Engineering Design Entrepreneurship and Innovation: Transdisciplinary Teaching and Learning in a Global Context

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Abstract. This paper introduces an innovation course has been taught at Stanford University since 1967. In its 52-year-long journey and iterations, both teachers and students learn to dance with ambiguity, collaborate in teams, build to think, and make ideas real. They embrace design thinking and experience the entrepreneurial culture of Silicon Valley in this year-long course. Student teams work on innovation challenges proposed by corporate partners for eight months and deliver functional proof-of-concept prototypes along with in-depth documentation that not only capture the essence of designs but the learnings that led to the ideas. In recent years, several institutions worldwide have adopted this innovative way of problem-based learning with global collaboration.

Keywords: Design thinking · Transdisciplinary teaching and learning · User experience · Global context

1 Introduction

Engineering Design Entrepreneurship and Innovation is a year-long project-based design engineering course that began at Stanford University and has been operating continuously for over forty years [2, 9]. Created to provide engineering students with real engineering challenges, the course has evolved over the ages to meet the changing demands of the labor market. Over its lifetime, the course has shifted from practical engineering experience to design of mechatronic systems to design innovation and global collaboration [10]. Meanwhile, it has gone beyond the hedges of Stanford University and is now being taught in four different continents and eight different countries. The course is now focused on teaching students the innovation methods and processes required for designers, engineers, and project managers of the future. The course is well known for taking ideas from concept to fully functional proof-of-concept prototypes suitable for engineering and customer evaluation. Diversity has been demonstrated to correlate highly with design team innovation, and it is one of the core variables that Stanford's Center for Design Research finds valuable.

A. Marcus and E. Rosenzweig (Eds.): HCII 2020, LNCS 12202, pp. 451–460, 2020.
https://doi.org/10.1007/978-3-030-49757-6_33

2 Teaching and Learning Settings

Offered by the Mechanical Engineering Design Group, its global network of faculty and students come from some of the most distinguished design programs around the world. Student teams work on innovation challenges proposed by corporate partners for nine months (see Fig. 1). Company involvement provides the reality it is important for teams to improve their innovation abilities. In the end, teams deliver functional proof-of-concept prototypes along with in-depth documentation that not only captures the essence of designs but the learnings that led to the ideas [9, 16]. Furthermore, every team collaborates with another team from a foreign university for the duration of the project. The partnership adds diversity to the project teams and students are allowed to experience true global collaboration, a skill required in this highly globalized world. Project results are always copyrighted, often patented, and commonly implemented by the corporate partner.

Fig. 1. A typical course calendar

2.1 A Global Context

On every project, student teams at Stanford collaborate with another team from a foreign university. The diversity not only adds various skillsets but also different cultural perspectives on the design challenge that increases the chances of breakthrough innovation [19]. Diversity has been demonstrated to correlate highly with design team innovation, and it is one of the core variables that Stanford's Center for Design Research finds valuable. For students, the experience of working with different cultures is necessary in this globalized world as most designers, engineers, and project managers operate in distributed work teams.

2.2 Extensive Support Crew

The course is instructed by professors and aided by Consulting Professor and three to four Masters and Ph.D. students as teaching assistants. Furthermore, each team is assigned an engineering-culture coach volunteers who typically have taken this course and have between five and thirty years of professional experience with vast networks in the Bay Area and the global technical community. Every team is provided a dedicated project space in a design loft, which also houses a rapid prototyping machine shop and a Polycom video conferencing system. The full Stanford Machine Shop, the Product Realization Laboratory, is also available to the students along with various other on-campus resources. Students at the foreign partner universities also have access to similar personnel and infrastructure resources. The support crew is just as diverse as the students offering multiple points-of-view on engineering, design, and project management. The crew is passionate about letting the students design and innovate and goes beyond professorial duty to assure that students are given the best possible environment to work in.

