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INTERDISCIPLINARY DESIGN THEORY**

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ABSTRACT

It is generally accepted that superior products result from a balanced consideration of both “technology” and “aesthetic design”. Nonetheless, the gap between the two professions of the “design engineer” and the “industrial designer” has not been bridged since their origination in the course of industrialization [7]. One possible approach to enhance the collaboration of both disciplines is to teach the basics of the respective other’s. In Germany, the main work following this approach of trying to prepare engineers for design collaborations is the VDI guideline 2424 (“The Industrial Design Process”) [21], which was worked out and released in three parts from 1984 to 1988 by a group of engineering design researchers and industrial designers. As no accepted industrial design theory could be identified at that time, the authors of the guideline tried to apply some of engineering design methodology’s proven methods taken from the VDI guideline 2221 [19] that seemed to fit to industrial design. That approach ultimately failed, as the authors of the guideline had to conclude themselves in the opening remarks of its last part [21]. Even if the guideline is still officially in use for the lack of a replacement, it is hardly used in engineering education.

Since then however, accepted theoretical approaches have been produced by industrial design research that allow for the definition of an interdisciplinary theory on product development. This paper introduces these approaches and arranges them together with models of engineering design

methodology to serve as a basis for a design theory that explains both domains’ competences and responsibilities. A function-oriented product model is set up that illustrates existing interdependencies by classifying a technical product/project according to the relative importance of its technical function (engineering’s competence) on the one hand and its semiotic functions (industrial design’s competence) on the other. The realization of industrial design’s competence as signification and the organization of its devices according to the model of semiotic functions explain existing organizational problems of interdisciplinary design practice. It is demonstrated why industrial design cannot proceed according a purely technical design process such as the one defined in the VDI guideline 2221 and what implications that has on interdisciplinary design projects.

1 INTRODUCTION

The benefit of Industrial Design (ID) is beyond controversy among experts of design theory as well as representatives of most producing industries. On the one hand, anyone can relate to ID on a personal level as one’s own decision making has been influenced by ID at least once while purchasing consumer goods or even products intended solely for practical purposes. On the other hand, the positive effect of strategic investment in ID expertise on a company’s profit has also been proven empirically [8].

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It might therefore seem surprising that the actual integration of ID competence in product development processes can still cause problems, especially but not exclusively in traditional engineering sectors of the producing industries introducing ID for the first time. In many cases, such problems begin on a personal level and originate from a rivalry of engineering design (ED) and ID, an issue described as a “clash of cultures” [15]. It is the author’s opinion that the main cause for that rivalry is an ignorance of the respective other’s competence that might cause a designing engineer to ask what ID can possibly contribute to his work that he cannot do himself. While industrial designers might often ask the same question the other way around, design engineers can refer to a considerable body of engineering design methodology backed by engineering sciences and natural sciences to demonstrate their competence.

This paper describes an Integrated Design Theory (IDT) aimed at curing this ignorance, thus preparing designers of both domains for interdisciplinary development and design projects by integrating at least the most basic models and definitions of current ID theory into existing engineering design theory.

The main part of the underlying research was to identify a valid definition of ID’s “disciplinary core” to serve as a role model for the organization of the profession’s methods and knowledge. The theory’s main purpose is its application during the education of engineering students. Furthermore, it can serve as a theoretic foundation for research in the field of tools and methods for interdisciplinary product development.

2 THEORETICAL BACKGROUND

Before looking at the definitive aspects that separate the two professions it is helpful to consider their commonness:

Both define the shape and material properties of components that make up technical products, which are mass produced, marketed and sold on a competitive market. Even the kind of products, which can range from the most simple toys to the most sophisticated machines, are identical. This conclusion illustrates the explosiveness of the collaboration issue as well as the complexity of clearly identifying the distinguishing aspects of both domains.

There is no universally accepted, simple definition of the exact scope of ID. Some authors define ID according to all activities that might be carried out by I-Designers in practice, leading to a very general definition such as “the activity that transforms a set of product requirements into a configuration of materials, elements and components” [8]. As this wording might also be applied to sum up the engineering designer’s activities as described in the generally accepted models of the engineering design process [13, 17, 19], it obviously cannot be used to explain why both domains should be involved in product development. Some authors on design methodology [6] prefer to avoid the discussion on terminology altogether by using terms such as “styling experts” when necessary.

