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# Opportunity in Design: Extending and Enriching the Purpose of Engineering Education

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# Opportunity in design: Extending and enriching the purpose of engineering education

**Abstract**— In this paper I reviewed design literature to explore design as a context for teaching and learning in engineering education that can humanize engineering education by extending and enriching the purpose of engineering education. More specifically, I examined the humanistic qualities and sociotechnical nature of design to identify underlying principles that inform and guide best practices for teaching design and operationalizing humanistic purposes in engineering education. Opportunities exist particularly in the open-ended, ill-defined, reflective, and social nature of design. Leveraging these in teaching practices and curriculum promotes a broad and well-rounded education that inspires and enables a creative and productive life, and that is necessary to understand the impact of engineering solutions in a global and societal context. As such, design provides a unique opportunity to incorporate and promote the underlying humanistic qualities that operationalize humanistic purposes in engineering curricula.

## Introduction

Peters c.f. [1] developed a perspective of education that emphasizes its intrinsic merits; in other words, he argues that education is valuable in and of itself. This position is based on three criteria for classifying various activities and processes as educational: worthwhile knowledge of some value must be communicated; the manner in which people are educated is equally important as the content that is shared; and content must be seen in situ, that is, in relation to its place in a coherent pattern of life. Building on this perspective, [1] asserts that, in order for design to satisfy the previously mentioned criteria, it must contribute to individuals' self-realization and "to the development of an 'educated' person" (p. 5). In this paper I argue that design can do just that and reviewed design literature to make a case for design as a context for teaching and learning in engineering education that can humanize engineering education by extending and enriching the purpose of engineering education (i.e., contributing to individuals' self-realization and their development as "educated" persons).

My thesis is that design provides a unique opportunity to incorporate and promote the underlying humanistic qualities that operationalize humanistic purposes to affect engineering curricula. In fact, [2] referred to the rapid humanization of engineer education by emphasizing the role of design. Furthermore, the nature of design and human-centered approaches to design all contribute to reconciling the social and technical nature inherent in engineering and engineering education. To support this claim I, first, examine the nature of design itself paying particular attention to its ill-defined and open-ended character, reflective quality and social dimension. Second, I examine the human-centered approach to design, particularly as it relates to reconciling the social and technical nature of engineering to identify underlying principles that inform and guide best practices for teaching design and operationalizing humanistic purposes in engineering education.

## The Nature of Design

Design knowledge is embodied in the processes and products of design [1]. The nature of design tasks/processes emphasizes the proposal of multiple solutions and then systematically reducing them until an acceptable solution is found. The nature of design objects/products enables designers to understand the messages that objects/products of design communicate as well as create new objects/products that communicate new messages. Together these embodiments of

designerly knowing "facilitate the constructive, solution-focused thinking of the designer", facilitate manipulation of non-verbal codes that "translate 'messages' either way between concrete objects and abstract requirements", and are very effective for engaging in ill-defined problems ([1], p. 10).

The very nature of designerly ways of knowing offers justification for the intrinsic value that design offers education. For example, design develops students' cognitive skills and abilities in tackling problems, particularly ill-defined or ill-structured problems which typically lie outside the educational domain of the sciences and the humanities. Such problems are more like problems, issues, or decisions encountered in everyday life [1]; Fox (1981) refers to this type of problem engagement as 'real-world problem solving'. Reference [3] likens this intrinsic value of designerly knowing to the educational value of critical thinking. To extend this idea further, I would argue that [3]'s analogy presupposes the reflective nature of design. In the following sections I will present three aspects of the nature of design (i.e., reflective, ill-defined and open-ended, and social) and discuss how they can contribute to an engineering education rooted in humanistic purposes.

***Ill-Defined and Open-Ended Nature of Design***

The nature of a final design outcome cannot be known at the onset of a design endeavor [4]. That is because "The subject matter of design is radically indeterminate, open to alternative resolutions even with the same methodology" ([5], p. 24). Necessarily, design does not have an "enumerable (or an exhaustively describable) set of potential solutions…" ([6], p. 140). Likewise, design does not have "a well-described set of permissible operations" that designers can employ to achieve a desired end ([6], p. 140). That is because design is open-ended. In other words, "…the subject matter of design is not given. It is created through the activities of invention and planning, or through whatever other methodology or procedures a designer finds helpful in characterizing his or her work" ([5], p. 24). In practice, design must consider "…competing interests and values, alternative ideas, and different bodies of knowledge" ([5], p. 26). Therefore, by its very nature, "…design calls for both the process and the results of designing to be open to debate and disagreement" ([5], p. 25).

