A Broadened Perspective: Teaching Engineering Design in a Social Context

Jeffrey L. Newcomer, Ph.D.
Dept. of Manufacturing Engineering Technology
New England Institute of Technology, Warwick, RI, 02886

Abstract
The role and importance of design in engineering education is changing. Capstone design courses have become well established in many engineering programs in recent years, and their value has been realized by educators, students, and employers alike. As such, many of us recognize the need to introduce the design process earlier than the senior year, and spurred on by changing ABET requirements, many engineering schools are beginning to explore methods for integrating design throughout engineering curricula. Exactly what form engineering curricula will take when design is integrated throughout remains to be seen, although they will surely be varied. Nevertheless, there will be trends, and these trends will shape the methods and approaches engineering graduates use in their careers. These trends will have an effect upon engineering as a profession and society as a whole, as well as the innovation and creativity of industry in the future. I believe that as we teach design we socialize our students to behave in certain ways and not in others. By examining some of the commonalities in the well established capstone design courses that are offered by most engineering programs, I argue that these courses take a narrower approach to design than they could and should. While there is much about these courses to be lauded, there are things that we can and should change about the way we approach design education, especially as we begin to integrate it throughout entire curricula. By taking a broader perspective on design in engineering education, and treating design as a synthesis of many issues of a social and cultural, as well as technical and economic nature, we will provide our students with fewer implicit constraints and expanded concept of design. Students with broader perspectives on design will, I believe, be better designers, and in the long run this will benefit engineering as a profession and society as a whole.

Education and Design
I would like to begin my exploration of design and engineering education with B. Koen’s[1] assessment that design is behavior. Koen uses this argument in the context of suggesting that design be taught in a manner that reinforces good design behavior, such as getting students to work consistently on a project over a period of time rather than letting them rely upon all nighters to get work done at the last moment. Regardless of the approach, however, Koen’s message is that as our students undertake design projects and receive advice and feedback from their teachers, they are developing habits that will affect their approach to design in the future. I would then like to take this idea one step further and incorporate Ludwik Fleck’s concept of a thought style.[2] Fleck defines a thought style as “[the readiness for] directed perception, with corresponding mental and objective assimilation of what has been perceived (99).” In the context of teaching engineering design, we can take this to mean that our students not only obtain a behavioral approach to design problems, but they gain a viewpoint on design and what it means to design. Therefore, boundaries that are implicitly defined by the manner in which design is taught will become part of the engineering thought style vis a vis an engineer’s approach to design. Thus, as engineering educators, we must be aware of the implicit boundaries that we create when we teach design, for we are shaping the approach of the next generation of engineers to the most interesting and influential job they have -- designing the next generation of technology.

As we are all aware, the design content of engineering education is a major issue for all engineering programs. There have always been, and will always be calls from industry to produce graduates that are ready to contribute immediately. Over at least the past thirty years, this has manifested itself in a call for an increase in the design content in engineering education. The initial impetus for calling for an increase in design content was a reaction to the growth of engineering science based curricula during the post World War Two and Sputnik Eras. Aside from a few programs, however, there was no significant movement to incorporate design into engineering education in a coherent or common fashion until the 1980s. In the 1980s, spurred on by a new (or at least increased) rhetoric of international competitiveness, and a governmental push to increase the interaction of businesses and universities, there was widespread development of capstone design courses in many (one might surmise most) engineering programs.
Now in the latter half of this decade, capstone courses are well established, and while they vary, there are still many commonalities among them.[3,4,5]