An attempt to clearly distinguish the two fields of expertise has been made at the beginning of the VDI guideline 2424,

which was worked out at a time when Industrial Design theory as such did not exist as a broadly recognized field of science, although producing companies as well as the general consumer grew aware of ID’s relevance on product qualities. Here, Industrial Design is indirectly defined by being assigned to a scope of functions of products named “human interaction”, while the two other aspects of products, technical functions and economic requirements are the domain of the designing engineer [21].

Although the guideline does not refer directly to emerging approaches of that time and years before, most notably the works of Gros [9, 10, 11], striking similarities do exist. This concept, the “Offenbach approach”, states that a product fulfills “semantic functions” as well as its technical or practical function. To some extent, this concept, which draws from semiotics as ID’s newly identified core science [5, 18], seems to agree with the guideline’s approach to categorizing ID’s functions into “visual appearance”, “information” and “usage”, but a close inspection reveals one crucial flaw of the guideline’s categorization: As “usage” here is meant to sum up the physical aspects of man-product interactions - anthropometry and biomechanics - the guideline defines ergonomics to be the core competence of ID. While neither ID practitioners nor theorists generally consider ergonomics a primary ID’s competence but rather one of many relevant specialist side fields among others [5], the VDI itself proved that ergonomics are - at least to a certain degree - part of the designing engineer’s responsibility by publishing numerous guidelines on ergonomics such as [20].

In the third part of the ID-guideline [21] titled “The industrial-design procedure”, it is concluded that an ID-process as such can not be identified and that a successful collaboration between ED and ID can be achieved by means of communication and iteration, which in effect means leaving the linear sequence of actions and intermediate results of the general process of engineering design. This and an aborted attempt at setting up a system of ID-specific requirements and ID elements, rounded off with a loose collection of ID’s devices and examples leaves the general impression that the term ID does not stand for an area of expertise but rather the lack of such, a profession of generalists mingling with marketers, design engineers and production engineers. This outcome is the more frustrating as almost all of the points made in the guideline are valid; the considerations only lack an argumentative base to form a consistent and comprehensible model.

One could argue that the VDI was not the right body to try to set up an “ID-theory” or to describe the “ID-process” but even the ID theorists of their own field were struggling to identify the profession’s “disciplinary core” [5]. In the 70s and 80s, the favored approach in ID-theory [4, 12] was to apply the ED-process as described in VDI 2221 to the methods and activities of ID in accordance with the VDI’s attempt. The results were equally unsatisfying. Bürdek, maybe the most important theorist in his field, abandons his own approaches

from 1975 20 years later, describing a change of paradigms that has taken place from a deductive to inductive generation of results [5]. He is obviously not referring to actual ID practice but only to the acknowledgement of the fact that drafting - the “quintessential activity of ID” [12] can not reasonably be described as a linear sequence of actions with intermediary results. This conclusion does not only match observations from practice (and the result of VDI 2424) but it can also be derived from the model of “semantic functions” respectively the “Offenbach approach” as will be shown in this paper. The underlying theory has been worked on since the 1970s in Europe [9, 10, 11] and the US [1, 14] and has proven its applicability in ID education, most notably at the ID institution “HFG Offenbach”, in Germany and Cranbrook Academy in the USA while remaining largely unnoticed by engineering design theory up to the recent past [3]. It was therefore decided that this model could form the argumentative base leading to a more convincing interdisciplinary theory that would base on an integrated product model.

3 OBJECTIVES AND METHODOLOGICAL APPROACH

The integrated design theory discussed in this paper is based on hypotheses, literature research, the author’s own experience from interdisciplinary product development projects and discussions with practicing industrial-designers and ID-theorists. The author does not claim the theory to be applicable or valid outside of the context of product development. The purpose of this theory is

- to explain the necessity of both ID and ED to be involved in product development by assigning an exclusive field of competence to either domain, both indispensable for the success of the collaboration,
- to give representatives of either domain enough insight into the other to allow for an efficient collaboration by understanding the purpose of the respective work steps, the applied tools and methods and the required input, and
- to serve as an argumentative base for the development of new methods and tools for interdisciplinary product development, design and innovation.

