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Teaching strategic and systems design to facilitate collaboration and learning

Abstract

As strategic and systems approaches are becoming more relevant in design education when it concerns collaborative projects with the industry, an explicit systems design methodology is needed to structure collaboration and learning among students, educators, and the Norwegian industry. This article describes three alternative studio projects for teaching strategic and systems design with the involvement of Norwegian companies. Besides this, the approaches and fundamental theories of design thinking and reasoning, which are characteristic of these projects, were reflected against each other. In the undergraduate (year 2) systems thinking design studio, the challenge was to train students to understand how system elements are rationally interconnected with their suprasystems and subsystems based on usability and man-machine interactions. In addition to the challenges pertaining to systems thinking, collaborative learning and designing based on a mentorship learning concept were introduced in the Vertical Design Studio, which involved second- and third-year students. Concerning the postgraduate fourth-year strategic design projects with the industry, the challenge was to involve Norwegian companies in product planning and goal finding as well as in innovation and design activities and to assess how supportive and receptive these companies were towards radical innovation/diversification. The analysis of completed projects shows that the Norwegian industry is supportive of strategic design but is rather conservative and risk averse when it concerns accepting and implementing radical innovation initiatives. Referring to user-centred and context-based innovation, this article also supports the implementation of a systems approach to facilitate social and hierarchical learning across the second-year systems design studio, second- and third-year vertical studios, and fourth-year strategic design studio.

Keywords: strategic design, systems design, collaborative learning, industrial collaboration

Introduction

In a globalised economy, companies constantly seek a competitive advantage through the development of innovative products, services, and systems. The creation of "stand-alone" products would no longer meet the needs for solving complex problems within an environment in which technologies become more advanced and complex and where user needs become more diverse.

To some extent, technology is seen as a means by which manufacturing companies can strive to adapt to the requirements of a competitive and turbulent environment. The growing complexity and pace of industrial technological change are forcing firms to forge new vertical and horizontal alliances and to seek greater speed, flexibility, and efficiency in responding to market changes (Rothwell, 1994). Although underlining the importance of "technology push" and "need pull" in search of innovation, leading-edge innovators and scientists who are believers of the five-generation (5G) innovation processes tend to support an industry dominant design, whereby the nature of innovative activity has shifted from an emphasis on product change to one on manufacturing process change (Abernathy & Utterback, 1978). In such cases, firms can become introspective in their innovation selection criteria (manufacturing cost focus), rejecting possibilities for radical product change and failing to respond to significant market shifts.

From a product and social sustainability perspective, incremental improvements will not suffice. Radical or systemic innovation is needed, whereby a change in the approach in searching for new solutions is essential (Ehrenfeld, 2008). This is complemented by Zahn's claim that strategising, as a core process of strategic management, is more than strategic planning and needs strategic thinking, which is foremost in systems thinking (Zahn, 1999).

This paper argues for a strategic and systems thinking approach to be adopted at various stages of the innovation and designing process to achieve a competitive and collaborative advantage as well as to enhance "social learning." Systems theory, as an interdisciplinary theory to investigate phenomena from a holistic perspective, will be used as a "red threat" when discussing various perspectives on systems design in this article (Capra, 1997).

A Multidisciplinary Approach towards Systems Thinking

A *system* can be defined as an entity that is a coherent whole with a perceived boundary around it to distinguish internal and external elements and to identify input and output relating to and emerging from the entity (Ng, Maull, & Yip, 2009). A systems theory is hence a theoretical perspective that analyses a phenomenon seen as a whole and not simply as the sum of elementary parts (Mele, Pels, & Polese, 2010). The focus is on the interactions and relationships between parts to understand an entity's organisation, functioning, and outcomes. A distinctive characteristic of systems theories is that they developed simultaneously across various disciplines and that scholars working from a systems theory perspective build on the knowledge and concepts developed within other disciplines.

Systems thinking comes from a shift in attention from the parts to the coherent whole (Ng et al., 2009). The relationships between the parts themselves and the events they produce through their interaction become much more important. Luhmann (1990) claims e.g. that this results in a situations where system elements are rationally intertwined towards a shared purpose. From a system-level engineering design approach, every complex system at a certain level stands in relation to suprasystems and subsystems. The former are hierarchically ordered as a function of their influence on the system; the latter ought to be directed and managed by the system to contribute to its finality (Barile, 2006, 2008). With respect to handling higher-level design challenges, Jones (1992) and Archer (1985) argued for a more comprehensive design process to support the management of complex and ill-defined problems (Cross, 1992). This indication that the design process should be extended from its concerns with products to include the design of systems emphasises the whole system rather than the product as a self-contained object. Complex systems may include large products, such as automobiles and airplanes, which comprise many interacting subsystems and components (Ulrich & Eppinger, 2003).

For several years now, corporate business has begun to shift attention from product manufacturing to the provision of a set of systemic solutions with high cultural and social content (Manzini, 1993; Pilat, 2000). In such a new context, the design and development of new products and service systems become a strategic priority (Albrecht & Zemke, 1985).

From a management systems perspective, the understanding of system theories, which address issues, such as knowledge creation and learning, value creation, and management of complex network systems, are essential to gaining competitive advantage in a dynamic global environment, which is characterised by an increasingly complex and demanding consumer behaviour. At a subordinate market systems development level, literature related to product design and development addressed this complex and dynamic consumer behaviour and their needs rather than the difficulties encountered in the use of such products (Kotler, 1976; Tushman & Moore, 1982; Dahlman, 1986).

When considering users' interaction with systems, Jung and Sato (2010) classified mental models into several categories to provide more elaborated and systematic explanations. Most commonly, these mental models are classified into two categories: structural and functional models. DiSessa (1986) argued that structural models are involved in users' in-depth understanding of a system and are not restricted to particular tasks, while functional models represent a system's functional properties involved in performing a particular task. Preece et al. (1994) also categorised mental models into structural and functional models, where structural models represent the mechanisms of a system's component parts, whereas functional models represent the procedures in using a system.

Different Perspectives on Innovation

The changing global environment is compelling organisations and businesses to permanently seek the most efficient models to maximise their innovation management efforts through new methods and paradigms, which efficiently serve existing and new markets with new and/or modified products as well as services (Christiansen, 2000; Ansoff, 1968).

