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MIND MAPPING AS A TOOL, AS A PROCESS, AS A PROBLEM/SOLUTION SPACE

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ABSTRACT
This paper discusses the use of mind maps by interdisciplinary teams of students during a collaborative design activity. In the context of a Graduate Diploma program aiming to train specialists in eco-design strategy, we seek to offer pedagogical content, delivery methods, and tools that integrate theory and praxis and help students to co-construct new knowledge. A project-based studio was designed as an introduction to the design process and collaborative design. Eleven students from different disciplinary backgrounds teamed up to work on the project in situations where they continually needed to reflect on their dynamic of collaboration, on the design process, and on their actions. At the end of the studio, students received a questionnaire with 14 open-ended questions about the approach and various tools used during the course. Analysis of the answers shows that students consider collaboratively developed mind maps as an essential cross-disciplinary boundary object useful for broadening the team's horizons, stimulating creativity, structuring thinking process and tackling the complexity of the project. In addition, mind mapping offered a platform for collaborative design: by going through the iterative process of mind mapping students developed a shared view, a common language, a refined understanding of the project, and design criteria which were meaningful and fitted their social, environmental and disciplinary values. Our findings provide evidence that mind mapping can be used to enhance both individual learning, and cross-disciplinary team interactions.

Keywords: Mind mapping, design tool, design process, problem/solution space.

1 INTRODUCTION

In 2015, our institution initiated a new Graduate Diploma program for established engineers (in different areas) and designers (industrial designers, architects, graphic designers) or recent graduates who wish to specialize as "Eco-design strategists". It aims to integrate, in a multidisciplinary teaching environment, the following subjects: engineering for sustainable development, design thinking, prospective design and creativity management. This kind of joint venture that seeks to close the gap between design, engineering, management and social sciences can be seen in many institutions, for example at MFA/MS of Design at Stanford University (USA), at IDMB at Alto University (Finland), Master of Design in Strategic Foresight and Innovation at l'OCAD (Canada), and Institute Without Boundaries (Canada). The program provides students with theoretical and practical knowledge that should enable them to become agents of innovation and transformation in industries by offering more sustainable product and services. The specific objective of the program is mastering a multidisciplinary toolkit to enable graduates to assume new strategic roles in companies such as project management for strategy or responsibility for innovation and development of sustainable products and services. This paper explains the pedagogical bases of the first studio-based activity of the program and discusses the significance of developing mind maps in the collaborative design process of teams of students. Teams used the maps to explore and generate insight (mind mapping as a tool), to develop shared understanding (mind mapping as a process), and to navigate through the complexity of the given project (mind mapping as a problem/solution space).

2 PEDAGOGICAL DESIGN AND CONTEXT

2.1 The program structure and pedagogical approach

The program runs as a one-year full time program, but can also be taken part time to accommodate professionals. It aims at an equal number of participants from two general backgrounds: design and engineering, in order to allow balanced multidisciplinary teams and to facilitate exchanges of knowledge. The curriculum consists of a number of mandatory course and elective courses, two project-based studios, and a final three-month professional internship. The focus of this paper is on the first project-based studio of the program: an introduction to the design process and collaborative design. This studio ran over 5 weeks, one full day a week. Project-based studios are multidisciplinary activities designed for hands-on knowledge acquisition and integration of learning into practice. Students work in teams and collaborate in all aspects of development and communication of real and prospective projects —product and service development, eco-design strategy, and innovation.

2.2 The project-based studio

The instructional design of the first studio was guided by the following question: How to bring a team of experts from diverse domains to explore openly and innovate in an area that is not directly related to their domain? Our answer was to offer pedagogical content, delivery method, and tools that integrate theory and praxis and help students to co-construct new knowledge. The following themes were explored theoretically and put in action: design/designerly thinking, design process models in product and service design, collaborative design, and tools and methods of designing. Students were asked to read two specific articles —on collaboration [1] and on design thinking [2]— and the booklet "The world of the open innovator" [3] which presents an approach called "4i" based on four concepts: *itch, insight, idea* and *impact*. These readings were used as foundations for the development of the project. The importance of both theoretical content and the practical aspects of the course were underlined through the project-based nature of the training. A very short description of this content follows.

