



INTERDISCIPLINARITY IN PRODUCT DESIGN EDUCATION. BALANCING DISCIPLINES TO FOSTER CREATIVITY

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Abstract: The focus of this work lies on teaching methods for product design to stimulate novelty within a multiple disciplinary educational context. To address this issue, the different types of multiple disciplinary approach are presented by reviewing existing literature. As the initial study involved looking at the correlation between disciplines and product features, the definition of product design and its relationship with industrial design and other adjacent domains are introduced. The structure of a newly developed interdisciplinary master in product design is presented and, within this program, an educational activity fostering creativity in heterogeneous multiple disciplinary environments is described. Inspired by the approach of industrial designers to generate creative solutions, it is conceived to help product design students to flexibly adapt the problem and the solution space together through an iterative process.

Keywords: *Design Theory, Multiple Disciplinary Teaching, Industrial Design*

1. Introduction

The ability of today's students to preserve their own creativity when they enter their professional career has grown in importance due to fundamental changes in the economy and society. Over the last decades, the industrial economy based on manufacturing has shifted to a service economy driven by information, knowledge, innovation, and creativity (Kay and Greenhill, 2010). It is though key to understand how educational methods can favor this ability, since teaching can successfully foster creativity but equally it often prevents students from creating novelty (Cropley, 2001).

In one of the most viewed TED talks in history entitled “Do schools kill creativity?”, Robinson (2006) points out two phenomena that are addressed in this paper. Firstly, he is convinced that “creativity more often than not comes about through the interaction of different disciplinary ways of seeing things”. Nissani (1997) agrees on the fact that creativity often requires interdisciplinary knowledge. Specifically in product development, it is important for every stakeholder to be creative, no matter what the discipline. Artefacts are made through the interaction between a person’s ideas and a socio-cultural context made of the different disciplines involved (Csikszentmihalyi, 1996). The second thought expressed by Robinson (2006) is that “every education system on Earth has the same hierarchy of subjects” and only “at the bottom are the arts”. Many critics, who have argued that most universities have favored linguistic and logic-based disciplines to promote orthodoxy, support Robinson’s statement (Cropley, 2001; Biggs, 2007). Since people’s outcomes

should also be accepted as novel by a group to be finally recognized as being creative (Stein, 1953), ranking disciplines may have a less negative impact when professionals address their own field (e.g. an artist judged by other artists while expressing ideas on art). However, it may have serious impact on professionals when it comes to tasks involving different fields, as in the case of product design (e.g. a designer judged by an engineer while expressing ideas on a technical solution). Especially during brainstorming sessions, deferring judgment is one of the key rules to combine and ultimately improve ideas expressed by different stakeholders within a group (the so called “1 + 1 = 3” phenomena) (Osborn, 1953). If we accept the thesis that creativity is fostered by the interaction of more fields and we realize that our present educational system is ranking disciplines, it is a primary goal for educators to provide students with a system that may encourage an harmonious integration of domains.

This paper addresses multiple disciplinary approaches for teaching creativity in the context of product design. The aim of this work is to study educational methods ensuring a balanced cooperation of disciplines in problem solving to ultimately increase creativity in the different fields involved. To examine this research problem, the interactions and interdependences of disciplines covered within product design are explored in the next Section. In Section 3, the different levels of multiple disciplinary approach are described as multidisciplinary, interdisciplinary, and transdisciplinarity, respectively. In Section 4, the paper presents a newly developed interdisciplinary curriculum in product design and, in Section 5, an educational method is displayed to teach creativity across disciplines within this curriculum. In particular, to train students to alternate divergent and convergent thinking in the concept phase. Finally, a brief summary is presented in Section 6.

2. Correlation between disciplines and product features

The product design process is usually completed by a group of people through a concept, an embodiment, and a detail phase, respectively. In the concept phase, the identification of a market need is clarified as a set of design requirements to develop first ideas that could perform the requested functions. Promising concepts are validated and transformed into feasible design solutions in the embodiment phase by examining the implications for performance and cost (e.g. sizing the components or selecting proper materials). Once the design team has converged to one specific solution, product specifications as well as methods for production are finally set in the detail phase.