This ill-defined and open-ended nature of design of ten leads to practitioners encountering surprises, that is, an anomaly in the results one was intuitively expecting. This often causes one to reflect on her/his practice (one's actions and the knowing implicit in her/his actions) even while still engaged in the design activity [7]. In order to make sense of the anomaly, one also reflects on the understandings implicit in her/his actions, sometimes referred to as one's underlying perspective [7], [8]. These underlying perspectives may be made explicit, criticized, restructured, and then embodied in further action.

The surprise that one may encounter during a design activity acts as a disorienting dilemma which is, essentially, encountering an anomaly that causes one to question the appropriateness of one's expectations. This disorienting dilemma causes one to critically reflect on her/his unquestioned belief system bringing her/his unquestioned implicit understandings to the surface for critical examination. Critical reflection may result in a reconstruction of or an entirely new belief system leading to a more functional meaning perspective to interpret one's experiences in the world. Furthermore, one's implicit understanding is restructured and then embodied as one engages in further action.

To better illustrate this idea, let us look at a real-world scenario. Reference [8] presents a case in which a designer encounters a dilemma. The designer's frame of reference is, you can only have "spaghetti bowl" by completely avoiding "hierarchical order" ([8], p. 134). So he works harder to make sure each piece is beautiful with beautiful transitions expecting that, "if each of his moves…is marvelous, then the whole thing will make sense" ([8], p. 134). The designer refuses to shift his framing of the task or his underlying perspective. This disorienting dilemma demands a transformation of his frame of reference (i.e., his underlying perspective). The inability of the designer to do so results in an impasse. This case illustrates how engaging in design activities can create circumstances that require one to question her/his belief systems, in this case the designer's framing of the task. Helping the designer to engage in critical reflection, in this case, may have enabled her/him to assess her/his belief system and make the necessary accommodations which would result in a more functional perspective. This is just one example of how the nature of design provides opportunities to integrate humanistic purposes into engineering education.

***Reflective Nature of Design***

Design involves reflective practice to negotiate uncertainty, instability, uniqueness, and value conflict c.f. [7], [9]. According to [5], there is a "deep reflexive relation [that is inherent] between human character [itself] and the character of the 'human-made'" (p. 30). Reflective practice is "central to the 'art' by which practitioners sometimes deal well with situations of uncertainty, instability, uniqueness, and value conflict" ([7], p. 50) that arise during design. It involves reflection on one's practice (i.e., one's actions and the knowing implicit in her/his actions) even while still engaged in the design activity as a result of encountering challenges or surprises, that is, an anomaly in the results one was intuitively expecting [7]—a result of the open-ended and ill-defined nature of design. The ability to make good design judgments is grounded in reflective practice. It is at the heart of design wisdom, in all of its manifestations, which results in, "…good judgment, which enables right action aimed at appropriate change" ([10], p. 139).

For example, practitioners often encounter challenges while engaged in design activities that cause one to reflect on her/his practice (i.e., one's actions and the knowing implicit in her/his actions) even while still engaged in the design activity [7]. Reference [7] calls this entire process reflection-in-action and it is what distinguishes design as a reflective practice. What is more, reflection-in-action is "central to the 'art' by which practitioners sometimes deal well with situations of uncertainty, instability, uniqueness, and value conflict" ([7], p. 50) that arise during design.

The reflective nature of design also has a peculiar manifestation. Reference [11] describe this manifestation as a reflective 'conversation' practitioners have with artifacts during design activities see also [12]. The phenomenon of reflective conversation is not literal talking or dialogue, nor is it necessarily rational discourse, but an interaction between the designer and artifacts associated with a design activity, such as images, symbolic representations, sketches, texts, lists, tables, diagrams, or models, depending on the situation [11], [13]. Each interaction with an artifact, every mark on a page or change of perspective or new orientation, communicates something back to the designer revealing a new pattern, a new way of seeing which, not only transforms the artifact into a gestalt, but engages the designer in a conversation or dialogue [11]. These cognitive artifacts exist throughout the design process including problem

framing and scoping [13]. Reference [14] refers to this conversation as a dialectic between 'seeing as' (e.g. the artifact could be seen as a container) and 'seeing that' (e.g. the designer sees that the container analogy used for the artifact is inadequate).

The interesting thing about these reflective conversations is that they have the potential to promote the individuation of practitioners. Individuation represents a lifelong journey of coming to understand oneself involving a "sense of empowerment and confidence, a deeper understanding of one's inner self, and a greater sense of [personal] responsibility" Boyd, 1991 as cited in ([15], p. 13). Reflecting on cognitive structures represented in the cognitive artifacts may lead to "imaginative engagement [with] different [dimensions] of one's unconscious life" ([16], p. 1) which nurtures the expansion of consciousness resulting in greater personality integration [17]. The reflective nature of design provides another opportunity for integrating humanistic purposes by promoting a space for individuation within engineering education.

