THE EPISTEMIC ROLE OF ARTEFACTS IN CREATIVE DESIGN AND KNOWLEDGE CREATION

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ABSTRACT
Although the crucial role of shared artefacts as a means to create common understanding, to ground discourse and to pursue novel ideas has been widely recognized, the concept of artefact appears to be under-articulated as it often limits artefacts to mere carriers of information. This paper is an attempt to depart from this notion and to draft a conceptual framework of the various epistemic roles artefacts fill in different activities and how these are shaped by the material and sign-related properties of the various media used. To illustrate the intricate interplay of epistemic processes and the kind of artefact used we provide examples taken from courses in the fields of engineering and design-education.

Keywords: Design artefacts, inquiry, creativity

1 INTRODUCTION
The creation and use of various types of design artefacts, ranging from notes and sketches over drawings and models to complex prototypes and simulations, is an essential element of both design and engineering practice. Although the crucial role of artefacts as a means to create common understanding, to ground discourse, and to pursue novel ideas has been widely recognized, the epistemic role of artefacts appears to be quite under-articulated and is often limited to the idea of artefacts as mere carriers and representations of information. This paper is an attempt to depart from this notion and to draft a conceptual framework of the various epistemic functions design artefacts can fill in different activities and how these are shaped by the material and sign-related properties of the various media used. Raising awareness for the intricate interplay of epistemic as well as creative processes and the types of artefacts used, we aim to open up a new perspective on the purposive utilization of design artefacts in professional as well as educational contexts. Against this background the aim of this paper is twofold. First, we will sketch a conceptual framework for the description and analysis of the use of artefacts in processes of creative design and knowledge creation. Rather than treating artefacts as mere representations or carriers of information and ideas, they are understood as epistemic instruments capable to frame, explore, catalyse, inquire, but also to probe and assess ideas. Second, drawing on design artefacts created in student project teams, we will illustrate the complex interplay of the material and sign-related properties with a given task at hand. Examples were collected from three different courses on human-computer interaction, e-moderation & e-communication as well as media pedagogy & educational computer sciences. The examples show how the choice of a particular medium or format supports or hinders the utilization of an artefact for a particular purpose and that the actual utilization of an artefact might significantly differ from the teacher's intention. Finally, we will discuss the educational implications that arise from an understanding of design artefacts as epistemic instruments and outline future strands of work.

2 FROM ARTEFACT AS COGNITIVE TOOLS AND SHARED REPRESENTATIONS TO ARTEFACT AS EPISTEMIC OBJECTS
In general, the term artefact refers to all those things intentionally created by an individual or group of humans (cp. Merriam-Webster Online Dictionary, 2010). According to [1] design artefacts refer to those objects and artefacts, which are created and used in order to design something. Hence design artefacts are not the primary object of the design process but cover all those documents and models created in order to articulate or come to grips with particular aspects of given design problem or an envisioned product. Design artefacts range from verbal utterances exchanged between participants

over written text, sketches, photos and diagrams to functional prototypes, formal models and simulations (cp. [2][3]). In this paper we call these kinds of artefact knowledge artefacts to stress their epistemic function. Even though the relevance of knowledge artefacts has been widely acknowledged the concept often remains vague and ambiguous. The following is an attempt to discern different stances on the concept of knowledge artefact.

2.1 Knowledge Artefacts as Cognitive Tools

Authors such as [4] have conceptualized knowledge artefacts as 'cognitive tools' capable to expand the individuals' and groups' cognitive capabilities. From this perspective knowledge artefacts are seen as external aids for information processing and problem solving, while the main purpose of these artefacts is to store information, to illustrate and objectify ideas as well as to scaffold cognitive processes. Knowledge artefacts here are basically seen as representations of something else, either of some real world entity, e.g. a geographic map of a certain landscape, or of some mental model or theory held by one or more of the participants, e.g. the envisaged floor plan of a house. The epistemic impact of artefacts, according to this perspective, is basically attributed to the fact, that both the creation as well as the reception of artefacts requires the creator or recipient to actively re-represent and translate ideas across different formats and hence to approach the entailed information from different perspectives. Even though the conceptualization of knowledge artefacts as cognitive tools goes beyond traditional models of cognition in that it recognizes the epistemic function of artefacts, it nevertheless provides a reductionist perspective in that artefacts are reduced to an representational account of information already available somewhere else.