In general, capstone design courses serve the purpose for which they were designed. They provide students with significant, open-ended engineering problems, in an atmosphere that, to at least some degree, accurately mimics the environment that many students will find themselves in during their initial employment. Thus the various facets of students’ education come together, and they gain experience that makes it easier for them to quickly and meaningfully contribute in industry. Students’ transition, however, from three to four years of engineering science based courses to an open-ended and poorly defined capstone design problem is frequently a difficult one, as they must adjust to suddenly being faced with a problem that does not have an answer. The experience of watching students go through this transition has led many of us who have been involved with capstone design courses to acknowledge the need for more design courses earlier in the educational process, as well as the integration of design throughout the standard engineering science courses. Moreover, the impetus to increase the integration of design in engineering programs has been enhanced by the new ABET Criteria 2000 requirements. Now engineering educators throughout the country are wrestling with how to integrate design throughout their programs, and the twin issue of what exactly is design content. While much of this is likely to play itself out in the form of open-ended problems and design projects as integral parts of what have traditionally been engineering science classes, there is evidence that more and more programs will develop at least one course that will provide students with a major design experience during their freshman or sophomore years.[6,7,8,9,10]

As is the case with capstone design courses, the emphases and implicit boundaries that we as educators place on design during our students’ early design experiences will affect their future design behavior and thought style, and therefore their understanding of what design is and what it means to design something. Certainly this is evident to almost all engineering educators who must face the issue of trying to get freshman and sophomore students to use a design process when they approach open-ended problems, and to get them to apply the limited number of engineering concepts that they have learned, rather than letting students get into the habit of trying something and declaring the design a success if intuition happened to be sufficient to meet the project goals. We, as educators, must take the time to reflect and ask ourselves: what are the implicit boundaries that we are creating vis a vis design, and how will they affect the design thought style of our students in the future?

Capstone Design and Education

No one can argue that there is not a strong industrial bent to capstone design courses; indeed it is intended. Capstone design courses attempt to provide students with realistic work experiences. This ranges from schools that try to create “a sheltered industrial environment”[11] to those that work on industry sponsored projects or use consulting firms to provide actual project work, and many in between.[12,13] As the most significant design experience, and in some cases still the only design experience that students receive, I must therefore conclude that most students’ concept of design is strongly shaped by their capstone design experience. This means that most students leave school under the impression that to design something is to complete a project that has been specified by someone else. By specified, I mean that the major goal of the project as well as its deadlines, budget, and recipients are determined by someone other than the engineers who must develop a solution. While this is a very meaningful lesson for students who intend to follow a traditional career path, it leads to what I consider to be a narrow concept of design. An exploration of design should include issues of culture, race, gender, class, and environment. Issues of a political nature that, despite our efforts to ignore them, are part and parcel of everything we do as engineers and members of our communities. Certainly, as engineering programs provide students with more major design experiences, there is going to be room for design courses that allow students to explore design from a broader perspective, but some descriptions of design courses taken early in the curriculum seem to indicate that these courses will carry many of the same implicit constraints that are found in capstone courses.[6,7]

One can argue, as Samuel Florman[14] and many others have, that the design of technology and therefore the work of engineers is not political, and that the inclusion of politics into design is improper, but to ignore the wealth of work that has been done on the political nature of the design of technology and to deny that there could be political aspects to design is to do a great disservice to our students, and indeed to the entire community that must live with the designs that these students will go on to generate during their careers. Langdon Winner[15] has argued quite eloquently that many artifacts are inherently political in nature and others are political through the intention of their designers. One need not agree with Winner’s arguments (and certainly many do not) to introduce students to them so that they become aware of the mere concept that
design is a political activity, and can begin to make their own decisions as to the relevancy and importance of such ideas to their own work and careers. Certainly our students need to understand good business principles if they are to work in industry, but then should they not also understand the relationship of engineering to business?

Corporate engineers are in something of a strange position. We like to think of engineering as a profession, but sociologically it is not.[16,17] Most engineers are not individual practitioners, but are employees with responsibilities towards the company that pays their salary as well as to the public that will use the devices and objects that they design. Calls to restructure engineering so that a professional degree is needed before someone can call herself or himself an engineer have been made for at least the last 30 years, but without the support of the companies that employ most engineering graduates such a move has not been made. Moreover, since such a move is not in the best interest of most companies, it is unlikely that a change will come any time soon. Engineering has typically existed in an uneven partnership with business, and engineers have been quite harshly criticized for the role that we play vis a vis business.[16,18,19] Some engineers respond with defensive or apologetic tones, saying that as engineers we cannot and should not try to become political, and that the external critics are naive for thinking that engineers have the ability to do anything to enact change.[14] Any inability to enact change that engineers have stems from our very belief that we cannot do it, and we continue to pass this message implicitly and explicitly on to our students. As long as engineers continue to believe that we are not political in our work, we will remain subordinate players in the corporate structure and engineering will continue to exist as a pseudo-profession.