***Social Nature of Design***

The social nature of design means that practitioners will engage with others during design activities, either directly or indirectly, which may help them to develop empathy, perspective-taking, and compassion which will inform their social-awareness. For engineering education this presents an opportunity to integrate humanistic purposes as well as reconcile the social and technical nature of engineering by providing students with a space to develop empathy, perspective-taking, compassion and social-awareness. Furthermore, an opportunity arises "to address and embody questions of value and human purpose" (citation) potentially leading to greater appreciation for individuals. The social nature of design is easily discernable when looking at design from a humanistic perspective and a service oriented perspective.

The discipline of design is a humanistic enterprise [5]. In all its forms, design promotes freedom of men and women within the milieu of technological culture and empowers people "…to explore the diverse qualities of personal experience and to shape the common qualities of community experience" ([5], p. 29). According to [5], "The essential humanism of design lies in the fact that human beings determine the subject matter, processes, and purposes of design shall be" (p. 55). Necessarily, "Design rests on the ability of human beings to reason and act with prudence in solving problems that are obstacles to the functioning, development, and well-being of individuals in society" ([5], pp. 29–30). In this light, I agree with Buchanan's assertion that, "…design is the domain of vividly competing ideas about what it means to be human" ([5], pp. 55-56).

From this perspective, design is informed and guided by humanistic considerations. First, design is seen as "…an integral part of the stuff of life, necessary for everyone in a civilized society…" (pp. 35-36) not simply an intellectual nor a material affair [5]. Second, design broadens and humanizes rigid positivistic and materialistic thinking [5].

Reference [10] assert with their definition of design, that it is a service relationship. More specifically, "All design activities are animated through dynamic relationships between those being served—clients, surrogate clients (those who act on behalf of clients), customers, and consumers or end users—and those in service, including the designers" ([10], p. 41). What is more, "The presence of a binding service relationship in design contributes to a clear distinction between the tradition of design and the traditions of art or science" ([10], p. 41).

Necessarily, "…the service relationship is the basic teleological cause that is to say, the purpose of design" ([10], p. 42). As such, design is about service on behalf of another as opposed to "…changing someone's behavior for their own good or convincing them to buy products and services" ([10], p. 41). Therefore, designers must embrace a posture of other-serving not merely self-serving [10]. From this perspective:

> The success of the design process can best be determined when those being served experience the surprise of self-recognition. …. The designer's role is to midwife that desiderata, which could not have been imagined fully from the beginning by either client or designer, and to provide and results in the form of an expected unexpected outcome. ([10], p. 42)

Seeing design as service emphasizes the sociotechnical nature of engineering practice, situating it in three dimensions: for people, with people, and as people [18], [19].

***Summary of The Nature of Design***

The nature of design provides opportunities to integrate humanistic purposes into engineering education by creating spaces where students can: critically reflect on their unquestioned belief systems bringing their unquestioned, implicit understandings to the surface for critical examination; imaginatively engage with different dimensions of one's unconscious life; and engage directly or indirectly with others, whether similar or completely different from themselves, during design activities. These experiences may help students to better understand themselves, that is, embracing "a sense of empowerment and confidence, a deeper understanding of their inner [selves], and a greater sense of [personal] responsibility" ([17], p. 4). Or they may result in a reconstructed or entirely new belief system leading to a more functional meaning perspective. They may even help students develop empathy, perspective-taking, compassion and social-awareness. Whatever the result, students will have the opportunity to grow and develop in multiple dimension, actualize their self/social identity, awareness, and acceptance, and be better able to reconcile the social and technical nature inherent in engineering and engineering education. By doing so, the nature of design itself emphasizes that engineering practice is done "as people" according to the People Part of Engineering framework [18] for engineering education.

**Human-Centered Design**

Human-Centered Design (HCD) provides a unique opportunity for humanizing engineering education, particularly as it relates to reconciling the social and technical nature inherent in engineering. HCD adopts a sociotechnical perspective balancing the social system (e.g., "interacting human activities; multiple, implicit, often conflicting goals; human understanding and knowledge; business context; application-specific cultures and practice", p. 31) and technical system (e.g., "formal, rule-based procedures and technology managed by performance indicators", p. 31) [20].

Many authors use UCD and HCD interchangeably and expand the boundaries of UCD to include what some would consider as HCD, for example [21], [22]. Others use the term HCD because it suggests concern for people whereas UCD suggests a narrow focus on individuals' roles as users, for example [23]. Still, some draw a distinction between the two approaches, for example [20], [24]. Regardless of the various distinctions, UCD and HCD share a common value for a broad

understanding of people and including them in the design process to varying degrees. For the purpose of this paper the term HCD will refer to design approaches that share these common values.

