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TEACHING DESIGN THINKING: EVOLUTION OF A TEACHING COLLABORATION ACROSS DISCIPLINARY, ACADEMIC AND CULTURAL BOUNDARIES

Carolina GILL[1] **and Merce GRAELL**[2]
[1]The Ohio State University
[2]IED Barcelona, Designit

ABSTRACT
This paper's aim is to describe the collaborative efforts of two designers/educators who have been teaching the application of mindsets and methodologies associated with design thinking during the last eleven years. This journey started with a request to one of the authors to co-teach a course in the engineering training program at NASA in 2004 and has taken both authors through multiple iterations of courses in academic and professional environments. Several dimensions of the design-thinking curriculum are then detailed, explaining the evolution of the courses as the processes, methodologies and tools become increasingly recognized as useful tools to address complex challenges in which analytical approaches offer limited results. Participation of multiple disciplines, contexts and delivery methods are also discussed.

Keywords: Design Thinking, Design Education, Teaching Collaboration.

1 INTRODUCTION

Design thinking has been defined as a fundamental premise to approach solving a problem in an innovative way. It borrows tools, methods and mindsets from the disciplines of design to foster innovation in multiple sectors and has gained wide recognition in the business environment in the last ten years. [1]. Design thinking offers multiple methods and tools that allow people to reframe the way in which they understand a problem and to develop ideas from a variety of perspectives. The number of tools and techniques available is daunting but they can be summarized under three specific characteristics that come directly from the disciplines of design: 1. a human centred approach that *can identify an aspect of human behaviour and convert it into a benefit for a user and a value for a business* [1], 2. the use of models and visualizations to explore and communicate complex challenges and 3. the application of iterative cycles of prototyping, testing, and refinement [2]. Tolerance for ambiguity and failure are also among the most important traits that designers use to bring ideas to life but these two traits can only be acquired over time and with the type of support that is provided through educational environments or supportive corporate cultures.

As designers, design thinking is embedded in our practice, and as educators, the methods used in the classroom to teach how to "innovate" are based on a constructivist approach [3] where discovery learning takes place *"through the active involvement with concepts and principles, where teachers encourage students to have experiences and conduct experiments that permit them to discover principles for themselves"* [4]. In design, the discovery process is conducted through the act of 'making', building and iterating. The goal is to explore ideas through experimentation, trial and error. Successful application of design thinking tools and techniques requires proficiency in the iterative process of learning by discovering [4]. In an educational setting, this is relatively easy to accomplish whereas in a corporate environment where the stakes are high and time is short, these attributes are a major challenge to overcome in the implementation of design thinking.

This paper describes the work of two designers/educators who have been teaching design thinking in domains in and outside design for the last eleven years. This journey started with a request to author ONE (Gill) to co-teach a course in the engineering training program at NASA in 2004. Following this course, Gill (product designer) was asked to develop and supervise a course for the design minor in the

university to be delivered by an experienced graduate teaching associate, author TWO (Graell). The development and implementation of this course fostered a lasting professional collaboration between the two authors who decided to teach and to practice what is now known as design thinking and apply the tools and techniques in multiple fields, professionally and in academia in the US and in Spain. In retrospect, each course developed by the authors shared the same **teaching methods** and delivered the same **design thinking tools and techniques** with changes in content and format due to the varying audiences and contexts (from highly specialized scientists (NASA), managers and experienced practitioners (Istituto Europeo di Design) to first and second year university students (OSU).

The **teaching methods** were based primarily on a student–centred approach. The delivery of the content was through direct instruction (lectures), inquiry-based learning (hands-on exercises) and cooperative learning (emphasis on group work) [3]. The teaching styles used were instructors as experts and as facilitators [4] and the degree in which these styles were emphasized in the classroom changed based on the audience's professional experience and disciplinary background.

The course format ranged from a three-day workshop (NASA) to a 10-week course (university minor course). All three courses included in-class hands-on exercises that allowed exploration of different tools and techniques that were ultimately applied to an open problem based scenario. The problem based learning (PBL) approach *"provides students with greater flexibility in developing solution strategies, and it better mimics the type of problems students will encounter outside the classroom"* [3]. The closed problem-based learning approach on the other hand, is more familiar to audiences outside design because they are easier to develop and manage but these types of scenarios do not support real innovation due to the fact that you need to know what the correct answer is in order to guide the students through the process. This implies that the instructor is an expert in the *content*. In design thinking however, the instructor is an expert on the *process* and the scenario is used as conduit to discover how the "process" can it lead to innovation. The level of complexity and the scope of the problem was dictated by the audience's needs. In each of the courses, there was a significant amount of effort invested in identifying and framing the appropriate scenario that could support the learning through discovery process in a context relatable to the audience.