2.3 Transdisciplinary Student Teams

Students come from different backgrounds and disciplines including various forms of engineering, industrial design, business, and economics [5, 18]. The diversity assures that teams take multiple perspectives on any given challenge, increasing the probability of breakthrough discoveries and innovation. All students have core competencies in their respective fields, and many have prior design project experience in academia or industry. Students in this course take on real-world design challenges brought forth by corporate partners. Unlike many other academic engineering projects, which require students to optimize one variable, students must design a complete system while being mindful of not only the primary function but also the usability, desirability, and societal implications. Throughout one academic year, student teams prototype and test many of their design concepts and in the end create a full proof-of-concept system that demonstrates their ideas. This course is open to graduate students or coterminal students with some engineering and/or design background. The support crew appreciates diversity and encourages students from all departments to apply for the course.

2.4 Corporate Partners

Companies, small and large, from all industries are invited to join and bring forward their innovation challenges. The support crew consults with corporate liaisons to define the right scope and scale of a project. Liaisons are recommended to keep in regular contact with the design teams to provide feedback [10]. The project spots are reserved on a first-come, first-serve basis. Teams are assigned industry coaches who are typically alumni of the course and working in a field related to the project topic. They provide a great resource to the student teams who can access a wealth of knowledge through the coaches and their social network. Coaches often meet with their teams once a week.

2.5 Diversity Drives Innovation

Students, faculty, and industry coaches from around the world come together to form the course community. While many of them come from different backgrounds, expertise, and industries, they all share the desire to design and help each other learn [3, 15]. Some have been part of the course for decades continuing the core design values, and some joined just this year bringing fresh ideas and new tools to the course. The team is always evolving to adapt to the ever-changing world we live in.

3 Methodology

Design thinking or the design innovation methodology pioneered by IDEO and engrained in the DNA of the Stanford design community is a hot topic in the business, product design, and applied research fields [4, 5, 14, 17]. The best way to learn the tools and processes is to experience it through a real-world design innovation challenges. Through the projects, students go through an intense and iterative process of need-finding, ideation, and rapid prototyping to create and develop new concepts [20]. See Fig. 2 for an impression.

