A Primer for Design and Systems Thinkers

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Teaching students to think in complex systems and design is presumably intricate, creative, and nonlinear. However, due to the overwhelming number of standardized tools and frameworks, the process sometimes ends up being procedural and deductive. Conformity to rigid procedures loses the intention of creative problem-solving towards tackling wicked problems.

Keywords: creative mindset ; design thinking ; interdisciplinary studies ; project-based learning ; engineering education ; integrative systems and design

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1. Introduction

> *"Today's problems come from yesterday's solutions."*
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> *—Peter Senge.*

Designers and engineers have long played the role of using creative and technological methods to design and build for the betterment of humankind [1]. However, disruptive innovations are also increasing the complexity and the pace of today's world. The integration of expertise from various disciplines has become increasingly important in our interconnected society, and the ability to think integratively is a crucial skill for success in emerging careers [2][3]. Addressing problems that arise in the form of intricate and dynamic systems require more than mathematical deduction, i.e., to be undertaken via systemic, creative, and humanistic approaches.

To this end, design thinking and systems thinking have gained popularity among educators as approaches for teaching students to think outside of the box and tackle complex problems [4]. Despite the open-ended nature of these approaches, learning modules commonly found today, especially in crash courses, would focus on the standardized steps (e.g., design thinking process—empathy, define, ideate, prototype, test) and tools (e.g., empathy map, user journey map, etc.) rather than the values and mindsets of design and systems thinking. After these short modules, students may only recall the steps and tools and find difficulty in conceptualizing these "thinkings" and adapting to other contexts. Recently, critics have pointed out the pitfalls of this routine and "over-promising" process and argued that "the shine of design thinking has been wearing off" [5]. Another criticism claimed that the process has often become overly simplistic or formulaic [6].

2. Design Thinking Approaches and Human-Centered Designs

When problems arise in the form of complex and dynamic systems, traditional approaches to thinking linearly about problem-solutions or using singular cause-and-effect logic are no longer applicable to addressing the real needs of people. Take the case of the global pandemic COVID-19 as an example. Although the fundamental root cause is the virus, the problems that arise are more far-reaching than the virus itself; solutions span across technological, social, economic, and political domains and would not be effective without careful and holistic considerations of their multitudinous impacts. Any innovation in one system may trigger a string of backfires in the others. Products, services, and systems nowadays should be designed via systemic, creative, and humanistic approaches.

To this end, new education programs are advocating the notion of design thinking approaches and human-centered designs. Design thinking is taught as a problem-solving methodology that emphasizes empathy, experimentation, and collaboration [4]. The most credited organization to first conceptualize design-thinking was IDEO, founded by Stanford University professor David Kelley and then popularized by the Hasso Plattner Institute of Design (or d.school) at Stanford University (Stanford d.school: https://dschool.stanford.edu/ (accessed on 22 November 2023)). The d.school has developed a curriculum around design-thinking concepts that are widely used in universities, corporations, and organizations worldwide [7]. To date, design thinking has gained a significant foothold in academia, and its adoption continues to grow as more universities recognize its value in preparing students for the complex challenges of the 21st century. Besides IDEO, a few examples of adopting the design-thinking educational programs are as follows: in the US, the innovation of products and services, i.e., MIT's approach to design thinking at MIT Sloan (Innovation of Products and Services: MIT's Approach to Design Thinking: https://admissions.emeritus.org/programs/mit_sloan_executive_education/design-thinking (accessed on 22 November 2023)); in Denmark, the design and innovation program at the Technical University of Denmark (Design and Innovation Program at DTU: https://designthinking.dtu.dk/english/ (accessed on 22 November 2023)); in Japan, the Master's program offered by Keio University's Graduate School of Media Design (Design Thinking and Innovation program at Keio: https://www.kmd.keio.ac.jp/academics (accessed on 22 November 2023)); and in Hong Kong, the division of integrative systems and design at the Hong Kong University of Science and Technology (Integrative Systems and Design at HKUST: https://isd.hkust.edu.hk/about-isd#what-is-isd (accessed on 22 November 2023)).