2.2.1 Design and design(erly) thinking

Design thinking (DT) is at times referred to as involving creativity, problem-solving, innovation, and strategy [4], but it always motivated by the desire to improve a situation: applying creativity and finding innovative solutions to generate positive social and economic benefits [5], [3]. Today, other experts (i.e. management, strategy) seek insights through design thinking and working with designers. The distinction between the use of the term DT by design thinkers and management professionals is important. Johansson-Sköldberg et al. [2, p123] help clarify the concepts of 'design thinking' and 'designerly thinking'. "[Designerly thinking] refers to the academic construction of the professional designer's practice (practical skills and competence) and theoretical reflections around how to interpret and characterize this non-verbal competence of the designers. Designerly thinking links theory and practice from a design perspective, and is accordingly rooted in the academic field of design." In contrast, they "reserve this term [design thinking] for the discourse where design practice and competence are used beyond the design context…, for and with people without a scholarly background in design, particularly in management." In this characterization, 'design thinking' becomes "a way of describing a designer's methods that is integrated into an academic or practical management discourse." The paradigm used for the studio is that of designerly thinking.

2.2.2 Collaborative design, co-reflective practice and interdisciplinary approaches

With the ever-increasing complexity of design projects, designers need to work collaboratively with other experts to find innovative solutions for complex and ill-defined problems, which are characterized as being "messy" and difficult to define [6], as well as uncertain, unstable, and unique [7]. But when teams of experts are formed, their communications and collaboration remains a critical challenge [8]: their discipline-specific approaches, different mental models, cultural differences, varying aptitudes, abilities and limitations, and lack of common language and understanding [1], [9], [10] may all be potential barriers to efficient interdisciplinary collaboration. In these contexts, individual members often initially experience problems of interaction related to their particular field of expertise and to the particular dynamics of the group—challenges of collaborative social process [11], [12], [13], [14].

Collaborative design, on the other hand, encourages team members to work together to share perspectives on project issues and exchange knowledge to establish definitions and outcomes of the

project. Team members are interdependent and accomplish together what they could not accomplish alone [1]. Creating a common language for collaboration and "co-reflective practice" [15] based on reflection and analysis of actions by design practitioners [7] is essential for understanding the complexity of these situations and moving toward interdisciplinary approaches [15]. Interdisciplinarity requires: (1) crossing traditional boundaries and engaging in the processes, methods, and tools of other disciplines; (2) examining all parts of a problem and interactions among the parts; and (3) developing critical vision, shared commitment, dialogue, and knowledge exchange among disciplines on innovative processes [3], [16]. Thus, design is a social activity [11], [12], and the context of design projects varies according to dynamics of the particular team.

2.2.3 "The world of the open innovator"

In an era in which the world is rapidly changing and our society is undergoing transformation, Valkenburg et al [3] focus on innovation as a necessary response. They explain the interdisciplinary character of the innovation process and the importance of combining different methods and tools from various (design) disciplines. The authors present guiding principles for the development of core skills and abilities that designers need to function as innovators. The 4i's of innovation – *itch, insight, idea,* and *impact* – are presented. Further explanation of the approach is beyond the scope of this paper, but it was explained in detail and put into practice by our multidisciplinary student teams.

In the fall of 2015, eleven students from different disciplinary backgrounds participated: architecture, industrial design, finance and environmental studies. Through theoretical presentations, methodological tools, selected literature, team dialogues, and a collaborative design project —'food market in 2025'— we aimed at creating a learning environment where students could focus on mentioned topics and apply them to the design of products and services. Students formed four teams, with one industrial designer in each team. The activity put students in situations where they continually needed to reflect on their dynamic of collaboration, on the design process, and on their actions. In addition to team discussions and the individual reflection-in-action during the design process, all students participated in discussions at the end of each day, which encouraged them to talk about what went well and produced results and what created barriers and was problematic for the project. At the end of the five days, students received a questionnaire with 14 open-ended questions designed to encourage reflection-on-action. By answering the questions, students deepened their thoughts not only about the tools used and collaboration, but also about design thinking. It was thus simultaneously a feedback tool and an important pedagogical strategy. Mind mapping, one of the tools proposed, emerged as an important element for the students.

3 METHOD

While we saw students exploring mind mapping during the studio, the full significance of this approach used collaboratively by small teams of students was revealed through the questionnaire. We compiled students' answers to the various questions in a table. A search for the words "mind" and "carte" (map in French) enabled us to identify places throughout the questionnaire where students referred to mind maps. We then analysed each statement and identified recurrent themes, in the tradition of grounded theory [17]. A closer analysis of students' answers suggests that collaborative mind maps were used in three different ways during the project-based studio. Our classification of the use of mind maps as tool, process or space thus emerged from our empirical data. The following subsections illustrate these various uses drawing on students' comments, all of which have been translated from French.