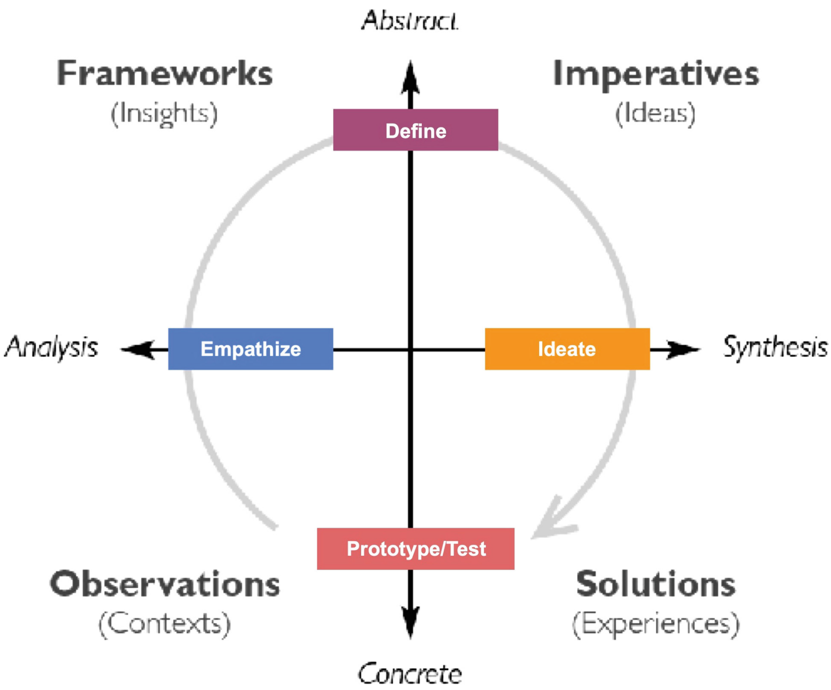

Fig. 2. The classical way of thinking and doing in this course

3.1 Design Thinking

Design thinking as a human-centered innovation approach has become more and more widespread during the past years (see Fig. 3). An increasing number of people and institutions have experienced its innovative power [6, 13]. The method of design thinking works when applied with diligence and insight. It aims to understand the innovation process of design thinking and the people behind it, and it focuses on what people are doing and thinking when engaged in creative engineering innovation and how their innovation work can be supported. The huge demand for transdisciplinary teaching and learning, and the rapid development of information technology have laid a solid foundation for innovations in multiple domains, i.e., education, healthcare, and personal mobility.

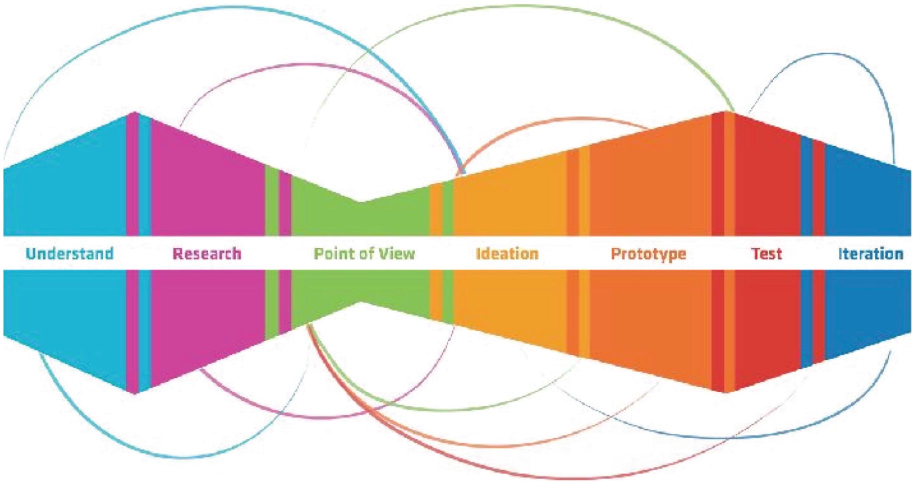

Fig. 3. The stanford design thinking model

3.2 Stanford Design Innovation Process

Through the course of the project, students learn, apply, and experience the Stanford Design Innovation Process (see Fig. 4) and many of its toolsets. Teams observe and interview users to better understand their needs, benchmark existing technologies, and products to identify the design opportunities, extensively brainstorm to discover the obvious, crazy, and novel ideas, and iteratively prototype to quickly test their ideas and get a better understanding of their designs. The result is a refined design concept backed with key insights [7]. With the social development and economic growth, the world keeps promoting innovation design, transdisciplinary subjects have become popular.