Many authors have written about different models and the impact of these models on the level of "radicalness" in terms of innovation. Utterback and Abernathy (1975) claimed that the relative focus of innovation changes as the firm matures, underscoring its fluid nature with respect to the firm and the environment in which it operates. Crawford (1994) discussed three levels of innovation, pioneering adaptation, and imitation. Likewise, it is suggested that the degree of technological change represented by a product is the most useful way to classify development projects (Wheelwright & Clark, 1992). Lee and Na (1994) distinguished between "incrementally improving innovativeness" and "radical innovativeness" while explicitly excluding commercial performance as a basis for classifying innovations. Christensen (1997) differentiated between two fundamental types of innovation: sustaining innovation, which continues to improve existing product functionality for existing customers and markets, and *disruptive* innovation, which provides a different set of functions that are likely to appeal to a very different segment of the market. Veryzer (1998) discussed innovation from the perspective of "technological capability" and "product capability" dimensions. In this context, radical innovation involves advanced capabilities that do not exist in current products and cannot be achieved through the extension of existing technology.

Existing firms and their customers are likely to undervalue or ignore disruptive innovations as these are likely to appear inferior to existing technologies in terms of measures of benefit and performance (Tidd, 2001). From a methodological and enquiry perspective, three types of innovation approaches can be distinguished: user-centred, design-driven, and context-based innovation approaches.

Significant efforts in recent literature studies concentrated on investigating a specific approach to design usually referred to as a *user-centred design* (Chayutsahakij & Poggenpohl, 2002; Veryzer & Borja de Mozota, 2005). This approach implies that product development should start from a deep analysis of user needs. In practice, researchers spend time in the field observing customers and their environment to acquire an in-depth understanding of customers' lifestyles and cultures to better understand their needs and problems (Belliveau et al., 2004).

Unlike user-centred design processes, design-driven innovation is hardly based on formal roles and methods, such as ethnographic research. However, this type of innovation plays a crucial role in the innovation strategy of design intensive firms but still remains largely unexplored (Verganti, 2008). Its processes are hard to detect when one applies the typical methods of scientific investigation in product development, such as analyses of phases, organisational structures, or problem-solving tools (Shane & Ulrich, 2004). In this case, design-driven innovation may be considered as a manifestation of a *reconstructionist* or *social-constructionist* view of the market, where the market is not "given" a priori but is the result of an interaction between consumers and firms (Kim & Mauborgne, 2005; Prahalad &

Ramaswamy, 2000). Hereby, users need to understand the radically new language and message, to find new connections to their socio-cultural context, and to explore new symbolic values and patterns of interaction with the product. In other words, radical innovations of meaning solicit profound changes in socio-cultural regimes in the same way that radical technological innovations do, soliciting profound changes in technological regimes (Geels, 2004).

In terms of context-based innovation, the user-product relationship is not something that takes place in isolation but is part of a larger context, consisting of all kinds of factors. Examples of factors are social patterns, technological possibilities, and cultural expressions that affect the way people perceive, use, experience, respond, and relate to products (Hekkert, 1997). According to Hekkert and Van Dijk (2003), these factors can be classified as “trends” and “principles.” Trends are developments, which change over time, such as behaviour, values, and preferences, whereas principles refer to immutable laws or general patterns that can be found in human beings or nature. Considering current trends towards innovation, with the ultimate aim of developing revolutionary products and services based on “new offerings” for “new users,” is a priority. Hereby, understanding user behaviour, use, and shortcomings of products and services is important (IDEO, 2009). Examples of Human-centred Design (HCD) methods, which have been researched and applied to better understand user behaviours, are “in-context immersion,” context mapping, cultural probing, and story telling (Stappers, van der Lugt, Hekkert, & Sleeswijk Visser, 2007).

However, when refocussing on user-product relationships from a HCD perspective, a systems thinking approach should be incorporated. This systems thinking approach is based on the understanding that a set of interconnected entities, comprising people, processes, and technologies, is dynamic in behaviour and has a purpose or reason for existence (Singleton, 1974). From an innovation management perspective, systems thinking has surfaced in different network theories and is likely to be associated with different environmental contingencies and types of innovation. For example, complex products have to interface with the products and services of other vendors, and it is in the interest of all organisations to share knowledge to ensure compatibility. In such cases, an “open” network is most appropriate. In contrast, a “closed” network seeks to control standards by economies of scale and proprietary standards to lock in customers and other organisations in the network (Garud & Kumaraswamy, 1993).

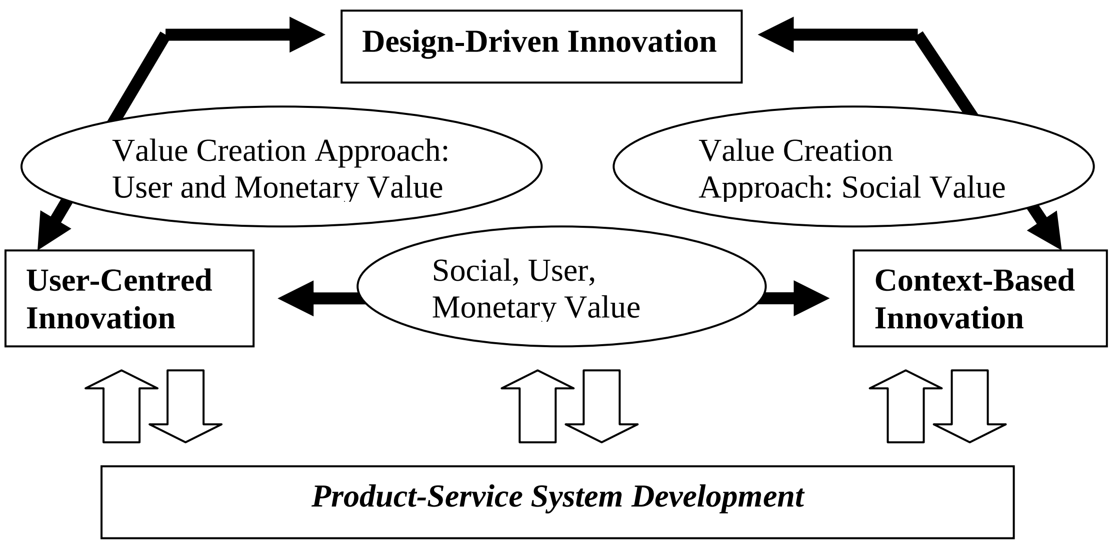

Figure 1: Relationship between different types of innovation approaches, value creation, and product-service system development

The three types of innovation approaches—user-centred, design-driven, and context-based innovation—have initiated a common platform in the search for innovative products and services (see Figure 1). Whether the objectives are radical or incremental, benefiting the receiver (customer/user) or provider (firm), the overall aim is some form of "value creation." Hereby, a Product Service Systems (PSS) approach would facilitate and enhance the user and social value creation in terms of "user-centred" and "context-based" innovation.

