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Reframing Engineering Capstone Design Pedagogy for Design with Communities

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Abstract

With engineers graduating into a global economy, it is no longer sufficient to teach students about design for manufacturing or reliability alone; they must be taught to design with humans, not simply for humans. Students can fail to incorporate the human aspect of design due to the initial framing of the problem as taught in current engineering design methodologies. Several engineering programs are integrating the concepts of Human-Centered Design (HCD) into their curriculum to aid in these framing gaps. This paper compiles the programs already encouraging design with communities and determines which methodologies are sufficient for empowering students and communities to collaborate together in mutual respect. Brief suggestions of the conceptual, methodological and pedagogical frameworks developed by these programs and potential areas of improvements are additionally investigated for revising the student-community relationship

Introduction

This paper presents a programmatic review of several engineering capstone courses and their methodologies for incorporating communities in the design process. Teaching students to design with communities and not for communities is dependent upon the context of the design process. This paper addresses the pedagogy of social engineering in the capstone design projects rooted in the framing of the design process for collaborative creativity.

The programs that enact multidisciplinary curriculums are exemplar in satisfying the ABET a-k guidelines. Institutions of higher education that additionally use multi-year projects and employ design progression though the undergraduate curriculum have more success in generating projects that have lasting effects on the communities. Due to the long-term commitment of the students to a specific project or community, there is greater potential for more social interaction and communication between the students and the communities as equal constituents collaborating to solve the same problem.

The coursework and teaching objectives for specific courses feeding into the Senior Design programs offer great insight into a more human-centered design process. The scope of the developed design process is framed around human interaction and communication with delineation between the communities and end-users. Through these courses, the project-based learning objectives of an engineering capstone program begin to specifically focus on the community aspect of engineering as an explicit "Design with Communities" pedagogy.

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Human Centered Community Development

The second edition of the Human Centered Design Toolkit allows for a definition of Human-Centered Design as:

"Human Centered Design (HCD) is a process and a set of techniques used to create new solutions for the world. Solutions include products, services, environments, organizations, and modes of interaction. The reason this process is called 'human-centered' is because it starts with the people we are designing for."[1]

Current engineering curricula do not necessarily focus on the human aspect of teaching. Instead they focus primarily on the technical aspects. While these technical aspects are of extreme importance for meeting ABET accreditation and producing technically competent engineers, it seems to be missing the mark on the design front. The gap comes when engineers fail to ask the primary design questions. "Who are they really designing for? Are the designs meeting the needs of these entities? How can we bring the human-factor back into engineering so that there is a marriage between technical prowess and user needs; or even better, with a whole community of users and their needs?"

The HCD Toolkit seeks to address this issue of the target audience by using three "lenses" to qualify and address the needs of the community. The first lens is a desirability lens that tackles what the people want. The second lens speaks to what is feasible organizationally, academically and technically. And the last lens operates under the guise of viability from an economic standpoint. In combination the design must deal with what people want, what they can do, and what they can afford. The Toolkit asserts that the most successful projects are created with a combination of all three lenses in a manner befitting a Venn Diagram (Figure 1). [1]

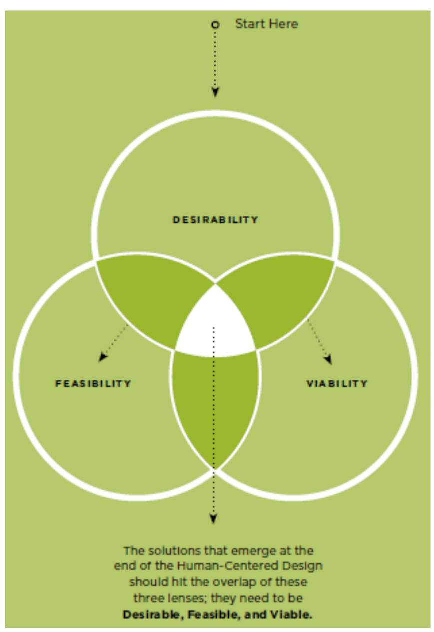

Figure 1 The three lenses of HCD as taught by IDEO[1]

HCD and Community Development Pedagogy

In order to contextualize HCD in the current engineering curriculum, it is necessary to establish how exactly engineering students define HCD. Zoltowski et al. found that students' understanding of HCD is based on the various ways students comprehend and experience HCD as a need.[2] The research seeks to answer (a) how students experience HCD and (b) how well do students integrate HCD into their design projects once they understand the design methodology.

