Design the Future Activities (DFA): Typology of Content for Case Studies

Hadi Ali
Engineering Education and Systems Design
The Polytechnic School, Arizona State University
Mesa, AZ
hwali@asu.edu

***Abstract*—This work-in-progress, research-to-practice provides a typology for content for case studies that are developed as part of the Design the Future Activities (DFA) framework. This work is based on the understanding that the nature of engineering design education and practice is changing due to the emergence of intelligent, autonomous objects. Traditional ways of teaching design, which are based on teaching design as a process of creatively solving problems, are not sufficient. Complementary to previous teaching practices is the need to provide *design content* to address the need for designing for the future, where intelligent objects act as a stakeholder in the design problem. In this paper, a typology of content is proposed to develop case studies that address the need for developing and delivering the DFA framework; that is engineering design education with the core of the technology of artificial intelligence.**

Keywords— Design for the future; AI case studies; technology analysis; making a value chain; creating responsible innovations.

I. Introduction

The changing nature of engineering design is largely influenced by the inclusion of intelligent, autonomous objects [1]. Objects that connect knowledge, talent and systems to create value continue to emerge, causing the shift for designers from focusing on product design, to processes design [2], to the design for the delivery of value [3, 4]. Table 1 lists examples of these objects, their potential applications, and their enabling technologies. Engineering design education has experienced a similar shift, from focusing on products [5], to focusing on processes [6], to the integration of the entrepreneurial mindset into the curriculum [7, 8].

The shift in the nature of engineering design practice and education calls for a need to revisit the *content* to be introduced to students in engineering design activities. Traditionally, engineering design has been introduced as a way to solve problems (e.g., [9]). Whether "solving problems" required specific content continued to be an issue to be debated [10]. Debates involved arguments around integrating mathematical modeling that students are introduced with in the theory-heavy curriculum into applied settings [11] and in various modalities [12]. Debates also involved the suggestion to codify problem solving into a structured process which facilitated the introduction of engineering design content as a subject matter [13]. Although engineering design has always been associated with creativity and imagination (e.g., [14]), the topic of engineering design pedagogy and assessment, especially its rigor compared to applied science topics, continued to be a contentious topic [15]. While advances have been made in engineering design teaching and learning [5], new challenges emerged due to advances in technology that require new approaches for designing for the future.

This work is based on the notion that a primary challenge exists in developing new *content* for engineering design that integrates advances in technology into the engineering curriculum, generally, and engineering design courses, specifically [16]. Emerging technologies, especially those that are characterized as artificial intelligence (AI)-augmented systems, require new approaches to engineering design that consider not only the technical aspect of technology but also the economic and social dimensions of the context within which the technology exists. We believe that authentic experiences are needed to provide a structured approach to engineering design education which integrates realistic context of the technologies of the future with meaningful contexts that match and build on students' engineering ability and general knowledge.

In this paper, we revisit the Design for Future Activities (DFA) framework; a framework that is based on a scholarship of integration to re-examine how engineering curricula incorporate a deep understanding of the coupling between technology, society and the future [16]. Next, the alignment between the DFA framework and *typology of structures* of pedagogy to address the different levels of the DFA framework is revisited [17]. The core for developing and delivering the DFA framework is the teaching of the technology of AI. In previous work [16], the DFA framework identified case-based teaching, inquiry, and discovery learning as important pedagogical approaches to linking "what" needs to be learned with "how" to teach it. Here, a *typology of content* is provided to supplement and expand upon the previous work.

Table 1. Examples of emerging designs, their applications, and their enabling technologies that are changing the nature of design for the future. [16]

• **Example of intelligent, autonomous objects**	• **Potential applications**	• **Enabling technologies**
• Social robots • Service robots • Collaborative robots • Robot arms • Drones • Lifestyle robots • Autonomous vehicles	• Public health service • Medicine • Agriculture • Building cleaning • Retail trade • Production • Monitoring • Shopping • Delivery • Cooking • Training • Transport	• Big data • In-memory data analytics • Gesture recognition • Brain waves monitoring • Voice recognition • Augmented reality • Wearable computing • Internet of things • Blockchain technology

II. The DFA Framework

The DFA framework is a three-level framework that categorizes activities for students to engage with in designing for the future as follows: (1) Understanding technology analysis and system integration (to allow students to identify *what* are appropriate solutions given the new technology); (2) Making a value chain (*how* are these appropriate solutions); and (3) Developing responsible innovations (*why* are these appropriate solutions). The framework is illustrated in Figure 1. In the DFA framework, Level 1—Understanding technology—represents the core of developing and delivering the DFA framework. It is based on teaching the technology of AI as it continues to transform the world we live in through a combination of disruptive potential of growth and speed of adoption. Level 2—Making a value chain—represents teaching around creating a value proposition that transcends simply the making of isolated things. Level 3—Developing responsible innovations—is concerned with grounding students in concepts related to socially responsive and responsible innovation. For more details, refer to [16].