Innovation through Systems Thinking and HCD

The introduction of PSS shifted the business focus from designing physical products to designing a system of products and services, which became more and more recognised as an important innovation strategy (Rocchi, 1997). This approach towards innovation and product management was based on a new interpretation of the concept of *product*, underlining that the client does not really require the products or services but what these products and services help the user to achieve (Mont, 2000; Stahel, 1997; Manzini & Vezzoli, 2002). In a previous study comprising two Scandinavian companies, Stokke and Håg, a strategic approach that is heavily reliant on ergonomic principles was used in the design of their products (Jevnaker, 1993).

From a business perspective, the PSS model could also be explored as a platform to initiate radical innovation as it introduces new types of stakeholder relationships and/or partnerships, new constructions of mutual economic interests, and optimisation of resources (Manzini & Vezzoli, 2002). Within this context, the designer is required to synthesise solutions emerging from the comparison of different viewpoints, needs, and socio-cultural models, iterating from the traditional design domain to the domain of design management, and vice versa (Morelli, 2003).

Methodologically, it may be useful to develop system models of the product design process from a human-centred perspective by involving potential users in the initial stages. The users' technological and cultural frames as well as behaviour in relation to material and immaterial aspects of service are very closely related to design (Andersson, 1990; Morelli, 2002). The PSS and HCD perspectives can be useful in establishing systems thinking as well as in defining and enlarging the overarching design problem to achieve a significant value-add in the design solution (Kleiner, 2006). According to Maguire (2001), HCD encompasses the following key principles:

- *The active involvement of users and a clear understanding of user and task requirements*. One of the key strengths of HCD is the active involvement of end users who have knowledge of the context in which the system is used.
- *An appropriate allocation of function between the user and the system*. It is important to determine which aspects of a job or task should be handled by people and which can be handled by software and hardware.
- *Iteration of design solutions*. Iterative design entails receiving feedback from end users following their use of early design solutions. These may range from simple paper mock-ups to detailed prototypes.
- *Multidisciplinary design teams*. Human-centred system development is a collaborative process that benefits from the active involvement of various parties, each of whom has insights and expertise to share. It is therefore important that the development team be made up of experts with technical skills and those with a stake in the proposed solution.

HCD Methods and Systems Development

Until now, a direct applicable methodology to support systems design has not been developed yet. However, within the context of Systems Engineering (SE), there was an increased interest in designing the "user experience" (Chapanis, 1996). The SE "cradle-to-grave" structure and systematic approach was based on the triumvirate of requirements, compliance, and reliability engineering. From a human-centred perspective, it was first applied to the micro-ergonomic range of hardware design/engineering, software development, human factor engineering, and seller/purchaser economics, but it later extended to macro-ergonomic endeavours when it was appropriate to effect organisational change (Hendrick, 1997; Samaras & Horst, 2005). This was emphasised from a life-cycle viewpoint, where the determination and analysis of the organisation's needs and wants put the consideration of user criteria as early as possible (Carayon, 2003).

The interest in designing experiences can also be seen as an initiative to enlarge the design space, as well as a development of design discourse "beyond the object," and a response to the shortcomings of existing models of how usage and users are considered in the design process (Thackara, 1988; Mitchell, 1993; Jordan, 2000). Methodologies were used to facilitate the generation of ideas and concepts systematically through specific creative and problem-solving techniques, such as the Morphological Chart Method and the Objective Tree Method, (Cross, 1989). However, most of these studies were approached from a product engineering viewpoint. For example, several design methods were introduced to develop quantified structural variations based on functional surfaces and form factors (Tjalve, 2003).

Concepts in Teaching and Learning to Facilitate Systems and Strategic Design

Much has been debated on how to direct undergraduate and postgraduate studio design teaching to create value-add beyond "core industrial design," focussing on systems and strategic design. At the Department of Product Design in the Norwegian University of Science and Technology (NTNU), an educational framework for systems and strategic design has been developed for undergraduate and postgraduate industrial design students to interact and collaborate with the industry as frequently as possible. This framework is based on the concept of collaborative learning through mentorship and scholarship to facilitate a win-win situation among educators, researchers, and students (Liem, 2008). Central in this framework are theories on social and hierarchical learning as well as theories on *communities of practice* and *Legitimate Peripheral Participation* (LPP). Social learning theory focuses on the learning that occurs within a social context where group members are encouraged to learn from and communicate with one another based on concepts such as observational learning, imitation, and modeling (Omrod, 1999).

According to Wenger (2000), learning is defined as an interplay between social competence and personal experience. It is a dynamic, two-way relationship between people and the social learning systems in which they participate. In the field of industrial design, social learning is embodied through project-based learning and master/apprentice relationships. Design educators both consciously and unconsciously instil fundamental value systems into students, especially through critiques (Holm, 2006).

The concept of collaborative learning was introduced in the second semester of the second-year undergraduate industrial design studio over a period of five academic spring semesters from 2005 onwards. Hereby, systems thinking was implemented in projects with Norwegian companies, such as the Norwegian Postal Service (Posten) (NPS), Lærdal Medical, Trondheim Renholdsverket, and Cavotec. This systems thinking approach was then pursued as an attempt to structure the fuzzy Front-End of Innovation (FEI) in strategic design projects at the fourth-year postgraduate level from 2005 onwards.

In 2010 of the spring semester, "vertical studio teaching," in conjunction with systems design, was implemented to facilitate and structure hierarchical learning among second- and third-year design students. This vertical studio was an intentional move to promote social learning theories of communities of practice and LPP. The companies Moelven Nordia, SINTEF Fiskeri and Havbruk, and Ulstein Power and Control were involved in this studio project. Although the students were from different stages of their education, their teamwork generally functioned well because they shared the same subjective viewpoints and spoke the same language. In short, they were enculturated (Brown, Collins, & Duguid, 1989).

Systems Thinking in Year 2 Undergraduate Design Studio Teaching

In the second-year systems design studio, students needed to approach a problem using an increasing number of parallel lines of thought (Lawson, 1997). Those with an aptitude to process information and think holistically found it easier to structurally develop the system inclusive of its elements, boundaries, and connections compared to those who preferred to process information in parts independently and sequentially. Based on the example of the NPS project, students were exposed to complex systems design thinking at an early stage of their education. According to the idea of the *mail transporter*, holistic systems were analysed and proposed to improve mail distribution. Subsequently, a wide variety of different products were conceptualised up to the level of design detailing. With continuous support from the NPS, selected designs were pursued for further refinement and materialisation beyond the studio environment.