By differentiating between whether the project was design-led or research-led the students were more open to the idea of altering their original project approaches. The authors found through phenomenography they could categorize how students learn HCD. The outcome of a study with 35 students produced 7 different types of learners:

1. Technology-centered
2. Service
3. User as Information Source input to Linear Process
4. Keeping the Users' Needs in Mind
5. Understanding the Design in Context
6. Commitment to Involving Stakeholders to Understand Perspectives
7. Empathic Design

Zoltowski et al. recommend a combination of all the various methods in order to reach the greatest number of students in a given course.[2] Figure 2 shows a pictorial representation of where the various design learning types fall based on interviews with the students when asked open-ended questions. Ideally, for community based design the most effective learners would be a combination of types 3-7. In this combination, the designers must use their skills for understanding and also for appreciating the user's needs in the design development process. This appreciation is not acquired through simply learning the design process or through technical skills. It is a balance of the technical knowledge with communication skills and practical application.

Zoltowski et al. additionally suggest that there are several important steps to creating a successful HCD curriculum. First, a specific vocabulary should be considered so that the students do not make any assumptions as to what is actually meant by specific words or phrases in both the design and the humanitarian arenas. With a specific vocabulary, the students avoid misconceptions, generalizations and ultimately poor designs. Students should be given time to reflect on their past experiences and how their HCD project fits into this larger experience picture. By having students write, journal or record their events they can formulate questions and ideas as to how their interactions or suggestions altered the design. Brainstorming and interactions in groups are strongly encouraged so students with various domains of knowledge can potentially increase the level of creativity in the product. As a final suggestion, teams should be as multidisciplinary as possible so that the experience for the students can be enhanced.

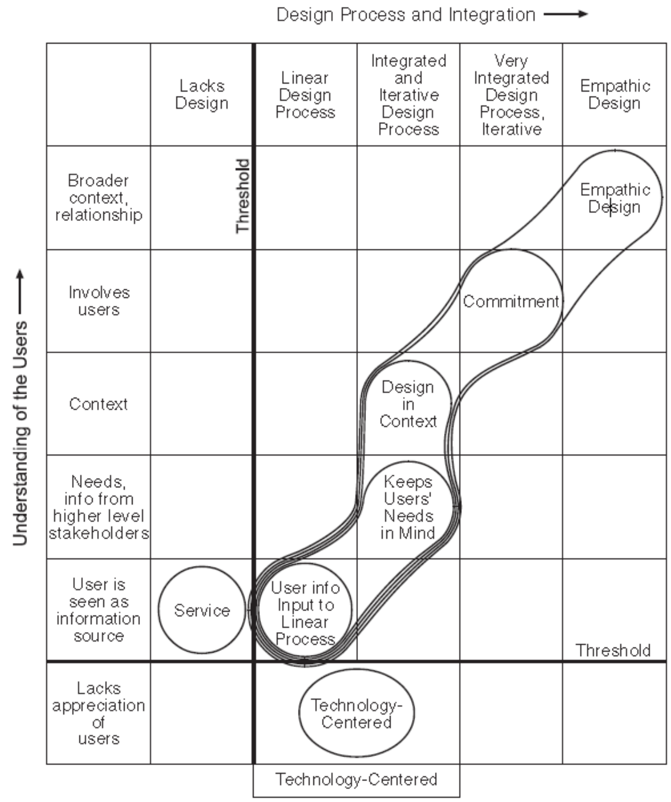

FIGURE 1. Outcome space for students' ways of experiencing human-centered design.

Figure 2 Learning relationships for HCD as experienced by students[2]

Dolan believes that the core of community development can be broken down into three topics: social support, social justice, and social capital. [3] Social support is the ability of a community to create and sustain networks and memberships vital to maintaining everyday life during times of crisis and nominal living conditions. Social justice is ensuring equity of resources and rights across all the community citizens; while social capital describes the bonding and bridging of a community. Dolan suggests that all three concepts be taught together and should be presented as a cohesive theory of successful community development. The curriculum should aim at students understanding the many variables in community development and the ever-changing assessment criteria are community-specific. However it should be noted that the suggested pedagogy here has yet to be incorporated into a design course.

Through government funded senior-design programs, Walsh et al. focus on gap theory within the community designed product.[20] This study gauges how well the products produced from engineering senior design courses meet the needs of the community based on the engineering design curriculum. These researchers suggest that the overall satisfaction of both the community and the students are tied into the expectations and experiences of all parties involved. Final suggestions encourage feedback from the community and the teams that could be included in the curriculum at various points throughout the design process.