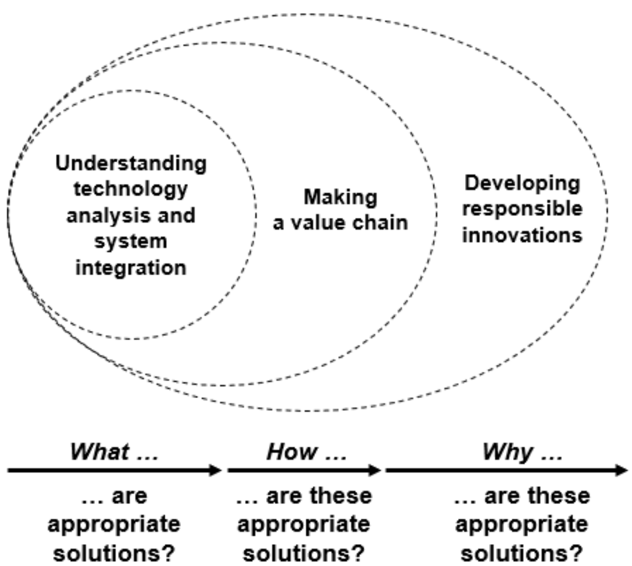

Fig. 1. The Design for Future Activities (DFA) frameowk [16].

III. Framework for Developing DFA Case Studies: Typology of Structure

In [17] a framework was proposed to guide the structural development of case studies for the DFA framework along four dimensions: time boundedness; place boundedness; well-defined parameters; and purposeful depth and insightful breadth. The *time boundedness* dimension characterizes how a case study should have clear boundaries in time, shedding light on the complexity of the situation with a clear beginning and end. The *place boundedness* dimension characterizes how a case study should have clear articulation of the landscape being explicated, whether it is physical or virtual, by selecting the boundaries of space in the case study. The *well-defined parameters* dimension characterizes how a case study should be structured in a way to improve the delivery of the intended lessons by making it easier to track decisions and their consequences. Finally, the *purposeful depth and insightful breadth* dimension characterizes how a case study should be focused, with the necessary purposeful depth, and while illustrating accurate, broad perspective of the context of events. For more details, refer to [17]. The previous work focused on the *typology of structure* of DFA case studies; here, the work is expanded upon to focus on the *typology of content* of DFA case studies.

IV. Framework for Developing DFA Case Studies: Typology of Content

The typology of content proposed here aims for providing an archetype classification of the content to be developed for case studies that focus on engineering design applications for AI-augmented system. While the typology of structure in [17] focuses on "how" to present the case study, the typology of content here focuses on "what" should case studies address. The four types of case studies discussed here are: trend analysis case studies; scenario planning case studies; backcasting case studies; and speculative design case studies.

A. Trend Analysis Case Studies

Observing the past can provide a general sense of the changing nature of technology and its use in the future. When carefully structured (see [17]), a case study provokes an appreciation of the general direction of AI-augmented technology development and its utilization by both the developers and the users. Patterns in the evolving interplay of the relationship between a developer's perception of a technology (for example, the World Wide Web) and the assorted ways that a user ends up utilizing that technology can be carefully examined in a well-designed case study. Hence, a *trend analysis* case study conceives of the "technology user" as an equal innovator in the technology evolution as the "technology developer." In this sense, and while the "technology developer" may not have initially thought of engaging the user as an innovator in the production of the technology, the "case study developer", for educational purposes, draws on resources to recreate this relationship.

One approach to recreate this relationship in the case study is to first highlight the original requirements of the technology as conceived of by the "developer." Then, the benefits and competitive edge attained by the "user" as a result should be highlighted. A critical review should be provided for identifying trends and as documented in primary and secondary sources, which include research trends, market trends and other relevant forecasts from early researchers, technology experts and market experts. In addition to identifying the evolution of needs and trends, the case study should highlight actual users and actual experts as early adopters and reactors in the evolution of technology and its use.

Overall, in order for a *trend analysis* case study of AI-augmented systems to be effective, the case study should strive for developing higher levels of abstractions of trends, by developing questions on topics in analogous markets. The co-creation framing of trends (of "needs" and "uses") in a *trend analysis* case study is useful in understanding the future of AI-augmented systems, given the highly iterative and prototypical nature of such systems.

B. *Scenario Planning Case Studies*

While trend analysis case studies focus on the evolution of needs, *scenario planning* case studies focus on analyzing the consequences of strategies. Analyzing a strategy involves examining methodically the plans of actions taken to select, develop and deploy an AI-augmented system in a very targeted way. Here, the focus is less on the *need* and more on the *solution* adopted by designers. The adoption of a specific strategy to implement a specific AI-augmented solution may not necessarily focus solely on the user but may also involve other factors such as financial goals of the developer, growth outlook and overall vision of designers, as well as efforts to shape the market and "create" potential future users.