Although HCD has no agreed upon definition, it has broadly been described by the International Organization for Standardization (ISO) in standard 13407 as:

> "the active involvement of users for a clear understanding of their behaviour and experiences; the search for an appropriate allocation of functions between people and technology; the organisation of iterations, within a project, of conducting research and generating and evaluating solutions; and the organisation of multidisciplinary teamwork." (as cited in [23], p. 44)

However, that broad description contains many nuanced conceptions of HCD with various guiding philosophies and underlying assumptions, as well as, the principles or tenets based on those philosophies and assumptions [20], [22], [31], for example, [32], [23]–[30].

These varying conceptions of HCD not only provide opportunities for reconciling the social and technical nature of engineering, there are opportunities to integrate the growth, development, and actualization of engineering students in design courses as well. For example, one conception of HCD places the users at the center of the design process [31], where their input influences how the design takes shape [32]. Integrating HCD principles into design courses allow engineering students to understand and integrate end-user data during the design process.

Another conception of HCD focuses on the human aspect of the design and provides for the needs and experiences, both articulated and unarticulated [33], by "[weaving] available knowledge of how meanings arise within relevant stakeholder communities into the design process in order to assure that a design encourages the meanings that lead to reliable interfaces while discouraging those that cause disruptions, disappointments, breakdowns, and harm" ([28], p. 230). By engaging in HCD, students are required to consider not just about the function the design provides, but also about the design's meaning [34].

More recent conceptions of HCD encourage the use of techniques involving empathy which helps to identify customer-needs by observing the user in the context of use and may also include simulating the context of the end-user for better understanding. Integrating empathy into HCD allows engineering students to identify with the challenges of the end-user.

However, [20] argues that certain conceptions of HCD "fail to promote human interests because of a goal-directed focus on the closure of predetermined, technical problems" (p. 41). Also, these conceptions "do not suggest any way of sensitizing the designer to the context in the absence of prior experience or direct contact to the respective context" ([35], p. 5).

Others have explored design approaches that attempt to accommodate for the limitations mentioned above. For example, [36] propose that service-learning projects promote students' social-awareness by helping them to develop cultural sensitivity and empathy. Reference [37] propose that "engaging students in somatic awareness exercises will enhance their empathic perspective-taking ability and ultimately their skill in ethical reasoning and engineering design" (p. 1769).

Two specific design approaches have potential to accommodate the limitations mentioned above. The first approach is participatory design [38]. Participatory design "attempts to actively involve the people who are being served through the design process to help ensure the designed product/services meet their needs" [38]. The goal is to "involve those who will become the users throughout the design development process to the extent that this is possible" ([38], p. 14). The second approach is generative design [38]. Generative design approach "empowers everyday people to generate and promote alternatives to the current situation" ([38], p. 15). Both approaches are about empowerment. The people are not passive recipients of the designers' genius and expertise but are actively engaged and committed in and throughout the process.

All of these design approaches consider the reality that engineering takes place in a human context. Accordingly, they attempt to place people at the center of design tasks. By doing so, these design approaches emphasize that engineering practice is done "for people" according to the People Part of Engineering framework [18] for engineering education.

**Conclusion**

In this paper, I made a case for design as a context for teaching and learning in engineering education that can humanize engineering education by extending and enriching the purpose of engineering education (i.e., contributing to individuals' self-realization and their development as "educated" persons). The nature of design provides opportunities to integrate humanistic purposes into engineering education by creating spaces where students can: critically reflect on their unquestioned belief systems bringing their unquestioned, implicit understandings to the surface for critical examination; imaginatively engage with different dimensions of one's unconscious life; and engage directly or indirectly with others, whether similar or completely different from themselves, during design activities. Intentionally integrating these opportunities into teaching practices and curriculum will afford students the opportunity to grow and develop in multiple dimension, to actualize their self/social identity, awareness, and acceptance, and be better able to reconcile the social and technical nature inherent in engineering and engineering education. The Human-Centered Design approach, particularly as it relates to reconciling the social and technical nature of engineering is based on underlying principles that inform and guide best practices for teaching design and operationalizing humanistic purposes in engineering education. Leveraging these principles in teaching practices and curriculum can promote a broad and well-rounded education that inspires and enables a creative and productive life, and that is necessary to understand the impact of engineering solutions in a global and societal context. As such, design provides a unique opportunity to incorporate and promote the underlying humanistic qualities that operationalize humanistic purposes to affect engineering curricula.

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