The design thinking tools and techniques used were visualizations and models for exploring complex problems. Physical exploratory models, diagrams, mind maps and sketches were used in both the problem space and the solution space of the exercises in the courses as well as in the process of addressing the problem in the scenarios given. *Visualizations aid in sense-making and cognitive processing of complex information. It accomplishes this through framing ambiguous states, bringing order to complexity, making sense out of seemingly unrelated things, and finding insights that are buried in data* [5]. Additionally, visualizations operate as instruments for thinking in analysis, synthesis, and insight generation [5], individually and in group settings. Visual models allow individuals and groups to discover relationships and meanings, to collectively understand what the problem is, deconstruct it, reframe it, explore, develop and communicate what the solution could be.

The additional component of design thinking used was the human centred approach to addressing the problem scenario. The goal of placing the user at the centre of the inquiry is for the designer or team to develop empathy and a deep understanding of the unmet needs (physical and emotional). This is accomplished by a variety of methods borrowed from psychology and the social sciences. According to IDEO, *"the Human Centred Design process begins by examining the needs, dreams, and behaviours of the people we want to affect with our solutions. We seek to listen to and understand what they want and what they need"*. This approach challenges the learner to consider multiple perspectives that go beyond their understanding of the problem and their idea of what is needed or desired. Currently, in most "design thinking" courses, the human centred component is at the core of the learning outcomes. In our courses its role varied in importance, it was primarily driven by the scenario and the context of the course.

2 NASA "IDEA" COURSE 2004-2006

In the summer of 2004, Gill was approached by professor Blaine Lilly in the Department of Mechanical Engineering at The Ohio State University requesting feedback and participation in a course he had developed for the NASA Engineering Training program NET. The course was called Innovative Design Engineering and Applications, known by the acronym, IDEA. Previous to this effort, the engineering professor had developed and taught a manufacturing course for the NET program and his experience led him to believe that NASA engineers, managers, and technicians would

benefit from exposure to some of the concepts in innovative product design that were in current use in industry [6]. Gill attended the course at Marshall Space Flight Centre as an observer. She identified specific opportunities for improvement that required some reorganization of the material and additional emphasis on the design process based on two distinct phases: problem definition and problem solution. The redesigned course was subsequently offered by Gill and the engineering professor at six NASA centres from 2004 to 2006.

2.1 Design Thinking Components

At the time, the goal of the course was to provide an introduction to tools and techniques that could help NASA participants become more innovative thinkers on the job. Although the in–class projects focused on hardware, the goal for the tools and techniques was applicability to almost any situation, no matter what the specific task, from hardware design to project management to system design. In 2004 the term "design thinking" was not widely recognized in either business or engineering contexts. In retrospect, both instructors (Gill and Lilly) intuitively developed the course based on principles now widely recognized as design thinking.

2.1.1 Teaching approach

The course was structured as a three-day workshop. The delivery of the content was through lectures, hands-on team exercises and a problem based scenario. The teaching styles used were instructors as experts during selected lectures and instructors as facilitators throughout the scenario exercise. One reason the lectures were limited to very specific content was nature of the audience. The participants included highly specialized scientists and engineers as well as upper level managers. The instructors (Gill and Lilly), didn't posses content knowledge in the areas of space exploration so the strategy was to lecture about innovation from the instructors' expertise (industrial design processes and mechanical engineering in the context of manufacturing industries), and to use the scenario to apply the ideation and innovation methods to a space exploration mission. The instructors believed that through this strategy, the necessary connection to NASA would happen as a matter of course. To make the exercise more relevant it was decided that an unmanned Mars sample return mission offered a rich design problem and since such mission was projected to occur in the 2013-2022 time-frame. The project provided two levels of challenge, one at the system level and the other at the product level. The use of this scenario was successful in engaging participants from different NASA centres and backgrounds. It provided them with a real future situation that called for an innovative approach where the need for new tools and methods was clear. This decision however, implied the sacrifice of the "human centred" component within the scenario.

2.1.2 Exploration through visualizations and prototyping (iterative process)

Gill and Lilly utilized visualizations to explore the complexity of the problem space and solution space for the design of the mission architecture and for the design of the sample container. The NASA engineers were at first resistant to the idea of using mind maps and other visual brainstorming techniques such as storyboarding, but by the end of the course they began to see their usefulness at different steps during concept generation. Participants who bought into our approach came to see the mission maps as cognitive tools, which they then referred to later when developing quick prototypes to describe future scenarios and when designing the actual components. The course participants generated low resolution prototypes to explore and describe both a "sample container" and also to use the physical materials like Legos, as "props" for "storytelling" to explore and describe the mission architecture. The intent was to persuade the participants of the efficacy of building "quick and dirty" models early in the design process in order to understand, formulate, visualize and communicate concepts collectively.