4 MIND MAPPING

4.1 Mapping: what is it and what are the educational impacts of mapping?

Mind mapping involves the graphical representation and visualization of connections between several ideas or pieces of information. The idea of representing complex information visually is old but the use of mapping has gained in popularity since its use in information and computer technology [18]. Maps are considered "tools" and are usually constructed to illustrate understanding of a process, a complex structure or a system. The terms "concept maps" and "mind maps" are often used interchangeably for these visualizations. There is, however, a distinction between the two terms: concept maps are arranged hierarchically with the main/most general idea at the top. They "show the specific label (usually a word or two) for one concept in a node or box, with lines showing linking words that create a meaningful statement" [18], [19]. Mind maps are non-linear general interpretations that "comprise a network of

connected and related concepts […] any idea can be connected to any other" [20]; their purpose is to stimulate associations among ideas, and their making requires free-form and spontaneous thinking. A mind map is loosely structured around a main idea that is positioned at the centre and grows outward organically in all directions [18], [20].
For our project-based studio, we explained how mind mapping is developed and suggested its use as a "tool" for exploration of the project in its early stage. As explained by Davies, we knew the potential of the tool and its impacts on student learning: (1) as a student works on representing a complex set of relationships visually, s/he is "more likely to understand those relationships, remember them, and be able to analyse their component parts. This, in turn, promotes 'deep' and not 'surface' approaches to learning." (2) For some students following maps is easier than interpreting verbal or written descriptions. (3) The work involved in creating maps "requires more active engagement on the part of the learner, and this too leads to greater learning" [18, p280]. However, maps were used not only as a tool for individual student learning, but also for knowledge creation amongst the multidisciplinary teams. As the project progressed, we observed a variety of situations where students collaboratively mobilized mind mapping: to manipulate complex relations between project elements, try to understand each other's viewpoints, and analyse problems related to the project and potential solutions.

4.2 Mind mapping as a tool

The most instrumental use of the mind maps was as a tool. Different groups used the maps to explore existing situations and conditions, with the goal of understanding existing relationships and generating insight. For example, *"One of our mind maps displayed what we knew about buying food in general by answering the questions who, what, where, when, why and how."* This group subsequently extended the scope of exploration to include buying food in 2025, and redefined the focus of its project (reframing). They decided to *"concentrate on a question that we had identified through mini-interviews with people around us: efficient use of time to choose and buy one's food… Then we made another map to explore the subject of time efficiency in this context."*
One of the most important uses of the mind maps was to generate ideas, either alone or collaboratively. Setting out all the ideas on a single map was instrumental for some to clarify their thinking and structure their individual understanding as a preliminary to collaborating with other team members. For others, it was more useful as a sort of idea generation, brainstorming tool. *"Without a doubt, making the map allowed us to approach the situation differently, because this tool makes you go outside the frame of established ideas to see everything without concentrating on one particular aspect. It lets you make links between ideas."*
The maps offered a view of the situation that everyone could see and orient to as a group: *"The mind maps we made together helped us to think, to see the supermarket from all different angles, but especially to understand visually the different things that we would need to consider."* The maps also allowed them to more easily see interrelationships between the various elements. *"We spent a lot more time on understanding all the flows, relationships and processes around buying food. Our simplified mind map condenses hours of hard work to identify and understand the actors, the processes and all the components of the system. It's after that intense stage that we realized the disturbing complexity of the food industry."* This understanding of the complexity and interrelationships was facilitated by the visual nature of the maps. Finally, the maps as a finished product acted as a synthesis of past work, a sort of visual memory aid.

