Design Thinking in Development Engineering

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"Development engineering" is a new interdisciplinary field that we define as creating solutions that improve human development in low-resource settings at a scale for large positive impact. We posit that design thinking [1] is the core of development engineering, but needs to be reframed for development applications to emphasize: 1) Incorporating development goals, constraints and opportunities; 2) Scaling for impact; and 3) Integration of novel sensors, experiments, and large datasets (e.g., from the Internet, satellites, mobile phones, etc.). We used this framing of development engineering as the basis for a newly formed Ph.D. minor and core courses in at UC Berkeley. This paper describes the foundational course in the program, elective courses and the theory and practice seminar. Lessons learned from formative evaluation are provided along with recommendations for improvement.

Keywords: design for development, development engineering, design thinking

1. Introduction

1.1. Design thinking in development

Design thinking [1-3] provides a rich human-centered toolkit for a deep needs assessment, a set of tools for creative ideation, and returns to its rich qualitative toolkit for iterative phases of rapid improvement. Figure 1 illustrates the design thinking model used at UC Berkeley [4] re-framed for development engineering. A design project would typically begin in the design research phase in the lower left quadrant and cycle clock-wise through the iterative design thinking process. Immersive user needs assessments (e.g., interviews and observations) would be analyzed to provide insights for framing the problem (upper left quadrant) and for developing imperatives and design principles (upper right quadrant) for concept development and prototyping (lower right quadrant). The cycle begins again when the concepts and prototypes are tested in the field with users, customers and stakeholders for rapid improvement (lower left quadrant again) and re-design.

Design thinking requires many iterations of design research (user studies and insights), ideation, prototyping and testing. During the course of a semester design class, for example, one would expect at least two full iterations, but encourage more, if possible. The starting point, however, may depend on where the project is in the product development process. For example, if the team is working on a project that has had prior user studies and has already developed preliminary concepts, they might want to begin with this solution in the lower right quadrant, but rapidly iterate by testing in the market and refine, or pivot as needed. This approach somewhat follows the "lean start-up" approach [5]. From a learning perspective, however, the students should also perform their own baseline user needs studies to complement prior work.

Design for development, in general, integrates appropriate technologies with goals of economic and social development [6-9]. To develop effective, scalable, and economically sustainable products and services in emerging regions, designers must understand the social factors and cultural contexts of the intended users and customers. Only recently have human-centered design methods been a driving force for development [10,11,12]. For example, Winter [13, 14] combines appropriate technology development with design thinking approaches to sustainable wheelchair design in developing regions. Wood and Mattson apply human-centered design research methods to assess customer needs and inform design on a range of projects in India and Peru [15, 16]. MIT's Amy Smith promotes a capacity building approach that empowers community members as co-designers during 3 to 5 week International Development Summits (IDDS). At IDDS, community members with expertise as artists, masons, mechanics, students, teachers, doctors, economists, priests, etc. create technologies to alleviate poverty [17, 18]. Stanford's Change Labs strives for large-scale transformations to solve humanity's major challenges in water, energy, climate change and social inequality [19]. IDEO, the world famous design consultancy firm, has started a non-profit, IDEO.org, specifically to "empower the poor" using "human-centered design to solve some of the world's most difficult problems." [20]

UC Berkeley's new interdisciplinary Development Engineering program [21] for students in economics, business, social sciences and engineering is housed in the Blum Center for Emerging Economies, with support from the USAID-funded Development Impact Lab [22]. Below we describe our model of design thinking for development, and then describe the foundational course in the program and the theory and practice seminar. Lessons learned from formative evaluation are provided along with recommendations for improvement.