Ideally, the theory should be simple, immediately comprehensible and compliant to common knowledge. It should incorporate existing theories, models and knowledge of both domains without contradictions and without adding too much new.

In short, the integrated design theory introduced in this paper consists of ED theory as according to [13, 17, 19], juxtaposed with ID theory as according to the “Offenbach approach” [5, 18]. Integration is achieved via an “integrated product model”, a combination of both domains’ “disciplinary objects”. Aspects forming this product model are derived from [18, 21]. This model is backed by the author’s own model [3] of demand emergence as an attempt to organize the terminology of needs and requirements and to explain how and why ID influences a potential buyer’s decision making

processes. By doing so, this model, which relates to Maslow’s theory of Human Motivation [16], acts as the pair of logical brackets around the existing components of the theory.

4 SUMMARY OF THE INTEGRATED DESIGN THEORY (IDT)

Most of the components of the IDT taken from ED theory are known or have been discussed at great length elsewhere [17], so only the integrating components, the integrated product model and the model of demand emergence are introduced here. As the approach of Product Semantics in general (or the “Offenbach approach” in particular) is not widely known in engineering circles, it is briefly outlined. Of ED theory, some aspects are discussed to demonstrate how IDT can solve existing ED problems or to explain a chosen term, such as the “disciplinary object”.

4.1 Disciplinary object

Working hypothesis: The „disciplinary object” shall be the generalized description of all items that can be handled by the domain’s competence; it determines its methods and the structure of the entire disciplinary theory, it defines the profession. As a direct reverse, objects that don’t show the characteristics of the „disciplinary object” are not part of the disciplinary domain, they cannot be handled by its methods, they possibly cannot even be described by the domain’s terminology.

Example: In plain words, the job of an engineer is to design a technical system that serves a practical purpose. More abstractly worded, the idea of the purpose - or practical function - is transformed into a technical system by engineering design. Thus, the object of engineering design is the practical function which itself by definition is the transformation of an input to an output, whereas input and output form a flow that is either material or energy¹ [13, 17, 19].

Abstraction is one of the two basic principles of engineering design methodology: The system to be developed is represented as a series of “product models” in the course of its development, starting with the highest degree of abstraction by working out a detailed specification (a problem description), containing a description of the practical function and the list of requirements on the product to be developed. Then, gradually, the degree of abstraction is reduced in each process step and its corresponding product model (function structures, principle solutions etc.).

The other basic principle is analysis and synthesis: the breaking down of the overall problem (the practical function) into sub-problems (sub-functions), the solving of the sub-problems by identifying partial solutions and their (re-) combination to form the overall solution.

¹ As signal transformation is always achieved by manipulating energy or material flows, this flow type associated with technical functions does not need to be considered separately.

Abstraction, analysis and synthesis - these principles determine the general process of engineering design, its methods and the organization of engineering knowledge (design catalogues etc.). This is the case because the object of engineering design allows for that treatment; a practical overall function is identical to the sum of its sub-functions while a technical solution can be made up of sub-solutions.

It should be noted here that this approach to problem solving can be classified as a “problem-oriented” approach as opposed to “solution-oriented” approaches [22]. While it is possible to solve engineering design tasks in a solution-oriented manner, i. e. to propose an initial solution and repeatedly modify it until all requirements are met, practice has proven that the problem-oriented approach such as the proceedings described in [19] are more efficient for complex problems.

This is the case, because working out a draft of any engineering product and each change on it is typically complex and time consuming. Therefore, to reduce the risk of changes on the overall draft, all applicable restrictions (the design problem) must be explored before any effort is put into working out drafts. It must also be noted that the separate realization of sub-functions by “modules” is another typical strategy to reduce the risk of an engineering project.

The requirements an engineer can consider in his design are more or less directly connected to the technical function; they must refer to measurable parameters or at least to issues that can be objectively assessed. This is not the case with product properties that relate to aesthetical or emotional interpretation. Aesthetics and meaning (as a result of a recipient’s interpretation) cannot be constituted as a flow of material or material (although these flows can have such impact, but that must not be confused), so in accordance with the working hypothesis, these issues fall outside of ED’s domain.