Program Evaluation Criteria

Engineering programs must adhere to the ABET a-k criterion to achieve their programmatic accreditation. It is assumed for the purposes of this research that all the programs reviewed meet these criteria and will continue to do so going forward. The criteria for this paper are centered on the incorporation of the human design factors in the engineering design curriculum and the three topics suggested by Dolan (social support, social justice, and social capital).[3]

Bridger and Luloff offer a set of five criteria that defines the criteria of a sustainable community development project. Their criteria includes local economic diversity, self-reliance, decreased energy usage and waste management, enhancement of biodiversity and stewardship of resources, and social justice.[4] Dr. Juan Lucena of Colorado School of Mines (CSM) has incorporated these criteria and built them to be more inclusive for engineering curriculum specifically.[5] Table 1 outlines the sustainability criteria with the revisions as provided by Lucena. It should be noted that technology has the capability to impact each of the criteria.

Table 1 Criteria for Sustainable Community Development (SCD)[4,5]

Criteria Name	Specific Criteria
Local Economic Diversity	Capacity building and diverse job creation
	Revenue re-invested locally
	Creation of new products and markets
Self-determination	Autonomy in decision-making
	Reduce dependency from external capital, materials, expertise
	Autonomy in problem definition and solution
Reduce Energy	Incorporate renewables, reduce fossil fuels
	Improve efficiency, curb consumption
	Include storage capability
Reduce/ recycle materials	Design for cradle-grave (replace, repair, durability)
	Reduce toxic materials while increasing non-toxic, organic materials
	Easy recycling and responsible disposal
Social Justice	Respect and enhance human rights
	Enhance opportunities equally
	Increase resources equally
	Reduce risks/ help equally

Local economic diversity encourages the formation of new markets while encouraging diversity in these novel markets. By exhibiting a wide range of markets, the communities in question avoid relying too heavily on one product alone that results in additional avenues for income and product resiliency. This criterion also includes the training of the populace and subsequent job creation from the use of the product and technology.

Self-reliance is dependent on the local economic diversity, but is stanchly different. Autonomy is the ability of a specific community to insulate itself from external economic and political entities. An offshoot of autonomy is more efficiency in the decision-making process and the factors impacting the local community. In layman terms, “the community has skin in the game” with this criteria.

The material resources available to developing communities are accounted for in the reduction of energy/recycling and waste management criterion. The physical resources such as construction substance are deemed equally crucial to the design as energy supply, and the disposal of the product.

Biodiversity and stewardship of natural resources accounts for the environmental surroundings the communities. The local environment, non-human species and natural resources are considered in this criterion.

The final criterion, social justice, greatly accounts for the human factor of the SCD projects. Lucena has attempted to make the concept less broad by providing a definition for social justice:

"A technology (artifact, system, process, project) is socially just if it contributes to the equal or fair distribution among community members of rights, opportunities and resources while reducing risks and harms in a given locality." [5]

Specific Programmatic Reviews

Program specific reviews were conducted on seven (7) programs for their inclusion of human centered design in their design curriculum. The use of the criteria for community development in their curriculum was based off the values of Bridger and Luloff [4] and Lucena.[5] The programs that included the criteria are labeled in Table 2 with an additional column for specifically teaching social justice as outlined in the previous section. [4,5] It should be noted that the focus of this paper is on the undergraduate curriculum so all graduate programs have been ignored.

Table 2 Programmatic review of programs conducting sustainable community development in practice

Program	Soph. Level Design Course	Jun. Level Design Course	Senior Design Capstone	Social Justice
MIT - GEAR & Tata Lab	●	●	●	●
Ohio State	●	●	●	●
Colorado School of Mines	●	●	●	●
UMD - GEMS	●	●	●	
Penn State - HESE			●	●
Purdue			●	●
Michigan Tech			●	●

At Michigan Tech, six specific programs have been supported in the hopes of training the future engineers for international sustainable development.[6] The D80 program is an umbrella for the (a) Engineers without Borders, (b) Aqua Terra Tech Enterprise (ATT), (c) International Sustainable Development Engineering Certificate, (d) International Senior Design, (e) International Sustainable Development Engineering Research Experiences and (f) Peace Corps Master's International. Each of the programs are discussed in a bit more detail below.[7]

The objectives for all the programs is focused on (1) students demonstrating substantial knowledge of economic, societal and environmental factors and their interactions in engineering for sustainable development, (2) students develop the ability to analyze the balance between economic, societal and environmental factors in an international situation, and define problems and solutions according to that balance, and (3) students show a predisposition to view engineering for the developing world through the triple lens of economic, societal and environmental sustainability.[6]