From a design education perspective, it was a challenging task to be clear and detailed in the organisation and management of studio teaching, as well as in the supervision of students on how to plan and manage their projects. According to Roozenburg and Eekels (1995), the terms “system” and “structure” were introduced in the project. The system is the collection of subsystems and products that make up the mail distribution service, and the structure is the predetermined logistic framework on which this mail distribution system is based. The term “structure” is diachronic in nature, which means that the relationships are time and sequence dependent.

The project stressed the development of ergonomic work systems where students worked in groups of four or five to develop product-service concepts prior to the actual design of its supporting subsystems and products. In the first stage, a wide range of system concepts were generated by the groups. In the second stage, subsystems and products were individually developed further into two or three detailed design concepts. The selected design concept was then subjected to iterative cycles of refinement, user testing, and materialisation. The final stage was an extension of the studio. Selected designs were commissioned by NPS for further development and professional prototyping. Figure 2 shows the connection between the overall system and subsystems.

To understand current systems redesign in the above context, students were guided to undertake observational studies, user-scenario development, story telling, etc., of a wide range of sequential and parallel activities. In the NPS project, the above activities uncovered critical issues in systems thinking and task allocation to student group members, including where to place the boundaries of the system. On the one hand, the tighter the boundaries are placed within the system to define activities, the lesser the number of parameters and variables has to be considered explicitly but the more the crucial interactions will be omitted or simplified. This may lead to errors or an unrealistic understanding of the user’s situation. On the other hand, the further the boundaries are placed, the more complex the set of variables and parameters to be considered is, and the more work in systems thinking and management is required (Siemieniuch and Sinclair, 2006). Course evaluation and feedback sessions showed that a systems design project as such proved to be too complex for undergraduate students to manage. The second-year design students experienced difficulties in combining broad boundaries with concrete consequence analysis. In such a teaching situation, customised supervision is needed to facilitate segmenting the system design process and allocating tasks.

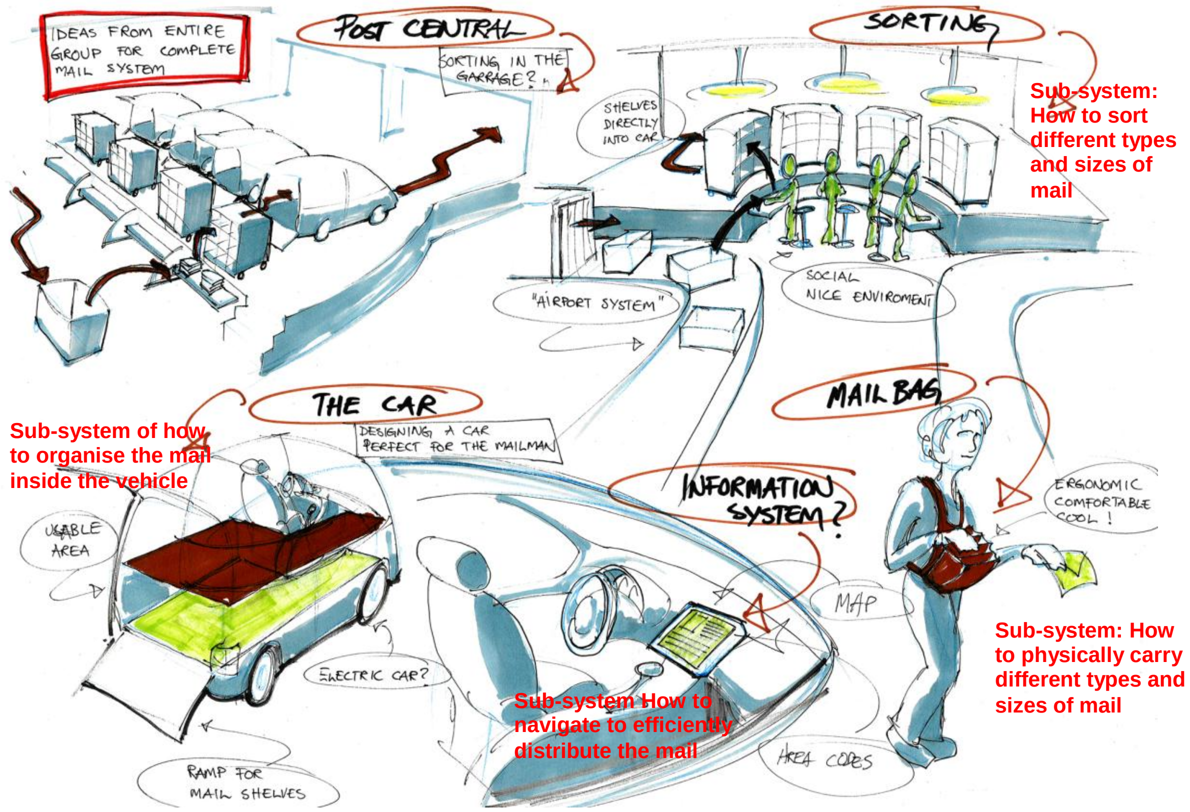

Figure 2: An example of the “mail distribution system for the Norwegian Postal Service” demonstrates how an overall system is classified into subsystems

Vertical Studio Learning and Teamwork in Year 2 Undergraduate Design Teaching

Within the framework of customised and flexible learning, several architecture and design schools have implemented their own programs. From an architectural design perspective, vertical studio teaching and learning have been widely practised to expose novice students to holistic and contextual thinking approaches, which is an inherent part of architectural design education. From an industrial design perspective, the Technical University Eindhoven is a good example of an institution that has introduced competency-based learning in their curriculum and in which students are grouped according to project and interest instead of education level. Similarly, ENSCI: Les Ateliers promotes “customised learning through practice and theory.” On the other hand, studio projects were developed according to themes of interest to the studio teacher, rather than to expose students to various levels of prescribed design complexities.

At the NTNU, vertical studio teaching and learning was implemented in the academic year 2009–2010 with 41 second- and third-year industrial design students. Six groups of six to seven students (comprising two or three third-year students and four second-year students) worked on contextual system design problems with industrial collaborators in the marine and office furniture sectors, respectively (Ulstein Power and Control, Moelven Nordia, and SINTEF. The challenge for students and educators was to manage the hierarchical and intertwined complexity of the design problems as well as the teamwork.