4.3 Mind mapping as a process

The act of collaboratively producing mind maps and of examining them together was sometimes as important as the ideas or concepts they contained. The maps contributed to the dynamic of discussions between team members about their perceptions and priorities, which enabled the teams to develop shared understandings and common ground and to more easily align the project's direction. Many of the students highlighted the importance of this process. *"The different mind maps that we developed together facilitated our cooperation because they help us align ourselves around a single idea."* Another student explained in more detail: *"The mind map was important for agreeing on a direction for the project without misunderstandings or misinterpretations by team members. The process of using the mind map to define the project from every conceivable angle ensures that understandings and related concepts are the same for everyone. What is more, it can be tempting to manipulate the mind map when you do it alone (especially when you already have an idea for the project), but when you make a mind*

map as a team it eliminates a lot of this bias because the ideas are generated from several people and the ideas of one person can enrich that of someone else and vice versa. So I think that the map allowed us to understand the relationships between the elements involved in consumption in 2025, to see the range of possibilities and then to agree on how to restrict the frame, with logical reasoning that explains why this group was targeted." Not only did the maps facilitate building common ground, they also resulted in a richer exploration and more considered choices. Finally, one student saw the mind maps as a way of equalizing the playing field between team members who express themselves in different ways: *"The disorganized way of getting ideas onto the map encourages throwing out new ideas, and leadership by those who are more vocal."*

4.4 The Mind map as a problem/solution space

Finally, the mind maps served as spaces within which exchanges took place. Some participants noted that they enabled participants to get to know each other, both personally and professionally. *"Mapping allows you to break the ice in a fun way by making a window into coworkers' internal worlds and encouraging the creation of links that will be useful during the creative process."* A number of students highlighted the possibility that the mind maps afforded to share information and expertise —a sort of shared repository— something all the more crucial in an interdisciplinary context. *"The mind map allowed us to quickly open everyone's libraries of knowledge, experience and ideas, whether they turn out to be relevant or not. Not only did the teams get to know each other, they also simultaneously and rapidly started to communicate with one another and assume responsibility and engagement in collective reflection. The idea wasn't to find a single project goal but to extend the roots of knowledge, to make connections and to develop a much greater understanding of the food system… Our team was much better at assimilating the importance of keeping concepts open, interlinkable and visually exploded. Boundaries don't really make any sense when you're trying to enlarge your collective thinking."* In this sense, the maps acted as a space within which to find or negotiate common ground. *"I think that making these maps allowed us to define a common subject, especially in a team whose members didn't know each other well and who come from completely different fields. These maps didn't really lead our team to re-question the subject as it was given at the start but rather to define all the aspects (and to define them thoroughly) and to see the relationships between them, and that gave us an appreciation of the breadth of the subject. Because the maps helped us to define our subject, they also let us share our understanding of it, since they brought together everyone's ideas. So we were able to continue on the same wavelength."*

Importantly, the mind maps operate as spaces in which problem and solution evolve together. As participants worked on exploring existing situations and defining the future desired solutions, they moved back and forth between both problem and solution spaces. According to [21, p1], problems and solutions evolve together in a non-linear iterative manner "during *conceptual design*, designers play around with ideas to get more understanding about the problem rather than focus on just finding a solution." By considering change in the definition of a problem as a response to a search for its solution, the team found best "fits" between design problems and design solutions. A participant wrote: *"The mind maps we developed together helped us to think, to see the supermarket from all different angles… The process also led us to see the shortcomings of the system and to redefine our 'itch'."* This is in line with the idea of Dorst & Cross [22] that design is a process that develops and refines a problem along with ideas for a solution in parallel—in other words, a back-and-forth iteration between two "spaces" of problem and solution.

5 CONCLUSION

Analysis shows that students consider collaboratively developed mind maps as an essential cross-disciplinary boundary object useful for broadening the team's horizons, stimulating creativity, structuring thinking and tackling project complexity. In addition, mind mapping offered a platform for collaborative design: by going through the iterative process of mind mapping students developed a shared view, a common language, a refined understanding of the project, and design criteria that were meaningful and fitted their social, environmental and disciplinary values. Students' comments suggest that the process of mind mapping contributed to widening students' horizons at the early stages of the project, and to framing the project later in the process leading to generation of solutions.

As will have become evident in the students' words, it is sometimes difficult to distinguish clearly between process and space, or between tool and process. We do not propose our categories as being

mutually exclusive. Nonetheless, we find them interesting in thinking about HOW mind maps are mobilized, particularly since much of the literature tends to frame them as an instrument or a technique. Our findings show that, while they may be approached as tools on the surface, there is in fact a lot more going on in how they participate in broadening the team's horizons, stimulating creativity, structuring thinking processes and approaching project complexity.

The importance of an attitude of collaboration and inter/cross-disciplinarity in the "real" world of design and engineering is clear. In design education, at the undergraduate level, programs rarely offer training that includes tools and methods for multi-disciplinary collaboration. This case study provides evidence that mind mapping can be used to enhance not only individual learning, but also the cross-disciplinary interactions of teams.

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