These programs all place an emphasis on human-centered design and the application of design- or systems-thinking processes for systematic innovations. This approach usually includes several steps to unravel the user's real needs and design solutions around them. It offers a great way to promote collaboration and creation in a wide range of contexts, and the notion of hands-on prototyping also helps students to construct physical products or services that redefine systems to enhance user desirability.

This approach gained popularity as it appears to guarantee results from students, offering some creative ways of addressing a problem. However, critics have challenged this claim as "over-promising" [5]. Ackermann's article posits that "… its short-term focus on novel and naive ideas has resulted in unrealistic and ungrounded recommendations". Another criticism is that the process would often be overly simplistic or formulaic and may not fully engage the creative and critical thinking skills of designers and innovators [8].

Indeed, when students are presented with many steps and tools, they would feel natural to follow these steps as if they are checking a series of boxes as part of their assessment. In particular, for engineering students, the majority of their training is to apply equations and generate well-defined models as solutions [9]. Introducing the concepts of open-mindedness and interconnectedness with no direct or right-or-wrong answers to wicked problems may sometimes be daunting [10]. As such, teaching students to think in systems and design should not only focus on the steps and tools but also, more importantly, on nurturing their mindsets to embrace non-linearity and divergent thinking.

3. Foundation for Instructional Design

In search of an epistemological foundation for instructional design, experiential learning theory (ELT) by David Kolb [11] and constructivism by Jean Piaget [12] are commonly cited references for project-based environments.

ELT emphasizes the importance of learning through direct experience and reflection. It consists of four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation [11]. ELT suggests that learners learn by actively engaging in real-world experiences and reflecting on their observations. Research findings indicate that incorporating ELT in the instructional design of project-based engineering courses leads to several advantages [13][14]. Firstly, it promotes active and hands-on learning, enabling students to apply concepts to practical situations. Second, ELT emphasizes problem-solving skills development by providing opportunities for students to reflect on their experiences and identify patterns, systems and connections. Lastly, ELT fosters a deeper understanding of the subject matter and enhances knowledge retention through active experimentation and application.

Constructivism posits that learners construct knowledge through their experiences and interactions with the environment. Learners assimilate new information by incorporating it into their existing mental structures and accommodate these structures when faced with new experiences that challenge their understanding [12]. Research suggests that incorporating constructivist principles into instructional design enhances students' motivation, engagement, and knowledge acquisition [15][16].

Both ELT and constructivism advocate learner-centered instructional design. They encourage instructors to create a collaborative and interactive learning environment where students can construct their own understanding from their learning experiences. By actively participating in project-based activities, students develop a deeper understanding of engineering principles and their applications.

4. Mindsets for Integrative Systems and Design

Conformity to rigid procedures loses the intention of creative problem-solving for tackling wicked problems. Merely recalling standardized steps and tools would be unlikely to lead to success in coming up with out-of-the-box solutions to a problem. Instead, nurturing creative mindsets can drive one's creative behavior, and these behaviors will steer us toward creative achievements and innovations [17]. "A creative mindset can be a powerful force for looking beyond the status quo" (p. 24) [18]. As Karwowski and colleagues explained, creative mindsets are the continuum of a fixed-to-growth mindset and stability-to-changeability [19]. To nurture creative mindsets, Tom and David Kelly at IDEO suggested that it is important to inspire curiosity and exploration, allow for open-ended play and experimentation, and provide opportunities to try new things and make mistakes without judgment or criticism [18].

Breaking down complex problems into manageable pieces requires systems thinking. Fourteen "habits of a systems thinker" were proposed by Waters Center for Systems Thinking [20]. Examples of these habits include seeing the big picture, changing perspectives, surfacing, testing assumptions, etc. Developing the habits of a systems thinker would help students to understand how systems work, how subsystems are connected, and how actions taken can induce changes seen over time [21].

Interdisciplinary awareness, also referred to as interdisciplinary attitudes, is crucial for learning integrative systems and design, as it allows for a more comprehensive understanding of real-world problems and the development of innovative solutions. According to Klein [22], interdisciplinary studies bring together diverse perspectives, methods, and knowledge from various disciplines to address interconnected issues that cannot be effectively tackled through a single disciplinary approach. The awareness of interdisciplinarity is being able to see the value when working in teams with students in other disciplines.

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