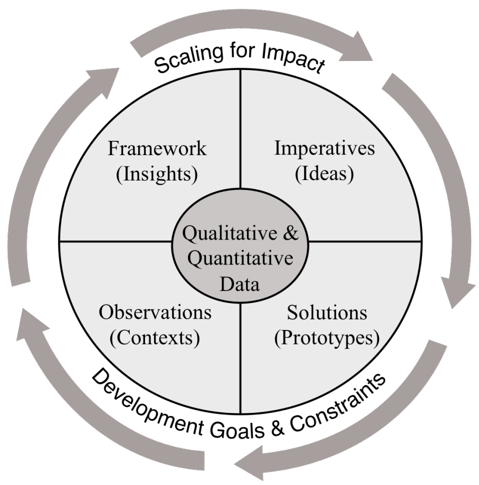

Fig.1. Design thinking in development engineering

1.2. Incorporating development goals, constraints and opportunities

The goal of development engineering – to improve poor people's lives at scale – affects all phases of the design process. The constraints facing the global poor also inform design of the solution and associated model for scaling [23]. In addition to the obvious constraint of poverty, poor regions typically suffer from "institutional voids"; that is, governments and markets that work ineffectively [24]. In most poor regions, the markets for capital, labor, supplies and distribution lack high-quality information, credible ways to certify quality, aggregators and market-makers that facilitate transactions, and trustworthy means to regulate and to settle legal or contractual disputes. In addition, the institutions and cultural norms that are present, such as gender inequality or ethnic discrimination, affect many domains of life [**Error! Reference source not found.**].

At the same time, developing regions have many opportunities. For example, the social goals of development engineering often attract donors and governments as potential funders or partners. Microfinance and community-level institutions such as women's groups can be particularly effective in development settings. Mobile phones are often distinctively prevalent. For example, Kenya has more advanced mobile banking than most of the 34 country members of the Organization for Economic Co-operation and Development (OECD).

It is critical that the user and customer needs research in development engineering cover these development-related issues. The needs assessment has to explore the challenge related to social goals as well as users' perceptions. For example, a needs assessment for a cooking solution must not only examine users' perceived needs, but also examine how inefficient cook stoves lead to deforestation and kill millions of people a year. If social goals mobilize more stakeholders (such as donors and governments), the needs assessment must also examine the needs of each stakeholder [23]. The needs assessment must address institutional voids; for example, most needs assessments examine if liquidity constraints are important, and existing sources of credit, timing of income and so forth. Similarly, gender inequality can be a challenge and mobile phones are an opportunity for almost every sector; thus, needs assessments typically must examine both.

Geographic distance is a barrier for many projects, and cultural distance can be even a larger challenge. There is no replacement for direct interaction with users in their own settings. At the same time, there are often low-cost substitutes that can help early-stage research: local experts, migrants who grew up in regions similar to those of the intended users, communication with local experts and users, etc.

Development issues can also provide stimuli for creativity. For example, many products will have to overcome liquidity constraints as the poor often have limited access to capital [25, 26]. Design engineers will want to brainstorm combinations of sales offers (e.g., installment payments or layaway), partners (e.g., microfinance institutions), timing of offers relative to income (e.g., selling at harvest), and other means to overcome liquidity constraints. On the opportunities side, designers will often want to consider the role of local groups (e.g., women's groups), microfinance, and mobile phones. Designers can also ponder how their solution can generalize. That is, if a solution fills an institutional void (e.g., by creating a cold chain for food), what other problems can the solution address?

Development issues also influence the process of prototyping, testing and redesign for rapid improvement. The process of rapid improvement must consider achievement of social goals as part of meeting customers' needs. The improvement process must also consider how well the prototype product, service and business model address the constraints of developing regions: poverty, remoteness, liquidity constraints, gender roles, etc. The plan for rapid improvement can also build on the strengths common in developing regions. For example, mobile phones can help in user surveys, mobile banking can often be used to test business models, and so forth, which leads to the topic of integration of qualitative and quantitative data below.

1.3. Scaling for impact

We posit development engineering should focus as much on concerns about scaling for impact as on the product or service itself. In rich nations, considerations of how to scale are important as well, but a well-designed product that meets a niche in the consumer market has fewer barriers to reaching markets than those faced in low-resource economies. As noted above, there are many institutional voids in poor nations that make it difficult for manufacturers to transport products, for consumers to trust manufacturers, and for vendors to process payments. The many constraints facing users in poor regions make it especially important for development designers to consider how to scale from the very start. In addition, a designer who solves a niche problem in prosperous settings can often make an economic return. The problems in poor regions are massive, and it is important for design engineers to focus on solutions that can solve problems at scale.