Assuming for a moment that issues like a product’s aesthetics and meaning are of any relevance (see 5.3 for the verification of that assumption), we conclude that ED’s disciplinary object is only a partial product model and that therefore ED’s competence alone does not suffice to define all of a product’s properties in the course of a product development. We further conclude that ED’s disciplinary object can be combined with a second partial product model to form an integrated product model, complete with respect to product development. This second partial product model is ID’s disciplinary object.

Fig. 1. Integrated product model

4.2 Integrated product model

ID’s disciplinary object is summed up by the term “semantic functions” meaning a product’s function on human sensory perception resulting in psychological effects [18]. This function complex is regarded as an analogue to language, as it uses form (aesthetics) to organize symbols that carry a meaning, either by denotation or connotation. The imparted information can refer to the object itself (such as its operation,

quality, origin etc.) or to the other contexts (cultural environment, era, social class). Semantic functions might “communicate” with the (potential) owner, or the owner can use them to communicate with his environment (status, interests etc.).

According to the integrated product model, each product fulfils both types of function, practical (ED’s domain) and semantic (ID’s domain), but not necessarily in equal proportions. In order to include all types of products, a

spectrum is introduced at the top of Fig. 1 that allows a classification of each product between the two extreme ends “artwork”² and “ideal product”³. With a stylish sports car for example, the semantic functions might even be more important than the practical functions.

It is important to note that, although the semantic functions are the exclusive domain of ID, they exist in each product, wanted or unwanted, even if no ID competence was involved in its definition. Some products might also not allow a change of the product’s appearance for technical reasons - such products have no “formal degree of freedom” [21, 12] - yet they still fulfil semantic functions. The only question is, if the resulting effect is desired or not.

The “Offenbach approach” to ID education organizes the disciplinary methods and knowledge according to the model of semantic functions. Fig. 1 shows the different classes of semantic functions, which cannot be explained in detail here. There are catalogues of examples and terms to exemplify the effect of each device [5, 18], a concept very similar to ED’s concept of organizing ED knowledge in catalogues as design principles and guidelines (“design for X”) [17]. Semiotics is the scientific base of the “Offenbach approach”, while hermeneutics is the scientific foundation of “work interpretation”, which can be roughly described as the humanities’ analogue to ED’s methods of evaluation applied during the product development process. The authors found that these similarities in the structuring of methods and catalogues of devices and design rules immediately improves the engineering students’ understanding of the presented ID examples if they have been exposed to ED methodology before.

The integrated product model is the main integrating device that links together both domains’ design theories to form an integrated design theory. It illustrates the different types of functions of each product which are clearly assigned to the different domains of ED and ID. If accepted, it creates an awareness of the scope both domains’ competence which is a prerequisite for a productive collaboration. The model does not however explain the relevance of both domains for the success of the product on the market. Therefore, it is complemented by the model of demand emergence.

4.3 Model of demand emergence

ED theory assumes that a demand exists before the product is developed, otherwise the problem-oriented procedure could not be initialized. The demand must be explicit or at least detectable with some marketing effort, and it can be documented in detail to form a product specification, containing a list of requirements. This assumption is not valid for all aspects related to ID’s disciplinary object, a problem already addressed above: some product properties cannot be formulated as requirements. This is not a philosophical problem but an issue relevant for design activities on the operational level. Purposive work only seems possible if there is a clear idea of the objective target worked towards.

This issue can be explored when starting at the most basic question a producer can ask: What motivates people to buy (my) products? Maslow’s “Theory on human motivation” [16] helps to form a very simple model to organize factors that lead to an individual “decision to buy”. In short, Maslow postulates that all human needs can be organized in five sets of “basic needs”: “physiological, safety, love [often generalized as “socialization”], esteem, and self-actualization”, “arranged in a hierarchy of prepotency” (generally pictured as a pyramid, Fig. 2.), meaning higher-order needs only become significant when lower-order ones are “fairly well satisfied” (all quotes from [16]). Furthermore: “Ordinarily the satisfaction of these wants is not altogether mutually exclusive, but only tends to be. The average member of our society is most often partially satisfied and partially unsatisfied in all of his wants.”