Ashby (2004) has proposed that each product possesses a physiological and a psychological side. While product physiology is described by the materials and processes used to manufacture it, the psychological part is defined by its usability and personality (i.e. aesthetics, associations, and perceptions). These two parts melt to define the overall product (e.g. the desired product personality is translated into the material properties) meant for the specified context (i.e. Who? Where? When? Why?). In order to successfully fulfill the requirements of functionality, usability, and customer satisfaction, several disciplines are involved in product design, Figure 1.

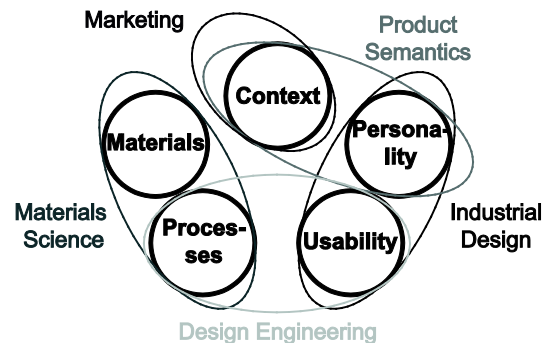


Figure 1. Disciplines involved in the definition of product features

Marketing is responsible for targeting the right customer in the field of Economics, while product semantics sets the right meaning that is communicated by the product through its form in the field of Sociology. Hence, product semantics focuses on the correlations between context and product personality. In the field of Engineering, design engineers address product function as well as ergonomics to fulfill safety requirements. They also address the processes to manufacture the product such as product assembly. The multiple disciplinary field of Materials Science (Chemistry, Physics, and Engineering) is responsible for designing new materials that cope with the chosen product function and, consequently, for the methods required to manufacture them. Industrial design is involved in product definition as well. At this point, it is important to clarify the difference between *product-* and *industrial design*, since their definition is still widely debated in literature (Kim and Lee, 2010). *Product design* is intended here as an ensemble of disciplines involved in designing a specific product (e.g. design, engineering, marketing and so on), while *industrial design* is defined here as the monodisciplinary task of the designer involved in the whole product design process. Thus, industrial design attempts to provide a satisfying user experience while interacting with the product in the field of Design. Usability and product personality are its main targets within the product design process.

3. Multiple disciplinary approaches for product design

The task organization among heterogeneous stakeholders within the design process, which ultimately leads to merge product physiology and -psychology together, can be challenging and is generally directly related to the level of technological content involved. In this regard, multiple disciplinary approaches can support product design teams. They can interpret issues outside normal boundaries and reach solutions based on a new understanding of complex design tasks by defining new organizational typologies among domains. Choi and Pak (2006; 2007; 2008) have made an extensive literature review on multiple disciplinary approaches and consider as their major objectives a) the solution of real world or complex problems; b) the provision of different perspectives on problems; c) the development of consensus definitions and guidelines; d) the supply of comprehensive services to people. Multidisciplinarity, interdisciplinarity, and transdisciplinarity are the three approaches involving multiple disciplines in product design, Figure 2.

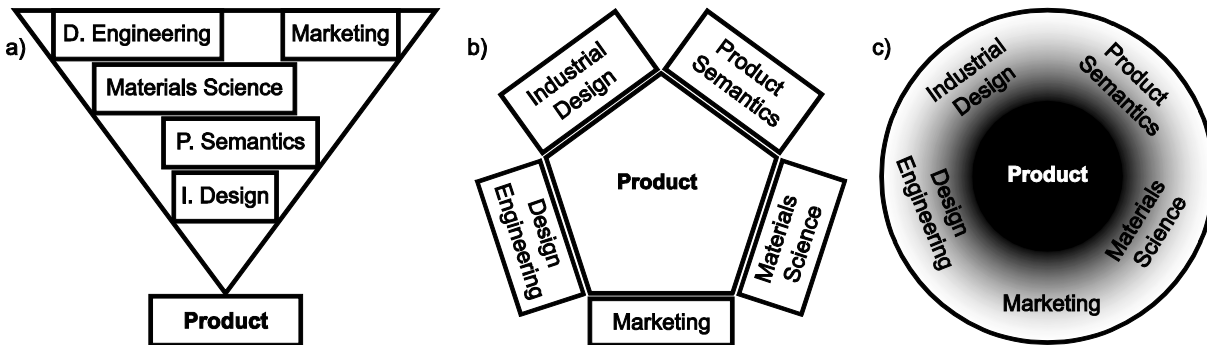


Figure 2. Pictorial representation of multi- (a), inter- (b), and trans-disciplinary (c) approaches in product design