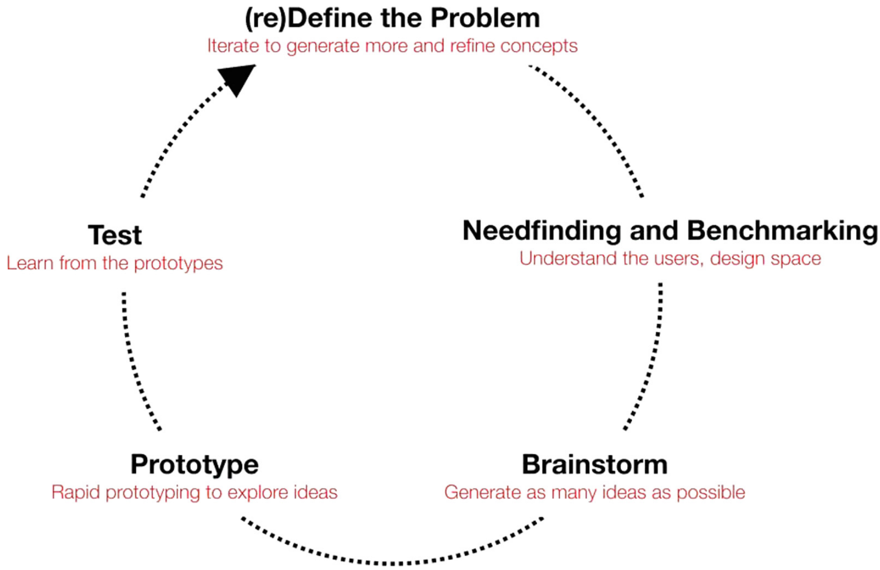

Fig. 4. The Stanford Design Innovation Process

3.3 Experiential Prototyping

Prototyping is at the very heart of the design process because it is the most effective way to transform ideas into tangible products [1, 8, 11]. Students create numerous prototypes to articulate their vision and test their design assumptions. Through iterative prototyping in many ways, broad problem statements are refined into concrete concepts that are eventually incorporated into a final, fully functional prototype [12].

4 Case Studies

Three case studies are described and showed below.

4.1 Vamo

This project is a collaboration between Stanford University, Hasso Plattner Institute (HPI) in Potsdam in Germany, and FutureWei Technologies to enhance human communication with Artificial Intelligence (AI). After exploring various user groups and potential applications of AI such as language translation, self-reflection, remote communication, and assistance in conversations, the student team decided to focus on communication within families, particularly between parents and children between the ages of 3 and 5 years.

Children of this age are at a crucial stage in terms of the development of emotions, language, and sense of time. They need time to prepare themselves for transitions between activities and engagement to keep them from being distracted while going through these transitions. The parents are concerned about their child's schedule and getting them from place to place on time while struggling with several other responsibilities, all while being tired and stressed out after a long day's work. This discrepancy between the child's need to prepare for change and the parent's wish to move from task to task creates a lot of tension, stress and negative communication in the household.

VAMO is a system that solves this need. Figure 5 shows how it signals an approaching transition to the child using light queues in the house, an association that the child learns, and provides them with a buffer time to prepare for incoming change. Once the buffer time expires, the system signals again and guides to desired locations. AI is used to create personalized stories relevant to the child's life to promote further engagement by incorporating information input by the parent through the app. The routine stress and negative communication is replaced by one of positive communication and engagement in the family.

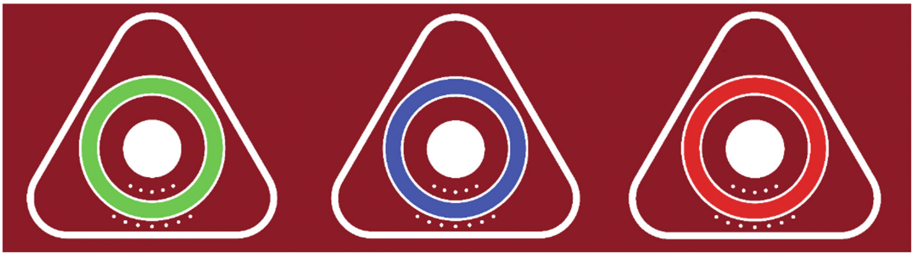

Fig. 5. Signals show different colors indicating three different states (Color figure online)

4.2 OpenRoad

This project is a collaboration between Stanford University, Technical University of Munich, and BMW to improve an open-air experience. Open-air enthusiasts know that in a convertible at highway speeds, the wind blows from behind you and throws your hair into your face. One can either endure the inconsistent hard-to-ignore backflow or install the clunky unsightly windscreen that takes the fun out of open-air motoring. The student team reinvented the open-air experience by drilling a hole in the windshield and an optimized duct that focuses the air between the front two passengers. The proof-of-concept prototype proved that a small change in airflow can change can significantly alter the passengers' comfort. The idea is now patented and being investigated by engineers with the underlying question: can we accomplish this without a hole in the windshield? (Fig. 6)