The International Senior Design (d) and the Peace Corps Master's International program (f) at Michigan Tech, demonstrate that the three objectives are effective in teaching sustainability to students. A post assessment of the programs shows that the students develop a greater knowledge base of sustainability through Project Based Learning (PBL) of international projects. The ability outcome demonstrates that students can understand and apply the sustainability concepts but tend to neglect at least one of the three pillars of environmental, societal or economic sustainability in engineering application. Additionally by encouraging international immersion into communities, the predisposition to economic sustainability could be encouraged.[6]

Much like other EWB chapters, the EWB program at Michigan Tech (a) is run by students. There are several faculty advisors and one professional mentor, but the organization is primarily run by students on a completely voluntary basis. The program has no formal curriculum and is based solely on PBL. The ATT program (b) focuses on water projects primarily by simulating a small engineering consulting firm. It is led by one faculty advisor with the support of several other advisors. The program runs from sophomore year through senior year as a continuous course sequence.[7]

Mihelcic et al. and Paterson discuss the International Sustainable Development Engineering Certificate programs (c) and (e) developed at Michigan Tech to train undergraduates to perform engineering on the global scale.[7,9] In this program, engineers are encouraged to participate in international exchanges where the students can act as both a technocrat and a public-service agent. The Sustainable Futures Model (SFM) is shown in Figure 3.

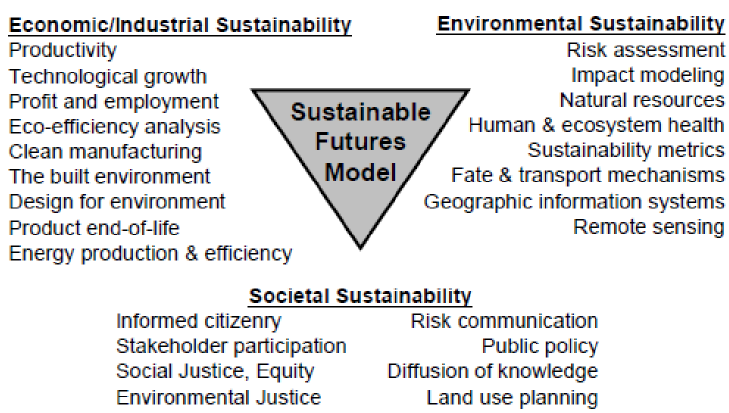

Figure 3 Sustainable Futures Model (SFM) of sustainable science and education. [9]

The SFM approach at the undergrad level includes programs such as EWB and an international senior design program focused on service-learning. For the senior design program, the main goal is to allow students an opportunity to have a project-based learning experience while tying in the ABET criterion throughout the design and development stage. This specific capstone project has historically included students from 5 different engineering disciplines and 2 non-engineering disciplines.

The International Senior Design (d) course is a three year long program that begins in the sophomore year and runs through senior year. The project for this program requires the design and construction of an engineering project in a developing community while working on multi-disciplinary teams. The program is supported by three faculty members who have formed networks with international NGOs and governmental organizations in countries such as Bolivia and the Dominican Republic.[7]

In a vertically integrated program, the International Sustainable Development Engineering Research Experiences program (e) pairs doctoral and undergraduate students together on an international design project. The exchange continues for one month in the communities being served with a final report handed over to the faculty and the communities being served.

At Michigan Tech, Huntzinger et al., performed a study on the current engineering curricula of ESD and identified the need to alter the current engineering approach.[10] The authors have identified the gaps in engineering pedagogy as relating to systemic sustainment and societal values. The change must involve multiple disciplines and be a grass-roots type movement working with the communities to be effective. Huntzinger et al. discusses four types of responses to incorporating sustainability into the engineering education, ranging from no action at all to a systemic overhaul. The most common level enacted at the moment is to marginally acknowledge the needs and teachings of sustainability or to ignore them entirely. The second level involved superficially adding the sustainability at a minimal level in additional to the current engineering curriculum. This method gives a short fix but provides no lasting results. The third level entails that sustainability be built into the curriculum and taught congruent with the engineering fundamentals. The last level is a complete overhaul of the engineering curriculum to be based upon sustainability principles.

The last program offered under the SFM umbrella (e) is both an undergrad and grad certificate program. The undergrad program includes topics such as ethics, resource equity, technological/societal interactions, environmental engineering and engineering materials at the global level. The undergrad certificate concludes with the aforementioned international senior design program. The graduate level certificate includes those topics covered at the undergrad level but additionally includes policy, societal, economic, environmental and industrial systems.