According to Choi and Pak (2006), multidisciplinary draws on knowledge from different disciplines but stays within their boundaries. The design of convenience products (e.g. packaging) usually takes place in a synchronized fashion, due to their low level of technological complexity. Therefore, disciplines give their own contribution at different stages of the process without necessarily overlapping with each other. Stakeholders involved tend to represent the design process as of a logical and linear kind. However, the frequently experienced dead-ends while testing possible concepts proves the reality to be otherwise. Multidisciplinary in product design can be represented as an isosceles triangle. Its surface area embodies

the interaction of disciplines, which are involved in an unorganized fashion at different stages of the process. The output finally converges into the final product that is represented by the unequal angle, Figure 2(a). Interdisciplinarity synthesizes and harmonizes links between disciplines into a coordinated and coherent whole (Choi and Pak, 2006). While multidisciplinary focuses on the actors interacting within a process (i.e. who?), interdisciplinarity focuses on the way in which this interaction takes place (i.e. how?). Specialty products (e.g. cars) often require a concurrent and overlapping interaction of domains throughout the whole process. In their design, translating design features into engineering requirements is often a difficult task also due to the lack of multiple disciplinary knowledge among the different teams involved (Luccarelli et al. 2014). In such cases, product design itself becomes an interdisciplinary function requiring skills that span traditional department boundaries (Eppinger et al. 1990). Correct timing in the involvement of all heterogeneous members and coordination of their interactions in the process is of specific interest to reach interdisciplinarity in product design. Over the course of time, as the stakeholders proceed hand in hand throughout the process from the very beginning, the interaction between the disciplines begins to permeate everything that the union does into the final product. Consequently, these teams experience a qualitative change in how their members relate to and identify with their union (Kleinsmann and Valkenburg, 2008). Interdisciplinarity in product design can be depicted as a regular polygon having a number of sides equal to the number of disciplines involved. It displays equilateral and equiangular properties due to the balanced manner among domains that keep boundaries and are equidistant to the center, i.e. the product, Figure 2(b). Transdisciplinarity integrates different branches of science in a humanities context, and transcends their traditional boundaries (Choi and Pak, 2006). The achieved level of innovation is the primary goal of this approach (i.e. what?). New outcomes are generated by mixing methodologies belonging to different domains. Within this context, the domains involved function as a whole and their contribution cannot be fully understood solely in terms of their individual expertise. As transdisciplinary thinking can only be the result of an individual cognitive process, transdisciplinarity in product design is demanding and simply joining disciplines may not be sufficient to reach it (Leblanc, 2009). However, new promising opportunities with upcoming technological trends such as open design and new maker cultures to rapid prototyping or digital fabrication make transdisciplinarity a tangible option for the design of future artefacts (Nascimento and Pólvera, 2016). This approach may be represented as a circle, whose circumference is defined by the boundaryless disciplines involved. By melting together, they give birth to a new common core that is the product, Figure 2(c). In summary, the three presented approaches refer to the inclusion of two or more disciplines to varying degrees into one complex activity, as is product design. While multidisciplinary is a simple additive approach, interdisciplinarity and transdisciplinarity focus on interactivity and holism, respectively.