2.2 Insights

The IDEA course included several components beyond design thinking such as the House of Quality, systems functions and systems architecture. With the implementation of the scenario and learning by discovering approach, participants were able to work in multidisciplinary teams practicing visualization techniques that combined both industrial design ideation methods such as mind-maps with engineering methods such as functional decomposition diagrams. The unmanned mission scenario presented the challenge of teaching design thinking without the human centred component

but the outcomes were successful in terms of introducing the NASA participants to new ways of visualizing, framing and communicating ideas in multidisciplinary group settings. Gill recognized the need to introduce the subject of human centred design to the participants and developed a stand alone lecture about usability, but the absence of a human–centred problem in the scenario did not keep the authors from teaching design thinking. The use of quick prototypes and visualizations proved to be successful in terms of meeting our course goals of introducing the audience to tools and techniques that could assist them in becoming innovative thinkers on the job.

3 DESIGN FOR NON-DESIGNERS COURSE 2006-2009

In 2006, Gill was charged to design and develop a course for a design minor in their University. The minor was initially conceived as an opportunity to generate more revenue for the department and the need to serve the many students including those who were not accepted in the selective design majors in the department. The minor gave the students an introduction to the professional design disciplines and a basic level of experience with design skills and tools (drawing, typography, 2D software.). The goals for professor Gill was to bring the "thinking" portion of the design process to the students, to develop connections between design processes and different disciplines and to identify strategies from design that could be useful for individuals in any discipline within the university. Gill enlisted the assistance of an experienced visual communication design graduate teaching associate (Merce Graell). Graell had extensive experience working in interdisciplinary settings and this course represented an ideal challenge to leverage her disciplinary knowledge and professional experience to teach design from a unique perspective to a diverse audience. Together, the authors selected key elements from the disciplines of Industrial Design, Visual Communication Design and the lessons learned by Gill in the NASA experience, and designed a "design thinking" course.

3.1 Design Thinking Components

3.1.1 Teaching approach

The course was structured as a 10-week studio course. Graell delivered the content through lectures, hands-on team exercises and short problem–based scenarios. The teaching styles used were instructor as expert during lectures and instructor as facilitator throughout the scenario exercises. The participants were students in their first and second year in engineering, business, art and sciences disciplines. The scenarios used in the course involved low complexity challenges such as the redesign of a nutcracker or a container opener. The second exercise was a problem based scenario of their choosing that required for them to conceptually apply the design process to their disciplinary field (solution space). This scenario was developed to challenge students to translate the "product design thinking process" to a non–product problem that related to their individual disciplines.

3.1.2 Human centred approach

The human centred approach was introduced in this course through several short exercises that included task analysis, contextual observations and interviews. The information gathered allowed students to generate empathy for users and identify opportunities for innovation of a hand held tool (in the case of the first scenario) and innovation in terms of processes (in the case of the second scenario).

3.1.3 Exploration through visualizations and prototyping (iterative process)

Learning through discovery was accomplished by applying the tools and techniques learned to the scenarios. For the first scenario, students developed visualizations of the problem space and the solutions space as well as physical mock-ups to explore, generate and evaluate ideas individually and collectively. Multiple ideas and multiple iterations were required. For the second scenario mind–maps allowed students to identify, frame and communicate design opportunities in their own discipline.

3.2 Insights

Students came to this class with a limited understanding of design and with the preconceived notion that they were going to gain only practical visual communication skills. The design thinking components learned allowed students to recognize how design could be used as a strategy that could be utilized to become more innovative in their disciplines. This concept was relatively new in the

academic environment at the time. Business schools were just beginning recognize that the use of analytical thinking exclusively would only produce gradual improvements and not innovative answers.

4 DESIGN THINKING AND CO-CREATION COURSE, 2013–PRESENT

Merce Graell moved to Spain in the early fall of 2009. Design thinking was not a term commonly known in Spanish industry or the design community at that time. There were however, a handful of design innovation consultancy firms that offered a human-centred approach. Graell joined one of those companies and also began teaching design for non-designers at Design schools, based on the experience as a teaching associate during her graduate studies. Design for innovation within this consultancy followed a similar path as it did in academia, where learning by discovering process was at the centre of the inquiry, where practitioners were in continuous need to adapt and develop new tools and techniques to deal with the uncertainty of finding solutions to increasingly complex problems. This process was very evident in Spain where the challenging economic environment heightened interest in innovation and in entrepreneurship training. Product design, engineering and architecture, among others, were fields facing a crisis and many of these professionals saw in design management and design for innovation an opportunity for a redefining their career paths. At the same time, design thinking was gaining relevance in MBA programs worldwide. The need for design thinking skills grew as did the need for training. Graell experienced the rapid change of design in her consultancy; bridging the everyday practice with the classroom helped her identify elements of design thinking that led to the Design Thinking & Co-Creation Summer course at a private institution. Graell invited Gill to participate in the development and delivery of the course.