Based on the “collaborative learning model,” a favourable hierarchical learning situation took place where level-3 students understood their mentoring and project management roles and level-2 students accepted their roles as “product designers.” The interaction between second- and third-year students, as well as among students in the same level, proved to augment systems thinking from a usability perspective. Rigour was established by “learning through confusion,” “hierarchical learning,” and “LPP” as each group member tried to create his or her own project space, whilst a decision to adopt an element or functional approach was found to be crucial in the allocation of subprojects. Five of the six groups chose an element approach in the division of project tasks because the group members found it easier to develop a mental image of something that is concrete and tangible (see Figure 3). The group of second-year students that chose to take a functional approach experienced less guidance from their seniors and felt more secure to work closer with one another. This group was unable to develop system guidelines and boundaries.

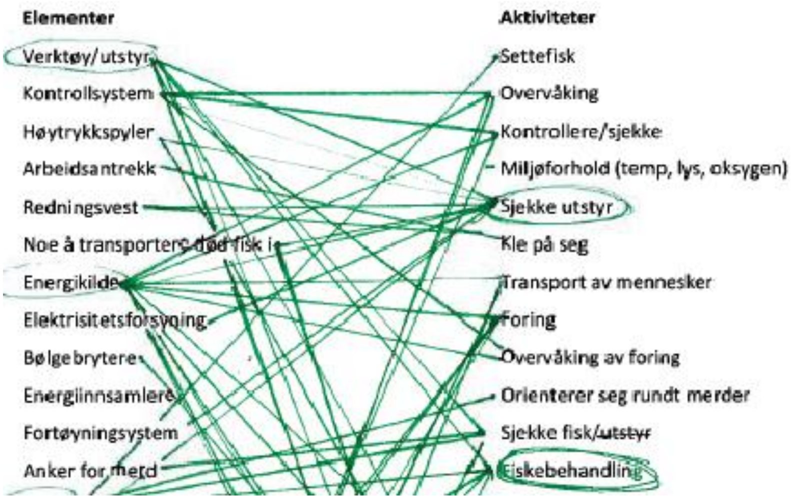

Figure 3: A systems thinking approach where relations among elements and activities/functions are listed and shown though a link diagram

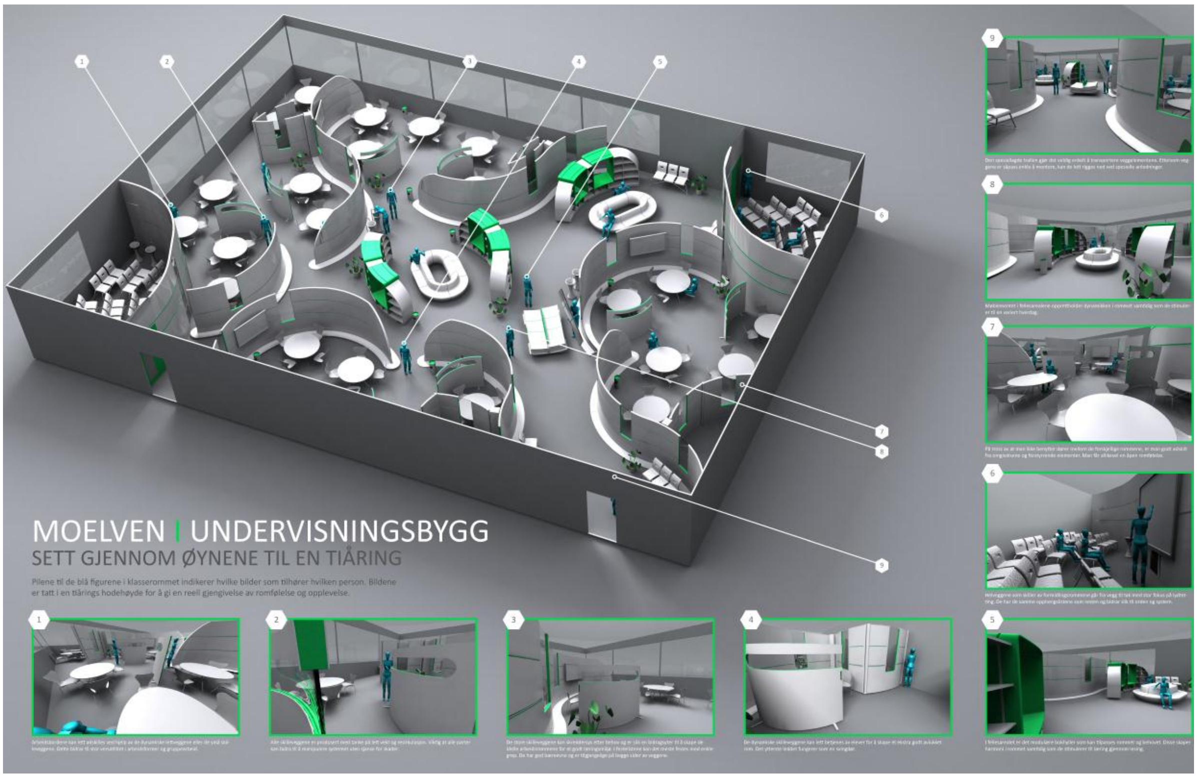

Figure 4: An example of an interior classroom setup for elementary school pupils, designed from a systems and product perspective

Figure 4 shows an example of how an interior classroom setup for elementary school pupils is designed from a systems and product perspective. Each group member was allocated a product (element) to conceptualise and detail. Overall, this group was successful in determining the system boundaries as well as the shared boundaries among the elements. Strong leadership qualities among the third-year members accounted for the clarity of design tasks. However, in the detailing and materialisation stage, group members still spent more time and effort in fine-tuning and reassuring that the elements interact in a coherent manner. This demonstrates the presence of an overcompassing iterative process between system and product/element design.

From a design thinking and process perspective, a problem-solving model of design reasoning (Simon, 1996) based on a positivistic philosophical worldview has been adopted in the planning and structuring of the vertical studio project to facilitate a hierarchical mentorhip-driven way of learning. However, in the interactions among group members, teachers, and collaborating companies, "reflective" (Schön, 1995) and "hermeneutic" (Bamford, 2002; Coyne & Snodgrass, 1992; Darke, 1979) approach to design thinking has been adopted. This reflective and hermeneutic way of designing enhanced by LPP modes of iterative learning inherently and positively brings in the element of learning through confusion.

Strategic and Systems Thinking in Postgraduate Design Projects

Since 2005, 8–10 established Norwegian companies have been yearly involved in a fourth-year collaborative strategic design project. The strategic design project is divided into two stages: Product Planning & Management (PPM) and industrial design. Students are required to adopt the role of design consultants in working groups of two or three. More than 50 companies, such as Stokke, Håg, Jordan, Ulstein Power and Electro, Tandberg, Lærdal Medical, Glen Dimplex, Vestre, and Lego Systems AS, were involved from 2005 to 2010.