4. Interdisciplinary product design curriculum

Interdisciplinarity and its focus on how heterogeneous members interact in a complex process is a promising way to teach product design. It improves students' tolerance for ambiguity, their listening skills and, consequently, their overall sensitivity (Newell, 1994). At master's level, some universities offer supplementary classes to graduate students enrolled in one of their schools to reach a multiple disciplinary environment (e.g. d.school at Stanford University). Other universities choose to reach interdisciplinarity through a specific curriculum (e.g. M.Sc. Integrated Product Design, TU Delft). Following the latter example, Reutlingen University has lately established the Master of Interdisciplinary Material Sciences (MIMS) within the School of Textiles and Design. The wide typology of products addressed by the new graduate program includes transportation, energy engineering, architecture and construction, healthcare, and technical clothing. Typically, universities involve a maximum of three domains in their multiple disciplinary curriculums (e.g. industrial design, mechanical engineering, and marketing at Carnegie Mellon University; industrial design, marketing, and informatics at Northumbria University). Instead, MIMS covers the domains of engineering (i.e. mechatronics, electrical-, and mechanical engineering), informatics, chemical engineering, textile and clothing technology (due to the specific orientation of the Faculty towards

textiles), and industrial design. The goal is to achieve a balance between the domains of engineering sciences whilst maintaining students' creativity that is required for product design. Students that earned a BA or a B.Sc. degree in one of these topics can apply for admission for MIMS. While the curriculum in Multi-disciplinary Design Innovation at Northumbria University awards either a M.A. or a M.Sc. degree depending on the focus of the final semester's work, MIMS is a M.Sc. degree and consists of three sequential semesters. Students that earned a three-year bachelor's degree must complete an internship in their own field prior to taking first year classes, thus bringing in some basic work experience. Following Bloom's Taxonomy (1956), according to which students should be guided to reach higher levels of reasoning, the three semesters are divided in *Creation of Common Knowledge Base*, *Interdisciplinary Project*, and *Master Thesis*, Figure 3.

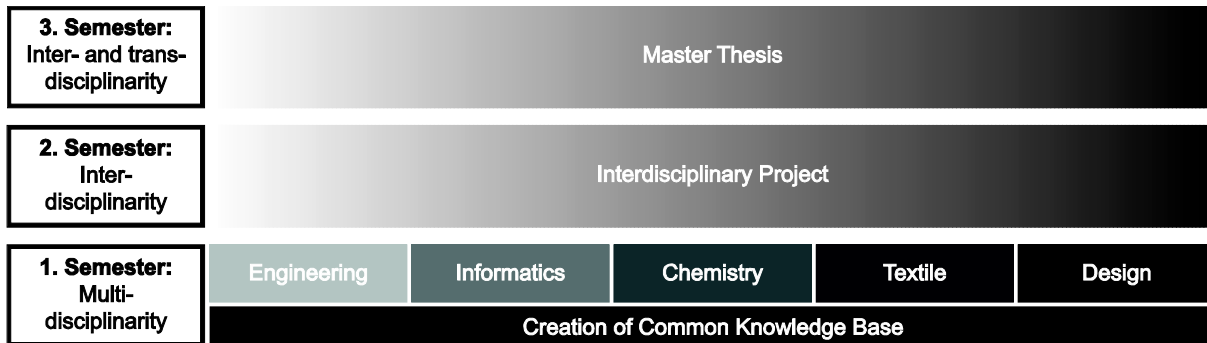


Figure 3. Structure of the Master of Interdisciplinary Material Sciences (MIMS)

The first academic term aims at providing students with knowledge in the other foreign disciplines involved. Students are required to choose from a list of elective courses according to their degree background. This part of the study is based on the classic “chalk and talk” educational method and each discipline is taught in a monodisciplinary way, no matter what the students' background. Once the first academic term is completed, students understand the context of multidisciplinary product design, in which different disciplines can contribute to the same goal without compulsorily overlapping (Figure 2a).

The pedagogy adopted in the second semester follows a project-based learning approach. The topic is chosen and given to a group of heterogeneous students covering (if possible) all disciplines. Once the brief is specified, the team has to concept and develop a specific product. This work is directed to the application of knowledge rather than to its sole acquisition and is meant to balance the different disciplines through the process of designing (Figure 2b). In addition, team members are requested to present their own monodisciplinary research carried out during the design process. A course on project management is offered in this semester as well to improve students' ability in efficiently developing a project schedule.