In developing *scenario planning* case studies, the case should clearly articulate a *strategy* (either real or hypothetical). Then, the students should creatively think of implications of this strategy into the future and critically analyze direct and indirect consequences of this strategy. Compared to trend analysis case studies (which can be characterized as passive in their approach to learning), *scenario planning* case studies involve more active learning approaches by presenting the students with "questions to be answered, problems to be solved, or a set of observations to be explained" [18, p. 127]. Most importantly, *scenario planning* involves the third dimension of the DFA framework; that is, "Developing responsible innovations" [16]. Being aware of the ethical consequences of an AI-augmented technology, while balancing that with potential market opportunities, should provoke critical thinking and intellectual growth on the students' part. For example, a scenario can be set to explore the moral stands of a strategy of a design of a system that acquires customers' data and uses it profitably in a business model.

Overall, by analyzing the *scenario planning* in the case study, the links between a strategy and its interpretation and consequences in various contexts can be explored. Students can develop better awareness of reality of the implications of technology by engaging and confronting the situations. Students can start working in small groups and gradually shift to more self-directed inquiry process [19]**,** encouraging students to contemplate conclusions in a guided way [20, 21].

C. *Backcasting Case Studies*

Backcasting case studies start with developing a vision by a team of students for what an AI-augmented system looks like (for example, human-robot teaming in daily household activities). Then, students attempt to work backward in an effort to identify what technologies, resources and policies might be needed in order to achieve that vision. Once heightened levels of creativity have been achieved, as can be provided through radical possibilities and imaginable created values, the instructor provides championed "backcasting events" that enable the achievement of the vision. Ideally, backcasting takes the form of going backward in time *in gradual steps*, determining policy measures in a step-by-step fashion when moving backward from the desired vision to the current point of time. *Backcasting* case studies are different from trend analysis case studies (which can be considered as "forecasting" of the future by predicting it *based on the past and present*) and are different from scenario planning case studies (which can be considered as less involved in defining the vision but rather analyzing the consequences of *existing strategies*). The term backcasting, and the associated methodology, was first coined by Robinson in [22].

Backcasting case studies clearly require the instructor to be an experienced facilitator. The process requires the instructor to champion a certain vision and recognize points in time, with relevant cases, that lead the students to converge in their analysis. In addition, the process requires active engagement from the students' part to identify cases and a combination of technologies and policies from the past that will lead to the desired future. The combination may include: cases of prior knowledge that leads to specific technology; cases of ground breaking ideas; cases of practical operation of technology; cases of migrating ideas between industries; cases of initial experience by users; cases of value creation; cases of unintended consequences of technologies; and cases of technology simplification.

Overall, *backcasting* case studies require the vision developed by students to generate attention for potential users to have the momentum to push the students to think in new ways, to offer a balance between a convincing vision and critical analysis of "backcasting events," and to provide an awareness of what the users recognize of as a need and what they may not recognize as a need.

D. *Speculative Design Case Studies*

While backcasting case studies attempt to paint a positive vision for the AI-augmented system in the future, speculative design case studies attempt to develop a dystopic fictional vision of the future. Here, students think of possible, but not preferred, context where an AI-augmented may exist. The process is very similar to the backcasting case studies (where the vision is both possible and preferred). It starts by asking students to (1) experience, (2) understand and (3) feel, like the user, the negative implication of an AI-augmented system.

Experiencing the negative implications of a technology can be achieved by recognizing critical needs of the user and starting to develop counter intuitive implications in *authentic situations* that take place *day after day*. Often times, the impact of AI-augmented systems is not sensed immediately; instead, it takes a longer time horizon to experience such impacts [16]. *Understanding* the negative implications of a technology can be achieved by developing an understanding of personal backgrounds, lifestyles, values, and contexts, where people think and act in the most varied of ways. Here, the link between the changing nature of design for future and the careful understanding of the working of technology becomes clear (see [16]). Finally, *feeling* the negative implications of a technology can be achieved by asking questions to actual, potential users while keeping aside personal experiences and values as much as possible.

Overall, *speculative design* case studies involve specifically the first and third levels of the DFA framework; that is, understanding the technology (what are appropriate solutions?) and developing responsible innovation (why are these appropriate solutions?) [16]. The process of *speculative design* case studies, as was illustrated, involves active engagement and designing by the students that go beyond reading and analyzing existing text. Rather, secondary references in *speculative design* case studies are used to back up claims, amplify speculations, and develop an open mind of the consequences of technology.

V. Conclusion and Future Work

There is a need to provide content for engineering design education to address the proliferation of advanced technology that cannot be overlooked in the engineering curriculum. Based on the DFA framework to develop content for engineering design for the future, this paper builds on previous efforts linking substantive content on the topic with effective pedagogy. In this paper, we provide an overview of ongoing work to developing case studies based on a typology of both structure and content and that focus on AI-augmented systems in engineering design education. Such case studies build on framings from future-studies and science and technology studies. There is a need for new design content, which should be carefully and fully coupled with effective pedagogy. Case studies on this topic in engineering education are lacking. We intend to develop content and attempt to delivering it to engineering design students based on the DFA framework.

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