Scaling considerations show up in the needs assessment, framing, ideation, and improvement phases. During the needs assessment, designers must also examine all the issues of the business model, such as financing, supply chains, and distribution. We use the term "business model" to encompass public, NGO and hybrid models for taking solutions to scale. During the ideation phase, development engineering must also apply creativity tools in designing the business model. During prototyping and testing for rapid improvement, development engineers must quickly prototype the business model as well as the product or service. For example, consider the challenge: Why will consumers trust or desire my product? Rapid prototyping can include showing consumers potential marketing messages; running pilots in a few shops and seeing what messages and presentations increase sales; lending out free trials and measuring consumer response; and so forth.

1.4. Integration of Qualitative and Quantitative Data

Design thinking builds on rich qualitative tools [27,28] as well as a range of quantitative tools for testing [29,30]. We posit that a new generation of quantitative tools offer novel opportunities for design thinking in development applications as well as across all phases of the design process: needs assessment and insights, design principles, creative design, and prototyping for rapid improvement. In fact, it is the geographical and cultural distance challenges in development engineering that motivate greater emphasis on such tools.

Sensors, for example, can help us understand current practices. Examples range from monitoring electricity use [31] or water pressure over the day or week [32,33,34] to embedding usage sensors in medical equipment [35]. Sensors can complement interview data by comparing what people say versus what they do. For example, Wilson et al. [40] found that efficient cookstoves with embedded sensors were able to triangulate usage patterns in rural Ethiopia, where interviews tended to over-predict actual usage. *Experiments* can help us understand barriers that a potential new solution must address. For example, to see if liquidity constraints are important, one can experiment and offer a product for sale with installment payments to some consumers and with a fixed price to others [36]. *Large datasets* (relative to a normal survey of users) are increasingly available in poor regions. Sources include the Internet, regular operations of enterprises (e.g., web purchases and mobile phone call records), government operations (e.g., procurement and school test scores), crowdsourcing (e.g., Yelp! product reviews), sensors and satellites. As examples, all of these data sources can help identify where a drought is worst or where an epidemic might spread [34]. The institutional voids of poor regions raises the value of existing large datasets relative to their importance in most prosperous settings.

These quantitative tools can also provide stimulus to creative design. Crowdsourcing can be used to expand the breadth and depth of creating solutions for the developing world and provide the ability for distant designers to work on global challenges [37,38,39]. Embedded sensors can improve functionality, speed improvement, and address challenges to scaling. Examples range widely, from using RFID tags on inventory to track stock-outs and corruption to putting sensors on appliances such as cookstoves to monitor usage that informs carbon credits or results-based financing from a donor. Large data sets can also add value to the product and address challenges to the business. For example, Amazon and Netflix provide recommendations to users based on millions of other users' choices. Data from weather satellites and soil sensors can help target advice for farmers.

Quantitative tools can also help in prototyping for rapid improvement. Sensors can help measure how well early design products or services meet users' needs. Usage monitors are integral to some products, such as pay-as-you-go solar lights and water kiosks [33], and services such as mobile banking. In other cases, a usage monitor may be easy to include (e.g., D-Rev measures usage of its lights to combat infant jaundice [35]). Usage patterns help inform both designers and users what is working and why. Sensors beyond product usage can often be useful. For example, an efficient stove can only reduce deforestation and household air pollution if cooks largely stop using their traditional three-stone fires. Measuring wood use, air quality, or usage of traditional stoves can help improve design of the new stove (e.g., answering: "Would multiple burners help?") as well as the business model (e.g., "Should there be more information on the dangers of traditional stoves?").

Experiments have a long history in speeding product improvement. Google's user interface is a famous example of how A/B testing is used in computer science [29]. In development engineering, consumer responses to variations in physical or on-paper prototypes can provide valuable information. Experimentation can also inform the business model. For example, installment payments greatly increase demand for both water filters and efficient cook stoves. In contrast, free trials help with cook stoves in some studies, but were not needed with a nice-looking water filter in Dhaka [**Error! Reference source not found.**,36]. Experiments can also provide rigorous evidence on the impacts of new products or services. Such evidence is required by some donors and governments, and can also be useful for attracting paying customers. In some cases existing large datasets can also be useful. For example, in a setting with reasonably valid data on hospital admissions, a large health intervention might be able to learn about its effectiveness by tracking changes in hospital admissions.