Students in their third semester are required to write their master's thesis. This term can be spent at the University or at an external partner such as the Institute of Textile Technology and Process Engineering in Denkendorf (ITV). ITV is Germany's largest center for textile research and conducts basic and practice-orientated research related to all stages of the production chain (i.e. from raw material to final product). Students can either pick a new topic involving an interdisciplinary co-design process or experiment transdisciplinarity on the same subject examined during the second academic term by mixing methodologies coming from the different disciplines explored (Figure 2c).

5. Switching from convergent to divergent thinking through iteration

Considering creativity as a result of the interaction of more fields implies that novelty could potentially be the output of any domain involved. Within an interdisciplinary context, designers should no longer be taken into account as those solely responsible for creative thinking. Instead, their experience and trained creative approach should be made available to all heterogeneous team members. In this regard, understanding the

industrial designer’s approach to target creativity is of specific interest to develop an educational method that translates and reveals this methodology to product designers.

Despite the inconclusive discussions about the definition of creativity, with more than 80 different interpretations of the term identified in literature (Dasgupta, 1994), it seems that specialist assessors are much more in agreement when it comes to evaluate the creativity of a design made by industrial design students or industrial design professionals (Christiaans, 1992; Dorst and Cross, 2001). In product design it is common to target product functionality, usability, and customer satisfaction, respectively. Instead, industrial designers are less rigorous in applying scientific calculations while designing (Lee and Radcliffe, 1990). They tend to develop and refine together both the formulation of a given problem (i.e. the initial brief) and the ideas to solve it to come to a creative solution (Dorst and Cross, 2001). Consequently, the problem space and the solution space co-evolve throughout the design process (i.e. in the concept-, embodiment-, and detail phases) to generate creative ideas (Maher et al. 1996). Considering the notion of surprise in the theory of creative design of Schön (1983), the unexpected part of a problem or solution ultimately drives the originality into a design project.

Based on these findings, an educational activity that follows the intuitive approach of industrial designers has been conceived for first semester non-industrial design students. The aim of this exercise is to set product design students on a creative path of preparation for the interdisciplinary co-design project of the second academic term. It addresses the conceptual design phase, since concept definition usually requires the highest level of creativity in the process. It consists of six assignments that follow an iterative process to apply divergent and convergent thinking in a collaborative and controlled manner. On one hand, the ability to switch regularly from divergent into convergent mode fosters designers’ creativity (Dym et al. 2005). On the other hand, a balanced alternation of divergent and convergent thinking is key to avoid reckless change in the design process (Cropley, 2006). Rather than being based on the classic “chalk and talk” educational method adopted in the first semester, this exercise is project-based. Heterogeneous teams are provided with an image representing a problem and guidelines for solving the exercise. The instructions include a list of tasks to be systematically handled, the media as well as the thinking approaches to be used, and a pictorial representation of the whole iterative process, Figure 4.

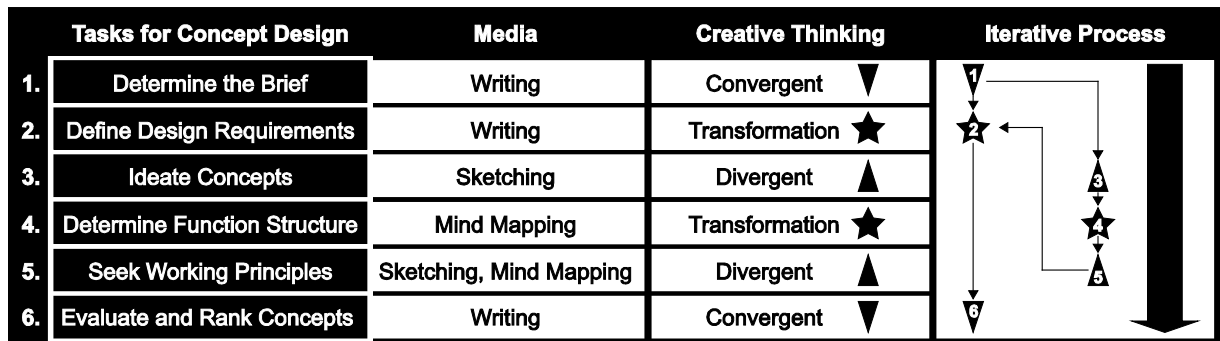


Figure 4. The iteration process to stimulate creative thinking in the concept phase