2.2 Knowledge Artefacts as Shared Representations

In addition and partly as a supplement to the understanding of knowledge artefacts as cognitive tools, authors such as e.g. [5] and [6] have stressed the communicative and coordinative role of artefacts. From this perspective knowledge artefacts can be see seen as shared representations which provide a common point of reference for the collaborators allowing to exchange but also to probe and contest one another's ideas. As shared representations knowledge artefacts can function as a means for grounding as well as for deictic reference (e.g. [5]). At the same time they might provide "boundary objects" [6] In that they mediate divergent uses, needs and viewpoints. The epistemic function of knowledge artefacts in this conception is basically to provide a means to express, exchange, and negotiate ideas among the collaborators as well as to detect misunderstandings or inconsistencies of an individual's or the groups' understanding of some subject matter. While this perspective stresses the social and situated nature of artefacts, the epistemic value is still seen in the artefact's capability to represent ideas in a way open to inspection and negotiation by the collaborators. The knowledge artefact is seen as a shared representation meant to convey ideas and information the collaborators deem relevant in respect to the subject matter at hand.

2.3 Knowledge Artefacts as Epistemic Objects

A different notion of the concept of knowledge artefact has been proposed more recently by authors such as [3] and [7], which suggested to understand knowledge artefacts not primarily as representations of some real world phenomena or idea but as objects of inquiry in themselves partly independent of the things they are supposed to represent. According to [7] the creation and manipulation of models can be understood as a genuinely epistemic activity that goes beyond the representation of a target system for communication purposes but aims to produce new insights and ideas. Accordingly, a main purpose for the use of knowledge artefacts is not to represent what is already known, but on the contrary to come to terms with what is not known yet. In his analysis of design practice [3] introduced the term 'inquiring materials' to describe the fact that designers are often actively engaged with various kinds of artefacts not only to express their ideas but to generate new insights about the subject matter, i.e. the design issue at hand. According to this perspective knowledge artefacts can be used as a means to explore and experience possible worlds but also to probe and test assumptions about a given subject matter. Due to their material form, the creation and use of knowledge artefacts is inevitably shaped and constrained by the particular medium used. Consequently the epistemic function of knowledge artefacts is not just a matter of its creators' ingenuity but also of the qualities inherent to the material used. Knowledge artefacts in this sense are

'productive things' in that they are not limited to represent what exists but also to provide insight into what might or could be.

3   CONCEPTUAL FRAMEWORK

Drawing on the ideas proposed by [3] and [7], Figure 1 outlines a generic framework for the description and analysis of knowledge artefacts. It resembles the triadic structure of actions put forward by activity theorists (e.g. [8]), in that knowledge artefacts are understood as instruments that mediate an actors engagement with some object of activity. Central of this framework is the idea that both the function of a design artefact as well as it qualities are not static attributes but can only be defined with reference to a concrete activity system and hence with reference to the actors involved and the actual state of the object of the design activity (cp. [9]). To illustrate this point one might think of the relation between a building, the corresponding construction plan and the customer who commissioned the building. Before the construction of the building starts, the construction plan is primarily a model for something, while only when the construction begins it becomes possible to test whether the construction plan is also a model of something. Similarly whether the construction plan is intelligible or not is not only a question of the plan itself but also hinges on its creators and readers familiarity with the format or notational system used.
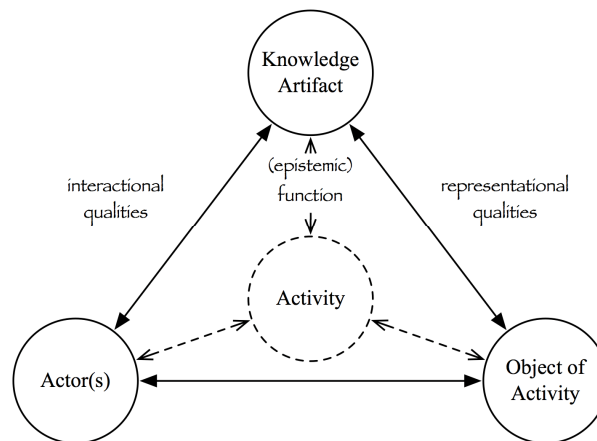