2. The Development Engineering Program at UC Berkeley

Until recently, many graduate students at UC Berkeley interested in development work were limited to engaging in side projects within their research groups, typically without mentoring outside their discipline. Addressing this need, faculty at UC Berkeley developed the Designated Emphasis[1] in Development Engineering (Dev Eng) as an interdisciplinary training program for doctoral students whose dissertation research related to the application of technology to address the needs of people living in poverty. Through coursework, mentoring, and professional development, the program prepares students to develop, pilot, and evaluate technological interventions. The program builds upon ongoing research in technological innovations, human-centered design, development economics, remote sensing and monitoring, data science, and impact analysis at UC Berkeley.

[1] A "designated emphasis" at UC Berkeley is a Ph.D. minor.

The program is overseen by the Graduate Group of Development Engineering, a group of over 20 faculty members from various disciplines as shown in Table 1. The Designated Emphasis in Dev Eng is affiliated with the Blum Center for Developing Economies, the Center for Effective Global Action, Technology and Infrastructure for Emerging Regions, and the Development Impact Lab (DIL). This constellation of affiliates – through DIL [22] – is a cornerstone partner in the Global Development Lab, an entity of the United States Agency for International Development (USAID) that brings together a diverse set of partners to increase the application of science, technology, innovation, and partnerships to help end extreme poverty. As such, Dev Eng students are connected to not only an ecosystem of researchers and practitioners at Berkeley but also the larger global network.

The program encourages students from all departments to apply. Upon acceptance into the program, students must take two core courses, described below. In addition, students must take three electives from at least two of three thematic modules within the Dev Eng program: Project Design; Evaluation Techniques and Methods for Measuring Social Impact; and Technology Development [21]. Through this program, student innovators will develop multiple skills in ethnographic studies, qualitative research, hardware, analytical tools, hypothesis testing, prototyping, business model development and continuous impact analysis.

Table 1. Faculty representation in the Graduate Group of Development Engineering

Agricultural and Resource Economics	2
Architecture	1
Bioengineering	2
Business	4
City and Regional Planning	1
Civil and Environmental Engineering	2
Economics	1
Electrical Engineering and Computer Science	2
Energy Resources Group	1
Mechanical Engineering	1
Public Health	1
Public Policy	2
School of Information	2

3. Foundation Course: Design, Evaluate and Scale Development Technologies

The foundational core course for the designated emphasis is Design, Evaluate and Scale Development Technologies. This graduate course is co-taught in the fall term by one technologist and one social scientist, with instructors rotating from the pool of faculty in the Graduate Group in Development Engineering. The course is organized around analysis and application of case studies by multidisciplinary student teams in three modules:

- **Understanding the Problem, Context, and Needs** explores, via human-centered design processes, the integration of quantitative and qualitative needs assessment techniques such as observation, in the process of user identification, persona creation, insight communication, and question formulation.
- **Prototyping Solutions** investigates concept generation techniques and methods of low- and medium-fidelity prototyping with attention given to an iterative process of hypothesis testing, data evaluation and continuous improvement.
- **Rapid Improvement** extends this iterative process with examination of pilot tests in the lab and field, technologies for monitoring and testing, business modeling, rigorous impact evaluation, and sustainable scaling.

The goal of the class is to provide students with a set of skills that will allow them to address complex problem solving and design challenges in development engineering and to reinforce this learning through active participation, innovation and collaboration. Classes comprise of lectures, in-class activities, and guest speakers. During the first offering of the course, an optional one-hour workshop was held weekly to facilitate greater student interaction with development engineering practitioners from a range of disciplines and sectors.

To incorporate and reinforce learned skills through practice, students formed four- or five-member multidisciplinary teams to develop a capstone project throughout the semester. Project topics were selected from student projects begun prior to the class, teacher suggestions, and student proposed topics. The final project deliverable was a modified USAID Development Innovation Ventures (DIV) Letter Of Interest (LOI). DIV holds an open competition for bold development ideas in any sector and any country in which USAID operates, and the Letter of Interest is the first step of the process.

In the first iteration of the course (Fall 2014), we had 34 graduate students representing a range of disciplines: business, engineering, energy and resources, information management and social welfare (Table 2).