Assignment 1 requires students to determine the brief by interpreting the given picture. In order to encourage new solutions, teams are asked to define the problem in a solution-neutral form by avoiding the expression of a possible solution in their statement. In this phase, new team members get to know each other and elaborate a common goal through convergent conversations. Once the problem is defined, the statement has to be transformed in product requirements in assignment 2 according to functionality, usability, and customer satisfaction. Task 3 is the most demanding in terms of creative thinking. Keeping their brief in mind, students have to brainstorm about possible concepts without considering the product specification defined in the previous task. Instead, they have to reconsider the brief defined in task 1 by addressing the context only (i.e. Who? Where? When? Why?). Since this divergent phase is not in a dependent relationship with the previous one, students get an impetus for reframing the defined brief and

their new ideas to solve it, as described by Dorst and Cross (2001). At the same time, their concepts are not directly associated with the previously defined product specifications and lead to unexpected and surprising ideas that are key to drive the originality streak in their project, as outlined by Maher et al. (1996). Each member is asked to present at least one idea, using hand sketches as medium. Ideas are not ranked at this stage and the combination of more ideas expressed by different team members is welcomed by the tutors. Once all ideas are collected, students are requested to operate another transformation by translating their sketches into functional systems in task 4. Mind maps are used as medium to list and correlate the functions needed to make their concepts work (i.e. what?). In phase 5, students are required to define working principles by which these functions are achieved (i.e. how?). The results of assignments 3 (sketches) and 4 (mind maps) are re-elaborated and mixed. Once they have prepared their graphics, students evaluate and rank concepts in phase 6. Each team checks and classifies the defined concepts in accordance with the product specification defined in task 2 either to converge to a final choice or to refine the concept that fits the product requirements the best. On one hand, this iterative approach should support students for exploring in depth the concept phase. They improve their flexibility in changing point of view as well as their own role in the process by repeatedly switching from convergent to divergent thinking throughout the tasks. On the other hand, this systematic methodology and its controllability helps students to keep track of important information to effectively move on from the concept to the embodiment phase for testing and optimizing concepts. It should also be appealing to students coming from engineering disciplines, who are familiar with a step-by-step manner (Pahl and Beitz, 2006).

6. Summary

Among the disciplines contributing to product features, industrial design is responsible for product personality and usability to target customer satisfaction. Industrial designers reach creative solutions throughout the product design process by developing and refining together both the formulation of a given problem and the ideas to solve it. As successful products are more and more related to the degree of creativity possessed by each stakeholder involved, designers should no longer be taken into account as those solely responsible for creative thinking. In order to enhance the communication, cooperation and, consequently, to stimulate an interchange of creative ideas among domains throughout the process, universities build up multiple disciplinary product design curriculums. Among the three presented multiple disciplinary approaches, multidisciplinary is a simple additive approach, transdisciplinarity focuses on holism, and interdisciplinarity addresses interactivity. The latter specifically addresses the balancing of disciplines during a complex process, as is product design. It fosters the ability of perceiving differently, thus deferring judgment during the creative process. The new Master of Interdisciplinary Material Sciences at Reutlingen University has been developed to guide students through the different multiple disciplinary approaches and is based on three academic terms. While the first semester is conceived to offer a multidisciplinary view of product design and the third semester comprises the master's thesis, the interdisciplinary product design project offered in the second semester is the curriculum's core. In order to prepare students for this co-design project, an educational activity that incorporates industrial designers' approach to foster creativity has been integrated in the first academic term. The exercise is based on an iterative process that trains young product designers to apply divergent and convergent thinking in a collaborative and controlled manner. Future work will address educational activities to support students in exploring transdisciplinarity in their individual master's thesis, since transdisciplinary thinking can only be the result of an individual cognitive process.

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