A specific Humanitarian Engineering program is hosted at Penn State (HESE).[29] Their program incorporates a Social Entrepreneurship factor with the Humanitarian Engineering. They have intentionally established their program to perform international community projects. The courses pertinent to the design aspect of engineering education are: (a) Social Entrepreneurship, (b)

Projects in Humanitarian Engineering, (c) Design for Developing Communities, (d) HESE Field experience and (e) HESE Reflection and research dissemination. While these are the main cornerstones for the programs, there are options for additional minors, independent studies, thesis–based research and individual projects.[11,12]

Many of the projects undertaken by the HESE program are multi-year, cross-discipline projects that entail the aid of people outside the engineering department (i.e. business school, law school, etc.) The projects are also vertically integrated to include students spanning the academic rungs from freshman to doctoral candidates. Each project includes a faculty lead, but it is mainly managed by students as the faculty act as the long-term point of contact for the communities.

At Purdue University, a multi-disciplinary engineering design program (EPICS) has been operating for almost 20 years. Coyle et al. have provided an assessment of the program from both the student and the community viewpoint.[13] The students and the community are polled for their project needs, while design fulfillment allows for students to get a first-hand experience of the design process. The EPICS program is vertically-integrated, multidisciplinary and potentially multi-year allowing for students to experience all phases of the design process. In these projects, the community operates as the customer encouraging students to practice customer-driven design. With these projects, the students generate products that are sustainable and community oriented. Through several curriculum iterations, the program has grown to include students from all engineering disciplines with a myriad of engineering projects that include various degrees of community involvement.

The GEMS program at University of Maryland has been practicing the multi-year, multidisciplinary concept for a number of years now.[28] As seniors in high school, students are identified as candidates for the program when they apply to UMD and express interest in performing undergraduate-team research. As freshmen the students develop a research topic that could have a societal impact, usually in the vein of science and technology. Their sophomore year, the teams develop a research proposal based on an approved research question and perform a literature review. In the third year, students are encouraged to study abroad and continue to perform research on their approved topic. In their final year, students are required to write a thesis as a team and present their findings at an Undergraduate Research Day.

While the GEMS program is not specifically for engineering students alone, they do attempt to emulate the projects students will face in industry by going through all the phases of a design project with the business aspects included. The projects approved all must retain an aspect of societal awareness and concerns for the public good with their degrees once awarded. The structure of this program defines itself by the programmatic ability to span the entire education of students over the course of their undergraduate degree with a single project that can be completed in eight semesters (6 semesters of actual work) with the support of various faculty across the campus. Additionally it acts as a feeder for graduate schools since students already can perform research, data analysis and thesis writing.

The TATA Center at MIT has created projects in their undergraduate and graduate programs that are solely focused on meeting community needs. Their five areas of research are in energy, health care, agriculture, water and housing/infrastructure.[26] They are developing technologies and system solutions that take into account the social, environmental and political implications. A quick review of the projects listed on the website show that they are all multidisciplinary in nature. The undergraduates are included in the program as REUs under the direction of Masters Fellows or PhDs.

The GEAR lab also at MIT is a great example of engineering HCD. [25, 27] Under Dr. Amos Winter, the lab focuses on HCD at the undergraduate level with dedicated courses. The topics covered include the gambit of design processes, business and technology dynamics in design, communication and HCD. The students of Dr. Winter's course are paired with industry partners and other stakeholders to develop products for use in the developing world.[30]

The Humanitarian Engineering (HE) program at Ohio State University marries the design process with both humanitarian engineering and social justice. The program offers dedicated programs at both the undergraduate and graduate level with minor options. Additionally the HE program can be paired with other programs at OSU that have a global engineering focus. The HE department encourages students to use projects throughout their engineering coursework containing the HE dynamic.

At Colorado School of Mines (CSM), the Humanitarian Engineering (HE) program offers undergraduate students the option of pursuing tailored interests.[22] Undergraduate students can select from (a) Area of Special Interest (ASI) in Humanitarian Studies, (b) minor in Humanitarian Studies, (c) ASI in Humanitarian Engineering, (d) minor in Humanitarian Engineering, or (e) a certificate minor in Humanitarian Engineering. The minor programs require 18 credit hours of coursework, while the ASI require 12 credit hours and the certificate minor requires 27 credit hours. The programs all necessitate an introductory course (Nature and Human Values) before allowing the students to diverge off into their fields of interests.

