledge and corresponding criteria for the transfer and creation of these knowledge types in the context of design-educational exercises. This framework allows educators to classify their design exercises and to understand their working mechanisms. Moreover, the suggested framework might provide some insights or ideas for designing new exercises. A comprehensive understanding of the different dimensions of design knowledge as well as the corresponding working mechanisms of design exercises may be crucial to avoid focussing on only certain types of knowledge, and neglecting others.

The presented framework is considered as a starting point for an extensive analysis of design educational exercises. Future work will include a comparison of the curricula of different educational institutions - e.g. comparing design programs with engineering programs - to find out how the different knowledge types are addressed in their teaching concepts. Moreover, we want to analyse whether specific types of knowledge are more frequently addressed in a Bachelors programme, compared to a Masters programme, and vice versa. And finally, we are planning to conduct a protocol analysis within one single semester of an educational institution, to determine what exactly is being taught to individual students.

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