In the PPM stage, students were subjected to a model for integrated product development where they had to follow a systematic innovation-step model that guided them to determine their design brief (Buijs, 1987; Buijs & Valkenburg, 1996). This activity of strategy development and goal finding lasted for ±6 weeks. Buijs' innovation process was used to introduce strategic design among the students as no other direct applicable processes were found in the area of SE, Macro-ergonomics, PSS Design, or HCD.

However, in recent years, the introduction of "value opportunities" and value creation through product/service positioning maps has been implemented to provide a more detailed direction to the design brief (Cagan & Vogel, 2002). The "how to" design was introduced as a response complementary to the "what to" design as framed by Ansoff's Product-Market-Technology (PMT) model (Ansoff, 1968).

Based on the analysis of nine recent strategic design projects, this paper showed that visionary capabilities were important in generating radical and incremental innovations. In five of the nine projects, a "new product–existing market" strategy was targeted, whereas two projects aimed at creating a "new market for existing products and technologies," Two companies adopted a "natural" diversification strategy because they were contract manufacturers and did not have a history in developing their own products. Design goals were determined through discussions among company management and design students, driven by a conjecture–analytical design approach (Figure 5A).

However, concerning the new product–existing market and new market for existing products and technologies strategies, six out of the seven projects were driven by a systems design approach, whereby students proposed product and service variations/extensions, which enhanced value creation and competitiveness. This has been achieved through innovative design concepts that challenge new technologies and style (=ergonomics and form) and by positioning products and services in the “upper left and right quadrant” of the 3D “style” versus “technology” positioning map, as described by Cagan and Vogel (2002) (Figure 5B). Social, economic, and technological trends formed the basis for systems thinking.

	Existing Product	New Product
New Market	• Sweets • Social Game Play	• Multi- functional Outdoor Fire Place • Load-Crosser
Existing Market		• Heating Systems for the Future • Energy Control Systems for the Future • Monitoring Fish health • New Thinking in Bridge Design • Bridge and Identity

Figure 5A: Positioning of strategic design projects on product-market matrix

STYLE		TECHNOLOGY: *LOW*	TECHNOLOGY: *HIGH*
	HIGH	• Sweets • Social Game Play • Multi- functional Outdoor Fire Place • Load-Crosser • Monitoring Fish health • New Thinking in Bridge Design *(Current and near-future concepts)* • Bridge and Identity *(Current and near-future concepts)*	• Heating Systems for the Future • Energy Control Systems for the Future • New Thinking in Bridge Design *(Mid.- and far-future concepts)* • Bridge and Identity *(Mid.- and far-future concepts)*
	LOW		

Figure 5B: Positioning of strategic design projects on Cagan and Vogel’s positioning map (2002)

Lectures and workshops served as a vehicle for students to learn and reflect over a variety of design issues, research, and design methods, as well as to apply them at certain stages of the project, tied to the main process. A positive correlation has been observed between the quality of the design outcome and the degree in which the student understands the logic of design processes (Radcliff & Lee, 1989). This re-emphasises that postgraduate students who are expected to be more matured in their thinking capabilities should be given explicit exposure to a systematic approach towards design, but not to the extent of a rigid methodology. Additionally, a selection of design models (Lie, 2012) that facilitate complex problem solving should be presented to the students as a framework for design thinking and self-awareness. This framework for design thinking and practice is based on different philosophical worldviews and can be referred to in correlation with each other.

Hereby, the problem-solving model, as advocated by Simon (1996) and which is a key model for teaching processes and methods in industrial design engineering schools, such as NTNU, should be challenged by other design thinking and reasoning models. The most interesting models are the reflective model (Schön, 1995), the hermeneutic model (Darke, 1979), and the participative model (Clarke & Stewart, 2003). However, a reflective-oriented research and design approach (not only “analysis-synthesis” but also “conjecture-analysis”) should be equally emphasised in design thinking and process customisation (Schön, 1995; Bamford, 2002).

Acceptance of Strategic and Systems Design Projects within the Norwegian Industry

From an innovation perspective, companies often find it difficult to simultaneously adopt an open mind towards strategic and systems design projects, as well as to be enthusiastic and serious about its outcome. Organisations usually have in place a strong set of plans where design and development activities are required to fit in. This is especially so when these organisations are more specialised in their core business activities, such that the strategic problem space may turn out to be rather narrow.

Companies involved in the second-year and “vertical studio” projects were classified into two groups with different objectives. One category of companies, represented, for example, by NPS, Cavotec, and Trondheim Renholdsverket, was found to be more enthusiastic about the individual product design outcomes rather than the holistic system proposal. The other category of companies, represented by SINTEF, Moelven, and Ulstein Power and Elektro, was more interested in the overarching system design than its individual elements. They are companies with strong technological expertise and are capable of designing and developing elements for the system. However, they seek inspiration for developing new systems based on future user-centred design perspectives.

In the post-graduate (fourth year) strategic design project, companies supported a narrower approach towards strategic innovation by stressing that diversification was not the only generic growth strategy to gain significant competitive advantage in the FEI stage of the product development process. Most of the strategic design projects focussed on value creation through the "development of new products for existing markets" or the "creation of new markets for existing products" as generic growth strategies in combination with a design strategy targeted at the "upper right quadrant" of Cagan and Vogel's positioning map. However, proactive collaboration with the Norwegian industry proved to be an interesting learning experience for all stakeholders involved. Students were encouraged to think to a greater extent about design issues, processes, and methods.

Therefore, design thinking in design education should be emphasised to enable students to predict future trends and therefore gain strategic advantage in today's knowledge economy. A structured and comprehensive step-by-step methodology to support the early stages of the strategic design process is to be taught to the fourth-year students who assumed the role of external design consultants for the industry and were exposed to the FEI for the fist time. This structured methodology should be complemented with theories on strategy development and perspectives on how to conduct a more comprehensive external analysis.

A Systems-Oriented Methodology for Product and Strategic Design Projects

From a design education perspective, the following issues are to be discussed in conjunction with teaching systems and industrial design to undergraduate students, as well as strategic and systems design to postgraduate fourth-year students.

Issues Concerning Systems and Industrial Design Teaching at the Undergraduate Level

A systems approach in studio teaching proved to be an effective generator for a wide range of different design projects at a product level while allowing interconnectivity within the defined overarching system. Especially, within the context of vertical studio learning, students were exposed to alternations of team and individual project work. Social learning (Omrod, 1999) and LPP within communities of practice formed the basis for team members to balance between collective and individual practice throughout the entire project.