4.1 Design Thinking Components

4.1.1Teaching approach

The course is structured as a 4-week intensive studio course. The delivery of the content is through an industry sponsored problem-based scenario, lectures, workshops and hands-on team exercises. The teaching styles used are instructors as experts during several lectures and hands on exercises and instructors as facilitators throughout the scenario exercise. One difference from the previous two courses is that this experience involves a number of practitioners that teach individual modules in support of different design thinking and service design components. The rationale behind this strategy is that practitioners share examples of design thinking applied in their industry translating the theory into practice. The participants are international students from various backgrounds and professional experience who seek tangible examples to bring back to their own contexts. The scenarios are carefully crafted to allow students to interact with users and stakeholders. The scenarios typically include complex challenges such as exploring design opportunities around mobility in the city of Barcelona. The solutions are high-level concepts that are the product of learning through discovery, generative prototyping exercises and interdisciplinary teamwork. Graell coordinates the team of instructors and facilitates participatory sessions.

4.1.2 Human centred approach

The human centred approach is a significant portion of the course and is a major driver and constraint for the scenario. The sponsors are carefully selected based on their ability to provide the context for the scenario and facilitate interactions with different stakeholders. The first two weeks of the course focus on understanding and researching the context and the user experience. Course participants also interact with users and stakeholders in validating concepts.

4.1.3 Exploration through visualizations and prototyping (iterative process)

Visualizations models are used throughout the course as aids for collectively explore and frame the design problem and as aids to develop and propose solutions. Some of the visualizations used are opportunity maps, mind-maps, business model canvas, empathy maps, and customer journeys [7]. Low-resolution prototypes and props were used to engage different stakeholders in both the problem and the solution space. Tools and methods such as Velcro modelling, collages and Legos allow teams to collaborate with stakeholders in generating, evaluating and communicating ideas.

4.2 Insights

In terms of successes, the lectures and exercises given in combination with the human centred approach have allowed course participants to frame design opportunities in an industry context, actively collaborate with users and stakeholders, explore and propose design solutions and communicate key offerings. The individual exercises and examples presented by expert practitioners are valuable to the students but not clearly applicable to the scenario. Using multiple teaching practitioners as "experts" is an effective way to deliver content and translate theory into practice, but using the same practitioners to "facilitate" the learning through discovery process that is supported by the scenario has not been as productive. Overall the learning outcomes are met but there is still an opportunity to improve the outcomes and the flow of the course if the expectation of addressing the scenario is removed from the multiple instructors and is led by only one "facilitator". The next iteration of the course will reflect this change and we hope to be able to determine the best structure.

5 CONCLUSIONS

The authors have taught Design Thinking in different contexts, to different audiences and through a variety of teaching strategies and curricular structures. The courses have consistent design thinking components that have been positively received by the students. The problem–based learning approach, the teaching strategy of instructors as experts and/or facilitators, the use of quick prototypes and visualizations have proved to be successful in terms of introducing multiple audiences to tools and techniques that could assist them in becoming innovative thinkers on their context.

In terms of long term applicability of the methods introduced, tolerance for ambiguity and learning through trial and error are still major hurdles for most of the students, especially when trying to apply what they have learned in their own professional context. In an organization like NASA, the combination of extremely high risk missions and the certainty that failure will be both visible and expensive has naturally led to an extremely risk–averse engineering culture within the agency. Participants of the IDEA course expressed satisfaction with the visual strategies introduced and understood their possibilities and limitations within their organization. For undergraduate students in the university, the methods introduced in the course allowed them to understand possibilities for innovation in framing problems and in "discovering" through iterating concepts. Experiencing the progress made through prototyping confirmed for them the value of the process.

The students in the IED course appreciate the new perspective brought by the material and exercises presented in the course. They indicate interest in applying a human centred approach to their professional challenges and utilize visual models and prototyping to generate better ideas in collaborative settings. Some of the students also have expressed concern about the difficulty in implementing these methods at a strategic level in their companies.

There has been an increased interest in design thinking through the years. The visual models, tools and methods for design thinking have also multiplied since the IDEA course was first taught, but practical implementation at work remains challenging. The authors recognize the need to redesign the course using the same design thinking principles taught. Perhaps by prioritizing the stakeholders' needs and leveraging from the lessons learned from the multiple iterations of the courses, the authors can "discover" more effective teaching methods and more relevant design thinking strategies.

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