Figure 1. Role and properties of design artefacts in relation to the task

3.1   Representational Qualities

Given that the relation between a design artefact and the object of the design activity is not a static one and that representational accounts of design artefacts fall short to grasp their productive capabilities, the question arises how the quality of this dynamic relation can be characterized otherwise. Drawing on recent literature in the field of design research there are at least four qualities to characterize this relation, including (a) the scope, (b) the level detail, (c) the level of ambiguity and (d) the foundedness of the relation. According to [10] design artefacts can refer to different dimensions of the object of the design activity such as technical, aesthetical or ethical aspects. The scope therefore denotes which dimensions of the object of the design activity are also covered by the design artefact. The level of detail in contrast describes the precision with which the design object and the artefact can be mapped onto each other (cp. [10]). The level of detail might range from a vague indication of overall properties (e.g. "its roughly a square") to precise description providing concrete operational measures (e.g. "its 5.1 feet long"). In addition the relation between a design artefact and the object of the design activity is characterized by different levels of ambiguity, i.e. the relation might be more or less open to interpretation (e.g. [2]). While for example a scale-model of a car gives leaves room for interpretation regarding the proportions of the object in question, a metaphorical description of the car such as "it looks like a cat of prey" is necessarily ambiguous and requires active interpretation. The quality of foundedness finally refers to the existence of a material entity the design artefact refers to (cp. [11]). As design artefacts often precede the development of material entities design artefacts might be unfounded as the corresponding object is fictive. Figure 2 provides an example of a design artefact, in this case a storyboard, describing a hypothetical sequence of interactions with an existing tool. While the scope is focused on users interaction with the system and the level of detail is limited to users

actions (single operations can only be inferred) the design artefact leaves room for interpretation and hence is ambiguous.

Figure 2. A storyboard depicting a hypothetical sequence of interactions ambiguously

3.2 Interactional Qualities

Just as the relation between the design artefact and the object can be characterized by representational qualities, the literature on design research also mentions qualities that characterize the relation between the design artefact and the actor(s) involved. These qualities include (a) the accessibility, (b) the malleability, (c) the modality, and (d) the persistency. As mentioned for example by [12] design artefacts might be more or less accessible to an actor in the sense that the artefact is comprehensible and reachable due to the properties of the representational medium chosen. E.g. a physical mock-up is not directly accessible by a remote participant of a design meeting or a circuit diagram is not accessible to those unfamiliar with the symbols used. Irrespective of their accessibility design artefacts also differ with respect to their malleability, i.e. the effort required to modify the artefact by a certain actor (e.g. [14]). While for example a sketch scribbled on a piece of paper can easily be modified and amended, it is much more difficult and time consuming to modify a 3D-print of the same object. Furthermore, the relation between the actor and the design artefact is characterized by the sense-modalities through which the artefact can be perceived and manipulated be an actor (e.g. [10]). While for example a physical mock-up of an envisaged input device might be approached both visually and haptically a digital image of the same device can only be perceived visually. Finally, the persistency denotes the relative stability of an artefact in time and hence the possibility to approach the artefact repeatedly (e.g. [15][16]). While for example spoken words are highly transient, other representational media such as notes on paper or digital files are more durable and can be approached over and over again. Figure 3 depicts two design artefacts aimed to structure information about an observed process. The artefact on the left provides an example for a highly malleable format allowing the user to easily add new information but also to rearrange the material when needed. The diagram on the right uses an abstract and semi-formal notation to organize the information. While such a representational format might allow to depict information more effectively it also renders the artefact less accessible for those not familiar with the meanings of the notations used.

Figure 3. Different representational formats to depict processes

3.3 Epistemic Functions of Artefacts

While artefacts not only fulfil epistemic but also pragmatic, social and reflective functions we focus ourselves on the epistemic functions here. Other types of functions are at least partly discussed in [12][14][16]. In our conceptual framework the epistemic function refers to the role a design artefact can fill with respect to an activity aimed to gain insight in or intentionally transform a given object of