Fewer difficulties were experienced among students in defining the system's outer boundaries once the logistic structure of the human-centred system was partly determined by the nature of the project. However, when approaching the transition from group to individual work, students encountered more difficulties in determining intermediate boundaries and connectivity within the system concerning overlapping scenarios and products (see Figure 6). Extra guidance in team and individual work, as well as detailed project planning, was needed in terms of the following:

- to understand at which level of systems thinking concepts had to be generated, suggesting the need for intermediate subsystem development prior to design concepts
- to understand the network relationship between the various stakeholders and their roles within the project
- to determine whether the individual project needed to be centred around a product alone or an activity supported by overlapping products

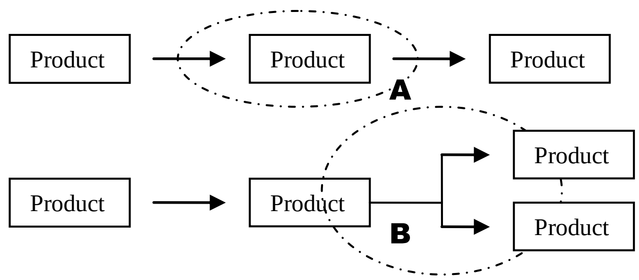

Figure 6: Situation A clearly defined the design assignment within the system in the form of a product alone, whereas in situation B difficulties may occur because the design assignment is based on an activity with overlapping products

Methods that could be considered are "scenario and task analysis," function analysis, and contextualisation of scenarios through a physical scale model of the projected environment (see Figure 4).

Issues Concerning Strategic and Systems Design Teaching at the Postgraduate Level

As Norwegian companies are not very receptive towards radical product proposals in the FEI stage (see Figure 5A), the "how to" design strategy represented by product positioning maps (Cagan & Vogel, 2002) should be emphasised above the "what to" design strategy as represented by Ansoff's PMT matrix. The reason for this "how to" emphasis is that chances for creating breakthrough designs can be achieved through a systems-driven, user-centred, or context-based innovation approach (see Figure 1). Figure 7 shows the traditional PPM process in relation to the "industrial design process" based on the PMT matrix (Ansoff, 1968) as reference theory.

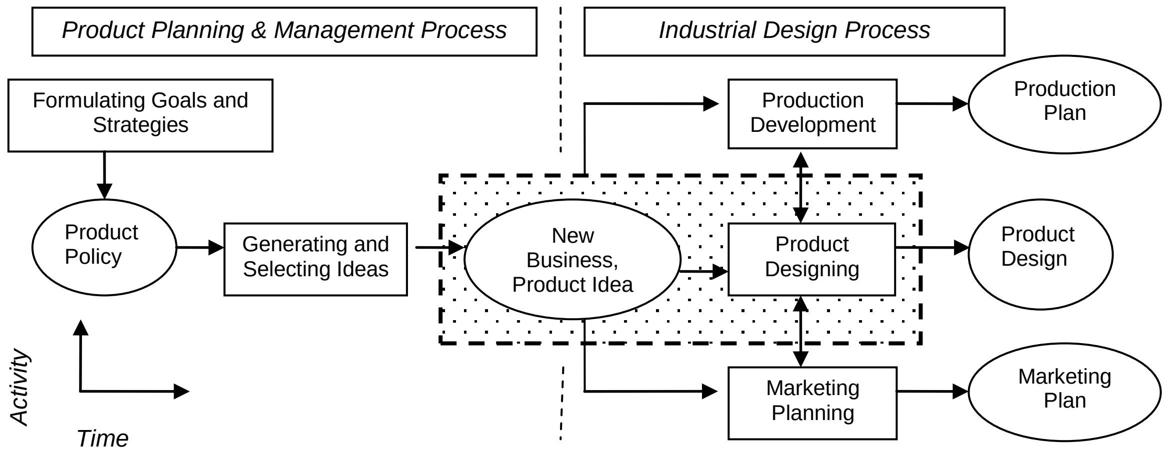

Figure 7: The transition between product planning and management and industrial design is clearly segmented into two consecutive stages

However, the methodology and focal areas for external analysis between the "how to" and "what to" design strategies are similar. Besides the analysis of markets, customers, and competitors, a more comprehensive approach involving social, economic, environmental, and technology factors within specific cultural and political contexts should be included in the external analysis. Once such an analysis has been properly conducted, a clear direction can be determined on how to develop a design strategy for value creation based on technology and style criteria.

Figure 8 shows that value creation can be optimised in product position maps when targeting design solutions capitalising on "new style" and "new technology."

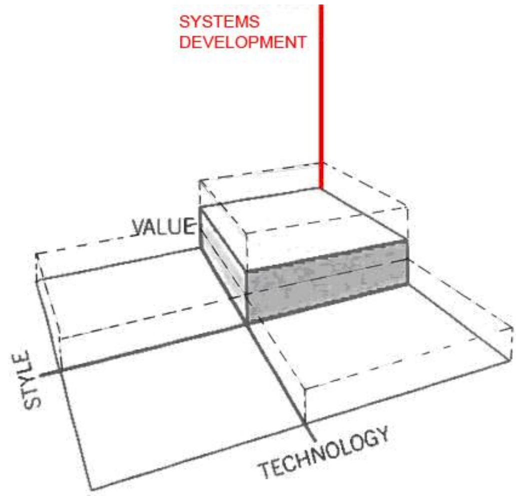

Figure 8: The three-dimensional positioning map showing the added value of a systems approach

As mentioned earlier, when companies aim to develop a new style based on a new technology, a systems design approach can provide added value in framing a winning design brief as well as guiding design activities from design research to design detailing. Figure 9 proposes an alternative to the traditional PPM process, as illustrated in Figure 7.