The ASI in Humanitarian Studies (a) is designed for students in the Engineering Divisions (mechanical, electrical, civil and environmental) or for students not seeking degrees with ABET accredited engineering degrees. Students take courses from both the Liberal Arts and International Studies (LAIS) department and the Economics and Business (EB) department. The minor in Humanitarian Studies (b) is targeted for the same group of students as the ASI except with two additional courses. The ASI in Humanitarian Engineering (c) is designed for students not in the Engineering Divisions but are still from an ABET accredited engineering program within CSM. This option focuses more on human development issues. The Humanitarian Engineering minor (d) is essentially the same as (c) above expect with a greater coursework requirement. The Certificate minor (e) is similar to option (d) but also allows students enrolled in the Engineering Divisions (mechanical, electrical, civil and environmental) to undertake a

Humanitarian Engineering senior design project. Additionally, students are encouraged to participate in internships that lend themselves to humanitarian work with partner NGOs.[22]

Community Development Pedagogy

This section attempts to document how the various institutions are endeavoring to meet or keep ABET accreditation with the various programs. Specifically, the ABET criteria a-k has been researched briefly but the main focus is on how Criterion c is accounted for (an ability to design a system, component, or process to meet desired needs with realistic constraints such as economic environmental, social, political, ethical, health and safety, manufacturability, and sustainability…) .

Passino has done extensive research into the code of ethics of various professional engineering societies. He calls for the social factors to be specifically included in the code of ethics. It is suggested then that professional organizations and universities specifically work together to change the professionalism of engineers. In the same vein as lawyers and doctors work, engineers should be required to perform some form of "pro bono" work. Passino argues that the volunteering of engineers should be required to continue their certification as professionals. The OSU Engineers for Community Service (ECOS) are already performing such through Service Learning with positive results.[15]

At Michigan Tech, the six programs specifically account for the ABET accreditation with the Criteria a-k. Paterson notes that there are several criteria that are still a challenge to meet. These challenges include: an ability to function on multidisciplinary teams; and understanding of professional and ethical responsibilities; ability to communicate effectively; the broad education necessary to understand the context of engineering solutions; recognition of the need of life-long learning; and knowledge of contemporary issues. Easier criterion include the ability to apply knowledge of mathematics, sciences and engineering; ability to design and conduct experiments; ability to identify, formulate and solve problems; and an ability to use techniques, skills and tools necessary for practice.[7]

The HESE Program at Penn State takes design to the next step. In yet unpublished papers by Metha, the authors discuss the importance of commercializing products and services designed for developing communities.[11,12] In order to be successful at this venture, engineers will need to consider many more social factors than they are accustomed to, such as reflection, ethical decision-making and grassroots diplomacy. The paper provides several case studies that show in much more detail the praxis of the aforementioned concepts. Yet the main focus is how service learning can be turned into a high-impact social venture that produces social entrepreneurs.

According to Metha, the design programs in action at many universities are all teaching design concepts, but not the humanitarian aspects. These programs do not effectively educate students on ethical decision making, how to build long-lasting equitable relationships with multi-sectorial partners or how to incorporate indigenous knowledge. To counter at least the ethical gap, the author has proposed that case studies followed up by group discussions be used more often. In order for the decision making process to be successful and uniform for all cases, the following seven steps have been suggested[11,12]:

- ✓ Step 1: Determine the facts in the situation
- ✓ Step 2: Define the Stakeholders
- ✓ Step 3: Assess the motivations of the Stakeholders.
- ✓ Step 4: Formulate (at least three) alternative solutions
- ✓ Step 5: Seek additional assistance, as appropriate
- ✓ Step 6: Select the best course of action
- ✓ Step 7: (If applicable) What are the implications of your solution on the venture

Grassroots Diplomacy speaks to the cultural norms and etiquettes of a community. Metha suggests that students again be given case studies to understand the specifics of various communities. For effective interaction with the communities and to formulate relationships of mutual trust and understanding, it is imperative that engineering students be cognizant of these cultural differences. Much in the same vein as the ethical decision-making, a standard procedure for effective interaction was outlined:

- ✓ Step 1: Determine the facts in the situation
- ✓ Step 2: Define the problem and the stakeholders
- ✓ Step 3: Determine and distinguish between the personal and professional motivations of the stakeholders.
- ✓ Step 4: Formulate (at least three) alternative solutions
- ✓ Step 5: Seek additional assistance, as appropriate
- ✓ Step 6: Select the best course of action –
- ✓ Step 7: List the exact sequence of actions you will take to implement your solution

In addition to the unpublished article, the HESE program at Penn State has several other courses. The Social Entrepreneurship class places students in multidisciplinary teams for a specific project with only a slight focus on the engineering design. Over the course of the semester, the students need to develop a business model and implement a business and marketing strategy for social ventures for use in the US, Africa, South Asia or Central America. The main objective of this course is to make the students value creators. Yet these creators need to work within the confines of political, social and economic constraints on both the macro and micro scale. Thus, the students are introduced to systems-level thinking with a special emphasis placed on working with the customer.