activity. Note, that we understand the intentional transformation of an object (such as repairing a car) also as an inherently epistemic process. Without being able to provide a comprehensive overview the literature suggest that design artefacts can be used as (a) frames, (b) catalysts, (c) probes, (d) experiential substitutes and (e) evaluands. Design artefacts can be used as frames in that they provide a background and entail assumptions against which a team operates (e.g. [14]), e.g. a requirements specification can be understood as a set of constraints a successful solution has to meet. But design artefacts not only convey what is assumed to be given, they also can be used to evoke new ideas, associations, or perspectives by providing elements of surprise and unexpectedness and hence fulfil a catalytic function (e.g. [16][12]). For example a sketch might be used to explore the realm of possible configurations. Design artefacts can also be used as probes in that they allow to challenge or test whether a design idea might work out in practice as expected and therefore deepen the understanding of the object of design (e.g. [2][3]). In this sense a prototype or a storyboard might be used to explore whether an idea would be acceptable for envisaged customers. Furthermore, design artefacts can also be used as evaluands to analyse and assess whether an idea is feasible or sufficient to meet some goal (e.g. [2][14]). As an evaluand a design artefact might be subject to analytic evaluation or controlled experimentation. For example a floor plan of an office might be used to assess whether it meets fire safety or ergonomic regulations. Yet another function is that of an experiential substitute in the sense that the design artefact allows to get an impression or idea of how it is or will be to interact with a product (e.g. [16]). In this case the design artefact is supposed to provide a bodily experience of a situation unfamiliar to the actor. Figure 4 shows two design artefacts used for different purposes. While the diagram on the left was primarily used to frame the design space the storyboard on the right was used to probe whether the envisaged interaction concept appears relevant to potential users.
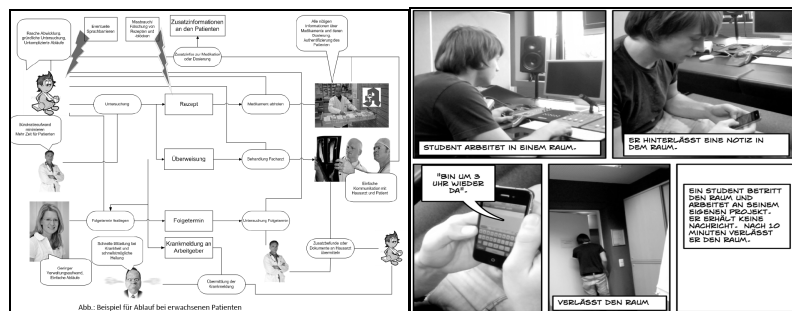

Figure 4. Design artefacts used as frame and experiential substitute

4   EPISTEMIC INSTRUMENTS: EDUCATIONAL IMPLICATIONS

While the notion of artefacts as epistemic instruments [7] and „inquiring materials" [3] is not yet perceived in pedagogical research, the use of artefacts as a means to guide but also to diagnose learning processes and outcomes has been discussed extensively in the learning sciences. In a certain sense artefacts provide some kind of 'natural' means and media of intervention for design and engineering education in that on the one hand teachers and instructors can easily make recommendations to the students on the type of artefacts to create and the media to use, while on the other hand the artefacts created provide access to the ideas and strategies the students have employed while working on an assignment. By selecting and structuring the type artefact to be created and the tools to be used, the teacher can effectively guide the learning process as s/he can either impose constraints, which support or hinder the use of artefacts in certain ways and/or stress particular qualities of an artefact and hence make them more salient to the students (cp. [13]). Conversely the artefacts created can be used to explore, challenge and crosscheck students' understanding of the object at stake as well as the course of action they have taken. In both cases, and especially if design artefacts are not just seen as representations of something else but as epistemic objects in their own right, it becomes important to be conscious about the qualities of the design artefacts and how they play out in relation to different design activities such as the exploration and framing of the design space, the creation of new ideas and different perspectives, the tracing of emerging phenomena, the questioning of tacit assumptions or the evaluation of a product idea.

Towards this end the conceptual framework outlined above provides an initial means to systematically relate the material and sign-related qualities of artefacts to different tasks. At the same time it

acknowledges the fact that one and the same type of artefact can be understood and used by students quite differently from teacher's intentions.

5   CONCLUSIONS AND FUTURE WORK

Aiming to depart from notions of artefacts as external representations or means for communication we have outlined a conceptual framework for the description and analysis of knowledge artefacts in general and design artefacts in particular. Building on this framework we have delineated both representational and representational qualities for design artefact as well as a preliminary set of epistemic functions a design artefact might be used for. Furthermore, we have argued for the conscious use of artefacts as a means to scaffold but also to diagnose learning processes and outcomes. To assess the robustness and utility of this framework we are currently a creating a collection of knowledge and design artefacts used in professional and educational settings. In addition we will use the framework to compare intended and actual use of knowledge artefacts in educational settings as well as to systematically create new types of knowledge artefacts.

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