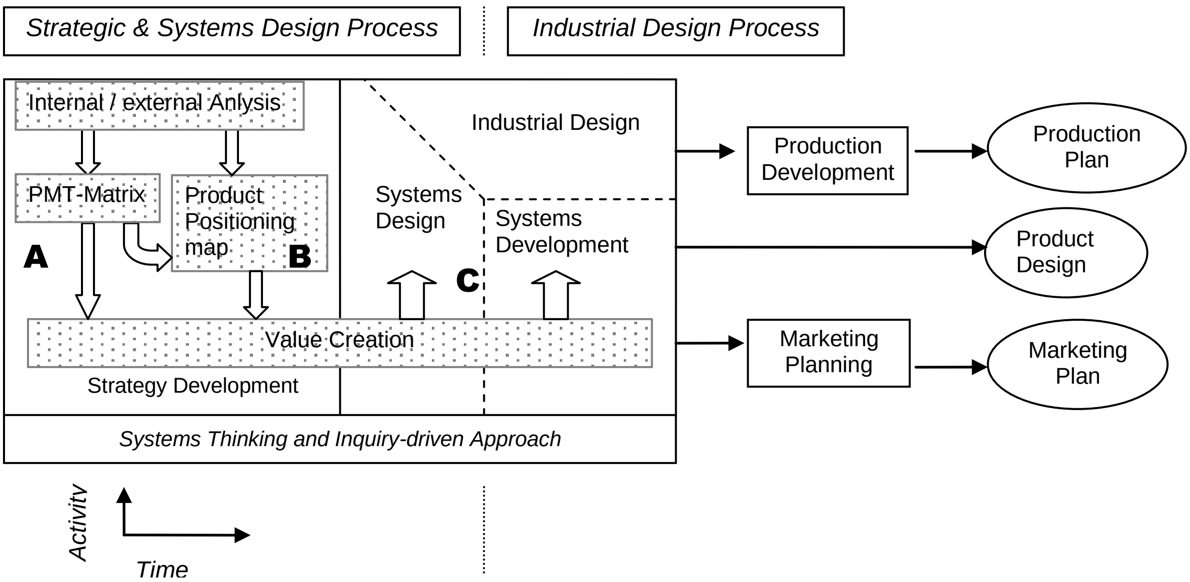

Figure 9: A proposed strategic and systems design process, which is characterised by a systems thinking and inquiry-driven approach

As indicated in Figure 9, a flexible and interconnected strategic and systems design process should be introduced in postgraduate studio projects to allow project initiation to take place at three possible entry levels:

A. Product strategy level, where the initiating company adopts an open attitude and is supportive of radical innovation/diversification. Ansoff's PMT matrix forms the foundation for product planning and goal finding.
B. Design strategy level, where the project assignment has been defined around the second or third quadrant of the PMT matrix ("market development" or "product development," respectively. In this situation, a design strategy will be proposed to maximise a company's value opportunity based on one of the four quadrants of the product positioning map style versus technology.

C. Systems design level, where the assignment has been defined around a set of interconnected entities, comprising people, processes, and technologies.

A Reflection on Design Thinking and Reasoning

Design thinking and reasoning have become more important for designers who are searching for processes, methods, and attitudes to solve ill-defined problems or to discover hidden needs. The subject of "design thinking" has also aroused interest in management discourse. According to Johansson and Woodilla (2009, p. 31), design thinking occurs at the merger of business and design. In relation to how design may contribute to business strategy, Brown (2008) argued that thinking like a designer can transform the way you develop products, services, processes, and even strategy (p. 85). Liedtka (2000) linked strategic thinking to design thinking by arguing that they are both abductive in nature.

With respect to the three different design studio projects described in this paper, processes, methods, attitudes, and collaboration among different stakeholders can be reflected against six models of design reasoning (Lie, 2012). The undergraduate "systems design" project conducted with second-year students advocated a positivistic problem-solving approach towards designing (Simon, 1996), whereby the overarching problem/theme was segmented into subproblems, elements, and functions. The "vertical design studio" project maintains the positivistic and problem-solving approach in terms of design content development, but it introduces a reflective (Schön, 1995) and hermeneutic way of designing, mainly through concepts of mentorship and social learning (Omrod, 1999). The postgraduate fourth-year strategic design project embraces problem-solving, reflective, and participative (Clarke & Stewart, 2003) modes of design thinking and reasoning, reflected against a post-positivistic philosophical worldview. Although it is not possible to obtain a complete knowledge of everything as well as full control of the industrial collaboration, much pre-planning and research activities have taken place in these strategic design projects.

Discussion and Future Research

A deeper analysis of design reports, complemented with interviews with students, has surfaced limitations and opportunities in teaching strategic and systems design. From 2005 onwards, design projects conducted in collaboration with the Norwegian industry from years 2, 3, and 4 of the study programme have demonstrated the usefulness of a systems thinking approach in solving strategic, service, and product design issues. However, a more comprehensive and structured systems design methodology, supported by creativity and analytical tools, should be developed. The criticisms towards teaching students strategic and systems design are outlined below:

- Nature, history, and (short-term) pragmatic attitudes of some companies have favoured incremental innovation above radical innovation.
- Most of the companies have unconsciously influenced the students to focus on the new product/existing market or existing product/new market strategies.
- This has led to a "design strategy" approach towards innovation, where the development of style and/or technology in the design of products and services has been emphasised to create value.
- Although in some cases a radical product idea is "in the making," very aggressive time frames for the projects as well as the lack of experience among students to frame and communicate did not provide a convincing atmosphere for the company to pursue diversification.
- On the contrary, companies that aimed for diversification in their generic growth strategies may not always end up with a complementary "high-valued" design

outcome, as illustrated through the "multifunctional outdoor fireplace" and "load crosser" projects.

- The systems design project implemented in the second and third undergraduate design studios lacked an applicable step-by-step methodology. This created a feeling of uncertainty among students in terms of defining the project scope(s), task clarification and distribution, and teamwork. With respect to project scoping in the transition from group to individual work, students encountered difficulties in determining intermediate boundaries and connectivity within the system concerning overlapping scenarios and products.
- The second-year design students experienced difficulties in combining broad boundaries with concrete consequence analysis. In such a teaching situation, customised supervision was needed to facilitate segmenting the system design process and allocating tasks.

On a final note, trends in the "corporate world" of higher learning and research demand that industrial design students are to be mentally prepared to commute from generic to specialist as well as from abstract to concrete modes of working and vice versa. Comprehensive and complex studio projects should be implemented as platforms, where social and inter-disciplinary learning as well as collaborative practices can develop in line with selected design, themes, processes, and methods.

From a design educational resource perspective, it is recommended to establish a team with the following roles and qualities:

- Faculty inclined towards mentorship and scholarship able to promote learning and inquiry from a theoretical and process perspective.
- Professional designers who can contribute in skills development and share design experiences from practice, supported by design thinking.

In collaborative design projects and research with various stakeholders, students should be exposed to a culture of mentorship and scholarship that leads to an engaged way of learning and working that nurture a shared commitment and motivation for the ethic of inquiry and intellectual rigour to the excitement of speculation, creativity, and discovery. To be more specific for industrial design, structured systems thinking and social learning are to be embodied through project-based learning and master/apprentice relationships.

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