Table 2. Enrollment demographics of the first Dev Eng C200 class

Fall 2014	
All Students	34
College of Engineering	
Bioengineering	1
Civil & Environmental Engineering	4
Mechanical Engineering	13
Energy & Resources Group	1
Hass School of Business	13
Information Management & Systems	1
School of Social Welfare	1
Female	13
Male	21

1.5. Formative Assessment: Design, Evaluate and Scale Development Technologies

In addition to the semester-end teacher evaluations, the instructors conducted two feedback exercises during the semester and one reflective design thinking exercise at the end of the semester. This latter exercise required students to bring in "lessons learned" for the class on sticky notes that they clustered and summarized in randomly formed teams on the last day of class. Four themes highlighted the course: transforming theories into practice, applying design thinking, focusing on social impact, and connecting with the multidisciplinary development engineering community.

1.5.1. Putting theories into practice

Students valued experiential learning through hands-on activities and exercises to use concepts learned in class. For example, to practice needs assessment and the rich qualitative methods of observation and interviews, an early course exercise focused on handwashing with soap, an important challenge both in the U.S. and in the developing world. Students observed local handwashing practices. They noticed changes in behavior once the observer was recognized, documented the associated facilities and interviewed users. Students learned not only how to collect qualitative and quantitative data but also how to understand the users' most important challenges and needs and communicate these insights. They also learned to gain insights from the contradictions between what people say (e.g., they say they wash their hands for 20 seconds with soap) and what they do (e.g., they are observed to wash hands with no soap for only 10 seconds).

Students also enjoyed the cookstove case study, in which teams tested several stove designs to cook a large pot of rice. Cookstoves make a good case study for development technology design and deployment as half of the world's population cooks on dirty and inefficient stoves [40]. On each team, students acted as participant observers (that is, cooks), focusing on the user experience; as design researchers, gathering observational data; or as data analysts, collecting temperature information using thermocouple sensors.

> *"What seemed like a very simple task (lighting a fire and boiling rice) turned out to be much more challenging than anticipated. Our success could be attributed to resources which the typical user would not have. The experience was enjoyable, in part because it was for class and not for our family's livelihood."*

Fig. 2. Cookstove exercise with three student roles: cooks, interviewers, analysts

1.5.2. Incorporating design thinking

Students from all disciplines appreciated the incorporation of the design thinking process throughout the course. In-class exercises of concept generation, journey mapping, persona definition and user assessment [27] were useful, especially when applied to the capstone group project. Practice of low-fidelity prototyping, using basic art supplies such as modeling clay, popsicle sticks, pipe cleaners and paper, was a fun and effective lesson on the iterative process and the need to fail fast, get rich feedback and improve the design. For some students, this course was their first introduction to human centered design (HCD). Through case studies of successful and not so successful development projects, students recognized the importance of HCD in development engineering.

> *"While working on the project, I realized that the concept of living on $1 a day is very difficult to grasp, especially for those who have never traveled to third world nations or those without experience in the development sector. Even with having read so many papers, there is little substitute to being exposed to it. Because of this, and as you both taught us, trying to design for this target population becomes twice as difficult."*

1.5.3. Focusing on social impact

Many students appreciated the introduction of a social business model and social impact evaluations as important considerations in designing, evaluating and scaling technologies. Even for the business students, the social business canvas [23] was a new way to present a business model with an emphasis on both social goals and stakeholders (donors, governments, etc.). Unlike traditional businesses, social enterprises are driven by a mixture of profitability and measurable impact and must consider not just the customer, but also beneficiaries (who are not always the paying customers) and other partners. Students found it useful to apply this framework to their capstone group projects. Thus, they recommended introducing the social business model much earlier in the course.

1.5.4. Connecting with the development engineering community

Many student comments highlighted the value of interacting with members of the development engineering community. Guest speakers from academic, public and private sectors gave interactive presentations on their projects and lessons learned from the field. Our speaker lineup included representatives from DIL, MIT's Global Engineering and Research Lab [41], CellScope [42], We Care Solar [43], D-Rev[35], IDEO.org [27] and Impact Strategy Advisors [23]. Some workshop speakers sat with student groups to give specific feedback on their group projects; all speakers encouraged follow-up communication. Students expressed interest and appreciation for learning different development engineering efforts and approaches, receiving detailed feedback on assignments and sharing lessons amongst the groups. Several students asked for more feedback and after-class interaction with the instructors and guest speakers. Furthermore, students requested increased discussion of development engineering opportunities for students and future career paths.