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Engineering educators should use the increase in the design content in their programs as an opportunity to expand students’ perspective of design. We rightfully demand that our students use a methodological approach to design, while making use of sound engineering and economic principles, but our inclusion of social issues is rarely more than a few lectures on engineering ethics and safety and liability. Engineering students should be introduced to concepts that explore their work and their chosen field in a social context. There are many issues that can be introduced in the context of engineering design, I present here what I feel to be some of the most significant ones, but this is by no means an exhaustive list. The goal is not to tell our students answers to these questions, but to let them know that these are issues for debate, and that the decisions they make as designers will have an effect upon more than corporate profit.

The Role of Engineers: Professionals vs. Employees

What does it mean to be a professional? Are we as engineers primarily responsible to the companies that employ us or to the customers that use the devices that we create? These are neither simple nor easily answered questions, but they are certainly worthy of debate. If engineers are to consider themselves to be professionals, then they must consider the issue of being responsible to multiple clients whose best interests are not always going to be congruous. If we consider the way that most capstone design courses are organized, then the message that we are sending to our students is that they are employees and that their responsibility is first to the company that pays their salary. I know some engineers that believe this is true, I know others that do not, but rarely have I heard the issue raised before a group of students, much less in the context of a design project on which they are working. Considering such issues can add concreteness to issues that are difficult to discuss meaningfully with engineering students such as engineering ethics and social responsibility. Introducing such thinking in the context of design will make young engineers more conscious of the role they play when they develop new devices and technologies.

The Cultural Context of Design

Devices are neither designed nor used in a vacuum, yet engineering students rarely are introduced to the concepts of how people interact with technical objects over the course of a normal day. One view of technology is that it is just a collection of things. Objects and gadgets, or tools that people use in their work (or are used in lieu of people in work). A broader view of technology is the interaction of people and things.[20] With this definition, the technical objects must be considered in the context of the social organization and the cultural understandings of the people that interact with them. Issues of use, maintenance, and appropriateness of a design take on much larger implications if the social and cultural context of a device’s use is considered.

Even the most fundamental exploration of these ideas can make students better designers. In his book The Design of Everyday Things, Donald Norman[21] demonstrates that frequently the difference between a good design and a bad design is how intuitive the object is for the uninitiated user. Good designs imply how to use them properly. Bad designs send mixed, misleading, or downright incorrect signals. My favorite of Norman’s
examples is the design of doors that do and do not imply whether they should be pushed or pulled, and at which side force should be applied. Another factor in a successful design is often how well a device conforms to the normal patterns of the user. Designs that take into account how people do their jobs or tasks are well received, while designs that try to force the user to conform to a new method tend to lead to user frustration and devices that sit unused. Put another way, good designers take into account the existing organizational and cultural habits of their customers or clients when designing devices for their use.

In our increasingly global economy, engineers must understand the real cultural differences that can exist between themselves and their potential customers or clients. Can you design an object for global use and expect it to be received in the same manner throughout the world? If not, then how closely must you work with or understand the culture of your clients or customers before you can provide them with the best design for their specific needs? Realizing that technology is the interaction of people and objects, rather than just objects will give engineering students a better chance of designing solutions to problems that take advantage of the skills and preferences of their users.