The three higher-order needs can in fact be related to an individual’s communication within society, which partly is realized through a product’s “semantic functions”. We therefore conclude that well-designed products are bought, because the consumer identifies them as a means to gratify the unsatisfied needs for socialization, esteem and self-actualization⁴. Common knowledge further leads us to assume that the recognition of such means does not happen as a result of a conscious reflection, but by the individual’s confrontation with the product, which triggers a subconscious assessment. If the outcome is positive, a very specific demand (or “want”) has emerged.

As a result of these considerations, the following model of demand emergence is proposed (Fig. 2): Demand emerges, if an existing “deficit” is concretized by a means to “cure” that deficit. There are two types of deficits:

- The unsolved “problem”: As the individual is consciously aware of the deficit, the “cure”, i. e. the means to solve the problem, can be identified by a structured search or it can be formulated as a task for someone else to solve;
- The unsatisfied “need”: As the individual is not consciously aware of the need and a cure cannot be

² An artwork is an artefact with no practical function. It is not “useless”, but a carrier of meaning that might be extremely complex (too complex for example to be completely expressed in a written text), but subject to interpretation. It also “pleases the eye”.

³ An “ideal product” as in the definition of Altschuller’s “ideal machine” [2] fulfills a practical function without physically existing. Anything that exists physically is subject to sensory perception, i. e. a carrier of “semantic functions”. So, only the “ideal product” is free of “semantic functions”.

⁴ This serves to verify the assumption from 4.1 that “a product’s aesthetics and meaning are of any relevance”.

identified by means of reflection, it is identified by “accidental” confrontation.

While the former is the case for technical problems and generally considered to be the “norm”, the latter leads to purchases of goods that could in varying degrees be classified as luxury goods, as they are not “necessary” by conservative or rational measures. Here, a “problem” does not exist before the

potential customer is confronted with the product. Also, the individual decision to buy depends on factors that cannot be objectively measured such as personal taste. Therefore, product characteristics that satisfy “needs” cannot be designed by design methods that depend on the existence of a problem description and an objective assessment of the characteristics of solution variants.

Fig. 2. Maslow’s basic needs (left); model of demand emergence (right)

The consequences for product development are fundamental: While ED works towards solving an explicit problem known from the beginning, it is ID’s assignment to “propose” a solution to unspecified individual needs that will be accepted by as many individuals as possible.

Therefore, the ID-process cannot be problem-oriented; it must be solution-oriented. This conclusion also results from the disciplinary object. Unlike practical functions, the different classes of semantic functions cannot be realized individually and then synthesized to form the overall solution. The effect of a draft can not be assessed by assessing its elements; it must be created and assessed as a whole [5, 18]. For example, it is not possible to work out a product’s indicating functions without affecting its aesthetics.

It is assumed that any decision to buy is a result of a mix of both types of deficits resulting in a partially rational, partially emotional decision making process. If any one of these aspects is ignored during the development of the product, some of its market potential will be lost. The model of demand emergence therefore explains the necessity of the collaboration of both ED and ID disciplines. The further implications also explain why any interdisciplinary design process must compromise between problem- and solution-oriented approaches in varying degrees. Such projects will inevitably require more coordination effort than pure engineering projects.

5 SUMMARY AND OUTLOOK

In this paper, an integrated design theory is outlined that combines theoretical approaches from both professions involved in product development: engineering design (ED) and industrial design (ID). The purpose of this work is to improve

the efficiency of interdisciplinary product development processes by giving representatives of both domains a better insight into the respective other’s. The main point is the identification of each domain’s “disciplinary object”, the essence of the profession’s competence.

This is not the first try to establish such a theory. A very elaborate attempt has been made in the 1980’s by the VDI. The results of that effort, published as the VDI-guideline 2424 [24], failed to mark an impact mainly because an established ID theory wasn’t available at that time. The “Offenbach approach” to ID theory, especially the theory of “semantic functions” has since proven its validity in education and practice. With that, the only missing link to integrate both domains’ theories was an explanation of how both aspects of products relate to the customer’s needs, which is given here as a “model of demand emergence”.

The integrated design theory discussed in this paper has been introduced into education at RWTH Aachen University with good acceptance. In research at the IKT, it has led to new approaches in the development of tools supporting the interdisciplinary product development process and to product innovation, results of which are soon to be published. Future research will concentrate on configuring Product Data Management Tools for the needs of Industrial Design.

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