In the 452 HESE course, the projects in HE for community development are a continuation of the previous course. In this specific course, students are still working across disciplines but now the students are required to assess the engineering of their business plan. They are utilizing HCD and other "design for X" type of methodologies. Broken into two separate sections, one group focuses in the international applicability while the other focuses on the American context so as to cover both the national and international feasibility. [11,12]

The Field Experience course at Penn State finally provides the hands-on learning aspect of teaching. In this course, the students are finally able to travel, perform fieldwork and experience what they have been prepping for in their previous classes. Here they are meeting their designated communities and seeing their projects put to the test. Any design changes that result must be performed real-time while the students are in the field. This course would embody the HCD pedagogy in practicum. [11,12]

The final Penn State HESE course is a reflections class. In this course, the students are asked to write a report that is the culmination of their experiences over the past few semesters. In many cases, this turns into a dissertation of experiences, lessons learned, happy memories and what could be more effective in the future. In this final course, the ethical decision-making, grassroots diplomacy and research dissemination are three tracks this reflection can take. As part of the course, publishing rules and regulations are included. [11,12]

Morris et al. point out that engineering is a very technical profession taught at a sub-system level with more depth than breath. The authors are suggesting that the curriculum be pulled up to the systems level of teaching and touch multiple technical areas but remaining superficial. Table 3 captures the gist of this argument as to keep it broad and incorporate all the technical learning of individual members into a team environment.

Table 3 Comparison of engineering and design pedagogy[17]

Pedagogy	Engineering	Design
Subject matter	Itemised, modular	Integrative, holistic
Subject range	Narrow, deep	Broad, shallow
Delivery	Lecture-based	Problem-based
Career	Professional, employed	Vocational, self-employed
Creativity	Problem-solving	Problem-defining
Interface	Technology	Human
Projects	Theoretical	Applied

The Humanitarian Engineering course at OSU covers the gambit of potential engineering social topics.[24] The course covers the topics shown in Table 4 which all vital to framing an engineering project. The HE course is a single semester class to be offered in the spring that is the core of the HE program. Two more courses for the HE minor are grounded in Service Learning.

From the EPICS Design Process notebook of 2009, one of the key objectives for the diverse students is to have a firm understanding of the social context in which the project partner operates.[18,19] This means ensuring the students ask a myriad of questions that account for social, cultural, economic, political and organizational questions that allows for a complete understanding of the design problem. Additionally, students must understand the social challenges that are trying to be satisfied with the current design project. Questions that differentiate the user from the client, and how their design could impact the social constructs are encouraged.

Table 4 OSU Humanitarian Engineering Course Topics

- Poverty and Development
- Principles of Humanitarian Engineering
- Social Justice
  - Religious SJ
  - Engineering Ethics and SJ
- Development Strategies
- Engineering for the Poor, Weak and Developing Communities
  - Communities and Technology
  - Sustainable Design
  - Failure Mechanisms and Unintended Consequences
- Universities and Humanitarian Engineering
  - HE Projects and Coursework
  - Volunteer and Career Opportunities
  - Engineering Student Organizations
- Humanitarianism via the Engineering Enterprise
  - Corporate Social Responsibility
  - Social Entrepreneurship
  - Engineering Ethics and Manufacturability
  - Globalization
- The Evolution of SJ and the Global Engineer

The design process is being taught in the typical fashion but the students are required to identify the user and customer needs at each step of their process. In this program, the major design milestones are called gates where the students themselves (with client input) establish evaluation criteria for their design project. The criteria here must include physical, functional/operational, environmental, economic, legal and human factors. Of special interest, is the human factor which takes into consideration the strength, intelligence, anatomical dimensions of the user and any physical limitations. Potential additions to the curriculum could be to consider the number of users and attempt to account for the incorrect use of the product during operation or maintenance as these factors directly affect the functionality and the front-end design. Once these criteria have been generated, the students score themselves and also accept the scores from the clients before incorporating any changes based on the criteria evaluation. The rest of the EPICS process follows the typical design game plan with reviews, prototyping, testing and ends with a final deliverable.

Returning to the MIT GEAR lab, students are required to learn the engineering design process with respect to HCD.[25] Dr. Amos Winters stresses the importance at the beginning of the course between the user and the client. This course is designed to include socioeconomic contents targeting the developing/ emerging markets. The deliverable for the course must be a tangible product that will be manufactured by industry partners once the term is over. The final objective of the course is to produce engineers capable of solving both the technical and the social problems of the developing world.