> *"Overall, the course was awesome, and potentially life-changing for me. Using engineering for development is something I never really considered until now."*

1.6. Recommendations for improvement

As with the first iteration of any design, there were many lessons learned from the first time course was taught. Beyond course logistics (e.g., clearer rubrics for assignments), students' major suggestion for improvement revolved around the capstone group project. In particular, students wanted to start the project earlier within an established ecology of development engineering resources and existing projects. While appreciating the skills learned from the homework assignments, students recommended applying as many exercises as possible to the capstone project to help propel it forward. A month into the course, the instructors recognized student engagement in the capstone projects and switched the assignment about ideating 100 solutions from the handwashing exercise (as originally planned) to the capstone project. Based on student feedback, this switch wasn't soon enough.

The final deliverable for the capstone project was a letter of intent and draft proposal, modeled after the USAID Development Innovation Ventures (DIV) program [44]. Students recognized the value of preparing the DIV proposal, which served both as practice in grant writing as well as exposure into what funding agencies like USAID are looking for. As such, students requested introduction and discussion of the DIV proposal components earlier in the course to structure their work leading to the completion of the capstone project. Based on student feedback, future iterations of the class should finalize capstone project topics and student groups at the beginning of the course, as well as discuss the DIV proposal, apply homework assignments to the group project, and project-related interim deliverables throughout the duration of the course.

Student experience with the capstone group project depended on the maturity of the project idea and technology (listed in Table 3). The groups working on established projects started with more resources, in the form of knowledge, contacts, and technology design, than the groups starting with a fresh concept or only an identified need. Existing projects may have focused less on the design of a technology and more on the business issues and scaling their known technology. In contrast, the new projects focused heavily on the design thinking process, especially needs assessment, idea generation, and persona definition to determine the development question they wanted to address. More than one group spent the first half of the semester changing the project topic several times before finally settling on a direction. While the process of problem scoping and project definition is a useful experience for students to have, for a project with such a short time frame (one semester), there is a huge tradeoff with advancement of the project. Several students expressed frustration with spending too much time on framing the project and seeking contacts than on design iteration and technology development.

Table 3: Finalized capstone group project topics, with listing of group member academic areas & whether topic is based on previously established student project, for Dev Eng C200 Fall 2014

Project Topic	*Group member major (No.)*	*Established project?*
5 cent smoke detector: a low-cost monitor of particulate matter emissions from cookstoves	MBA(3), MechE (2)	N
Training Ghana midwives in a low-cost method of screening for cervical cancer	MBA, MechE (3)	Y
Energy use in Pomo tribal homes: culturally-appropriate tools to achieve energy efficiency and tribal goals	MBA(2), MechE (3)	Y
Reimagining waste in Kenya: transforming public toilet urine into fertilizer for smallholder farmers	Bioengineering, CivE (2), MBA, Social Welfare	Y
Connecting reliable employers with verifiable workers in Kibera via mobile technology	Energy and Resources Group, Information Management & Systems, MBA, MechE (2)	N
Smartphones for health data collection for community health workers in India	CivE, MBA(3), MechE	N
Low-cost monitoring of black carbon emissions to the mitigate health impacts of residential biomass cookstoves	CivE , MBA(2), MechE	Y

Department abbreviations: CivE – Civil and Environmental Engineering, MBA – Masters of Business Administration in Haas School of Business, MechE – Mechanical Engineering,

All groups experienced challenges connecting with users in target communities. Because all except the one working with the Pomo nation (a local Native American tribe) were international, there were substantial geographical and cultural distances between students and users. Students recognized that human-centered design requires access to the customers and users. While students managed to connect with experts and secondary users familiar with the discipline or the geographical area their project addressed, few had interviewed or observed their target users by the end of the course.

Although the challenges of cultural and geographic distances face most development engineering projects, this course could implement several changes to increase user engagement. Some students suggested connecting groups with current projects of DIL faculty or companies, such as those presented by the guest speakers. Such projects should have both primary field contacts and secondary researchers who have worked with the target population. The next iteration will start early to identifying projects that have either local users or local partners who can connect students to users. We will also form teams earlier and require students to create a plan for engaging users and stakeholders (e.g., identify local secondary users, Skype sessions with stakeholders in the field, etc.).