Work and Diversity Issues in Design

Quality of work and quality of life are issues that engineering students should consider in the context of their designs, as they have the potential to have profound impacts among a diverse group of people. In the context of engineering design, there are many great issues and a wealth of work regarding the effect of introducing new technologies into the workplace.[18,22,23,24] When a new device or technique is designed, how will it be implemented? How will it affect the workers who must implement it or are expected to use it on a day to day basis? On a broader level, how do technologies affect communities? If technology is left at the level of devices, then students do not see the organizational side of design, both how existing organizational structures affect and are affected by design. When they are introduced to the idea of technology as the interaction of people and devices, however, they will consider entirely different solutions to their problems. My experience is that students will take a broader and more creative approach to design solutions if they are aware of the human element at all levels.

Considering the people who will build and use a design is relatively easy compared to the task of considering whether there are biases in a design, yet the consideration of such issues has value for engineering students. Many schools require students to take diversity courses on race and gender in order to graduate, but most engineering students do not see how such issues apply to their own work. For these issues to have meaning to students, they need to become part of the context of the students’ work in their field. Do characteristics such as the size of or available features on a device represent a bias on the part of the designers? Studies done on the development of tools and microwave ovens raise the possibility that such biases might exist in design, and not due to intent on the part of their designers.[25,26] Even cursory examination of the current problems with air bags, or the attachment point of the shoulder portion of seatbelts, which only recently became adjustable on a wide number of cars, will bring to light an interesting discussion of choices and compromises that must be considered in design when diversity is raised as an issue.

The Political Nature of Design

Are technical devices neutral or are they political in nature? Langdon Winner[15] defines the politics of technology on two levels: those technologies that are formed with a distinct political purpose in mind, and those technologies which by their nature are implicitly more compatible with one social or political organization than another. While the former case is interesting and worth considering, it is the latter case that raises the serious questions for students. When students undertake their designs, they should ask themselves what social organization are they implying with their design? Does their design fit into the existing social structure smoothly, or does it advocate change, and if so, in what manner? Even if the conclusion is that the design does not have any, or any significant political implications, it makes students aware that they are designing in a social context, and that the impact of the technologies they develop may be felt in ways that were not considered by the designers if the designers think of technologies merely as devices. Engineers who are more aware of the social context in which they work will develop designs that are more appropriate for the communities in which they live and work.

The Importance of the Context of Engineering Design

It is not enough to merely introduce issues of cultural, social, and political nature to engineering students. These issues must be introduced in the context of engineering design. Students have a tendency to struggle with or disregard issues that they cannot relate to their own work. By introducing social, cultural, and political issues in the context of their own project work, rather than in courses unrelated to engineering, or even as case
studies that many students believe are specific to someone else’s work, we can demonstrate that these issues do affect and are affected by design. The more that students see how their own designs are taking place and being implemented in a social context, the more they will understand that all design takes place in a similar setting.

Another issue for expanding our teaching of engineering design to include social issues is how do we teach the material? While this is an obvious opportunity to work with faculty from other disciplines, as has been done successfully at least on a trial basis[27], it is important that these issues be part of engineering design taught, or at least co-taught by engineering faculty. We need to let our students know that these are serious and real issues that will, and should, affect their approaches to design and their careers as engineers through our own involvement. When we rely wholly on social scientists to cover these issues in elective classes, we are sending a message to our students that social, cultural, and political issues are not important and are not part of engineering design.

Engineers should understand the context in which they are designing, and the social, cultural, and political aspects of their work, as well as the technical and business aspects. If engineering graduates are to be good designers as they advance in their careers, then those of us who are teaching them design need to introduce them to a broader spectrum of issues in the context of their engineering design experiences as undergraduates. The design experiences that engineering students have in school will shape their thought styles and affect their approach to design throughout their professional careers, and right now many students graduate with a narrow concept of design. If is my belief that introducing students to a broadened perspective on design will make them better designers and better engineers. Moreover, I believe that if more engineers come to think of the work they do as taking place in a diverse social context, engineers will become more active and involved members of the communities in which they live and work as well, and engineering will become stronger as a profession. Instead of lamenting that engineers are misunderstood and unappreciated, we should be encouraging our students to take the steps to understand their own roles in society more clearly, and as they do, so shall society begin to understand what it is that we do as engineers.

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