At Colorado School of Mines, a pilot class is underway for the sophomore and junior undergraduates of the mechanical engineering department.[21] Students have taken on a community based project that breaks the project into specific stages with gates of progress assessment. Each stage is constructed to have four different input/output with designated objectives. Figure 4 shows the grading and design criteria for stage 1, the conceptualization stage. This course focuses on the interdisciplinary nature of a community design project. The grading criterion for this course is based on class participation, group work and other such reports. It is a vertically integrated course built off the criteria of Bridger and Luloff [4] with corrections by Lucena.[5, 21]

The Senior Design program at CSM is a two semester course that includes civil, environmental, mechanical and electrical specialties. The multidisciplinary program encourages students to incorporate ethics and social implications by having all students complete a technical essay on their chosen design project. Additionally, all students are given the option of selecting a Humanitarian Engineering project to be completed at the end of the second semester.[23]

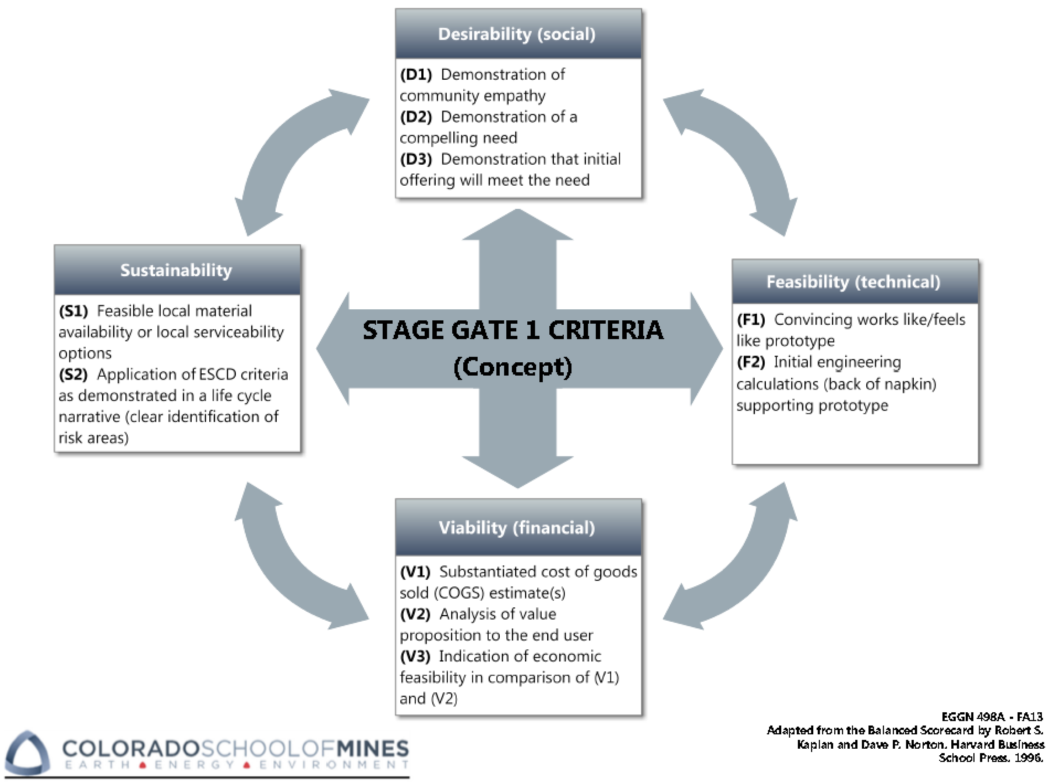

Figure 4 HCD process and objectives[21]

Conclusions

This paper attempts to meld design curriculum with the methodologies of designing with humans in mind. No longer able to design simply for humans, the problem facing new design engineers is how to exercise inclusionary design practices for a global market. As the opportunities afforded to students continues to allow for greater interactions with society, students need to develop a new toolset that uses both their technical and their social skills.

All the programs reviewed in this study offer various takes on the standard design pedagogies. The programs agree that interdisciplinary work across as many disciplines as possible is the most realistic representation of problems facing students outside academia. Although the type of interdisciplinary requirements and duration of the projects vary amongst examples, the cross-pollination of technical expertise leads to the fulfillment of the ABET a-k criteria.

With various programs offered across the country, it is up to the perspective students to decide what they value in their education. The culture of the programs and schools plays a large role in the final design approach and methodologies undertaken. Various design methodologies and diverse practices result in more gratifying products.

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