Considering the diversity of student's backgrounds and experiences, it is not surprising to see varying opinions about the depth of course content. Some students wanted more emphasis on business model creation, business case studies, market research methods for competitors, self-sustaining scaling strategies, and impact evaluations by data-driven organizations. Other students thought the class did not have enough engineering, in the sense of problem sets, lab work and prototyping. Thus, some engineers saw the class largely as "management" with few opportunities for them to use their technical expertise.

While most group projects did not significantly advance the technological state of their prototypes during the semester, all groups engaged in several stages and cycles of the design process. For future iterations of the course, connecting students to more in-depth market analyses and technical prototyping resources could prove beneficial. Furthermore, we plan to develop more peer learning exercises where engineering students share their expertise with others in the class.

Understandably, students preferred to do a deep needs assessment, design a new product or service (including both engineering the solution and designing the business plan), and start to prototype and improve. Unfortunately, a 14-week class that takes 10 hours a week of student time is never going to be able to accomplish much of that ambitious task list. The course was designed as a foundation course. We hope students will develop depth with follow-up research, field work and participation in the three additional elective courses.

2. Development Engineering Research and Practice Seminar

The semester following the core course, the first iteration of the Development Engineering Research and Practice Seminar (Dev Eng 210) was offered in Spring 2015. This two-unit course provides Dev Eng students with a context and community within which they can develop their research projects. The seminar focuses on work-in-progress presentations by graduate students, faculty and industry practitioners within the development engineering ecosystem at UC Berkeley and beyond. There is no textbook, and speakers provide reading material and discussion questions in advance of their seminar. Student grades are based mainly on class participation, discussion engagement and research participation.

To facilitate student-faculty interaction, the class registration is limited and faculty attendance is highly encouraged. In its first iteration, the course had ten registered graduate students, all pursuing the Designated Emphasis in Dev Eng and representing seven disciplines including engineering, energy and resources, agricultural and resource economics, environmental health sciences, physics and social welfare. Faculty and staff attendance varies from week to week, with an average of three faculty per week. A selected list of speaker and student topics is presented in Table 4. Based on student interest in development career paths, an eight-person panel was organized that represented academia, government, non-profit and private sectors and discussed the future of development engineering.

Table 4: Selected list of speaker and student topics for the first iteration of DevEng 210 (Spring 2015)

Faculty and Industry Speaker Topics
Development engineering frameworks
50 breakthroughs: critical advances needed for sustainable global development
User research with cultural & geographic distance
Measurement issues during the stages of design through scaling
Career panel on possible career choices in development engineering
Impact evaluation design of environmental interventions
Education and partnerships in international development
Design for sustainable wellbeing and empowerment
Graduate Student Speaker Topics
Qualitative & Quantitative Research on Biomass Cook Stoves
Compact, Inexpensive Black Carbon Sensor for Biomass Cookstove Emissions
An Updated Toolkit for Household Energy & Health Assessments
Examining Design for Development Online
Solar-Integrated Housing for Slums in India
Impact Evaluation of Community-Driven Development Project in Myanmar
Trans-disciplinary Human Centered Design Approaches for Poverty Alleviation

At the time of this writing (April 2015), the course was in progress and therefore end-of-semester survey data was not available. However, a focus group exercise found students enthusiastic about the program and the topics. Their strongest recommendation was to further expand the development engineering resources to include travel grants for fieldwork and provide more networking opportunities to enable students to engage with local development engineering research groups and organizations.

3. Conclusions

This paper provides a framework for embedding design thinking into the teaching, research and practice of "Development engineering," a new interdisciplinary field that we define as creating solutions that improve human development in low-resource settings at a scale. We reframe design thinking for development to emphasize: 1) Incorporating development goals, constraints and opportunities; 2) Scaling for impact; and 3) Integration of novel sensors, experiments, and large datasets (e.g., from the Internet, satellites, mobile phones, etc.). Although targeted to low-resource settings in emerging economies, the skills student learn can be applied in a wide range of global settings requiring what is sometimes called twenty-first century skills of problem solving and innovation, global awareness, skilled communication, interdisciplinary teamwork, customer focus, creativity, and collaboration [45,46,47].

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