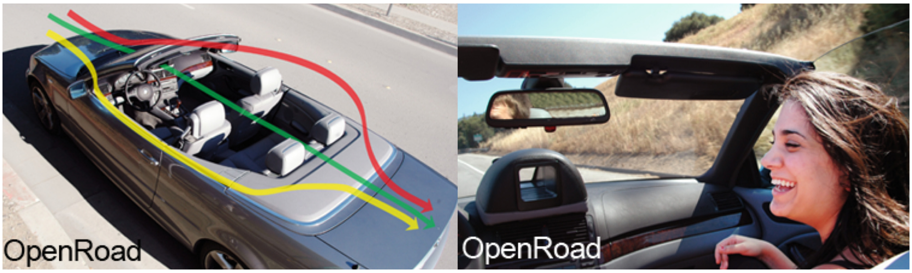

Fig. 6. The change in vehicle airflow

4.3 Ki'i

This project is a collaboration between Stanford University, Helsinki University of Technology, and Nokia to create a human-technology experience. Nokia asked the student team to forget the mobile phone and design the next device for a future 'Open Internet Communication Culture'. Identifying trends in Web 2.0 and user-generated content, the student team developed the Ki'i, a mobile handheld device that allows users to create and access self-expressive drawings and comments (see Fig. 7). Images captured by the Ki'i can be geo-tagged, marked-up, and shared with a select group of people or the larger online audience. Some of the ideas expressed in the Ki'i have appeared in the market as new web services and mobile phone applications.

Fig. 7. The mobile handheld device Ki'i

5 Discussion

In order to be successful, a winning project usually does the following: 1) challenge students' creative and intellectual abilities, 2) be conceptually and technically challenging while retaining modest cost and physical size, 3) be of deep concern to the company, but not on a critical production path, 4) give the relevant student learning team considerable freedom of action and decision-making authority, 5) benefit from an open-door policy between student team, company liaison, and company knowledge and insight. All of these factors are important individually, but when assembled, they provide a remarkable path for success and fulfilling, beneficial achievement.

Students may have friends from or traveled to different countries and cultures but this course is an opportunity for them to truly collaborate with both in-person and across national boundaries. After the course period, students gain a sense of empathy for people with different backgrounds and viewpoints, not to mention friendships that last a lifetime.

In the past, teaching and learning engineering's primary concern has been with feasibility, the traditional and technically oriented approach to problem-solving. As educators are asked to be more innovative in today's commercial and industrial environment, it becomes critical to weigh in on design thinking, transdisciplinary domains, and a global context as well. Pleasurable user experience of product-service systems is becoming more valued and requires us to focus much more strongly on human values in addition to technical requirements. In recent years, several institutions worldwide are committed to cultivating both innovative research talents and entrepreneurial talents to build a world-class curriculum and pedagogy. "We want them to record what didn't work, too. Those documents are a wealth of knowledge," Professor Toye said. "I am of the opinion, with some evidence, that learning best takes place when learners ask the questions and understand why the question is relevant to their work, lives or projects. This is profoundly different from having a lecturer ask questions that seek regurgitation of lectured material." Said professor Larry Leifer. This course seeks to better balance the equation between cooperation and collaboration, between doing what's expected and agreeing to disagree. It is a paradigm for re-designing our cultures at a global scale. It is no longer just a course. It has become a movement.

6 Conclusions

Unlike most project-based courses in universities, these projects are proposed by real companies, many of them are leaders in their industry, looking for innovative products and services. Project topics are loosely defined, and students are required not only to come up with radically brilliant ideas, they must prove the concept through real functional prototypes. This course is one of the most memorable and intense experiences that students go through, and something they can be proud of for the rest of their lives.

During the nine-month-long course, student teams brainstorm, design, build, test and create professional-quality prototype products for a sponsoring industry collaborator. Although they have plenty of coaching support along the way from faculty, industry professionals and class alumni, the course pushes students to depend primarily on their team, generating and exploring ideas as research and development teams do in the real world.

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