Implementation And Initial Assessment Of The Design That Matters Program At MIT And Other Universities

Timothy Prestero¹, Neil Cantor²

Abstract - This paper describes how Design that Matters has worked with engineering capstone design courses at MIT, Worcester Polytechnic Institute and the University of Cambridge, allowing successive student teams from different universities and engineering disciplines to collaborate on real-world projects for underserved communities in such areas as clean water, medical devices, renewable energy and access to education. We give a short list of projects students have worked on, and we point to some initial indicators of program effectiveness, including survey results and community implementations. We conclude with an overview of lessons learned.

Index Terms - Capstone Engineering, Design Education, Service Learning, Student Collaboration

AN OVERVIEW OF DESIGN THAT MATTERS

Design that Matters (DtM), a nonprofit organization hosted at MIT, helps underserved communities realize an improved quality of life by creating products and services that meet needs identified by the communities themselves. DtM acts as bridge to bring problems identified by nongovernmental organizations (NGOs) and the communities into the classroom for university engineering students to tackle in their capstone design courses. DtM serves as the “institutional memory”, capturing the ideas resulting from each capstone course to allow successive teams of students to build on each other’s work. Finally, DtM works with NGOs, corporate partners and local entrepreneurs to ensure that promising student innovations result in products and services for communities in need.

Since its launch in 2000, DtM has reached over 400 engineering students—roughly half of them women and minorities, and many of whom have realigned their life trajectories to include work in underserved communities. In 2002, DtM completed a proof-of-concept implementation in MIT’s mechanical engineering capstone design course with Prof. Woodie Flowers. DtM is now expanding within MIT and to other schools in the US and UK.

DtM Project Areas

Design that Matters works to address the needs of underserved communities in developing countries as well as indigenous groups, the disabled and the elderly. DtM student teams have tackled such challenges as an improved IV drip for cholera treatment [1], a non-electric incubator for premature infants in rural areas [2], a children’s talking toy for Native American language preservation, “smart canes” for the blind, hand-powered electricity generation for rural computing and communication tools for handicapped children.

In selecting problems to address, DtM relies on the following basic selection criteria:

• Need: the design challenge meets a real need, something that seriously affects the lives of thousands or even millions of people.
• Scope: we can provide sufficient information and enough focus to make the problem accessible to students in a single semester. This may involve breaking a large problem up into smaller component problems.
• Contacts: there exist community/stakeholder representatives, NGO contacts and domain experts who can answer questions and are willing and able to put the student innovations to immediate use.
• Status: there are no existing, satisfactory solutions to this problem, nor do any appear to be in development.

In addition DtM looks for opportunities in the area of “intermediate technology,” finding solutions that bridge the gap between the kinds of computerized, mechanized products available in industrialized countries and the basic technology found in rural regions of developing countries. Similarly, conservation of natural resources is a goal of all DtM projects. DtM specifically targets design challenges that assist communities to exploit local resources in a sustainable fashion.

DtM Design Challenge Portfolios

DtM packages problems identified by our clients into curriculum materials called Design Challenge Portfolios for university students in engineering, science, policy and business to work on in their courses. We transfer the resulting student innovations back to our partners in NGOs and industry to develop as new products and services that will have an immediate impact on the lives of communities in need.

Design Challenge Portfolios include background materials, a list of well-posed design problems and a survey of prior art. These design challenge portfolios are designed to...
move a concept to commercialization within three years of its introduction. During this time, the portfolios evolve in depth and detail and include design problems from every stage of the product development lifecycle. In engineering and industrial design, the design problems will focus on prototype development based on design criteria supplied by the community and local NGOs. For students in manufacturing engineering, the design problems will focus on product design based on existing prototypes, given local material constraints and manufacturing capabilities. For business students, problems will focus on market analysis, financing models, and the development of business plans based on the product and the local community.

Kinkajou Microfilm Projector: A Design Challenge Example

Over the last 18 months, we have applied our collaborative design process to the development of a robust, low-cost projector system for use in adult literacy courses in developing countries.

One in five adults worldwide does not know how to read. In rural regions of West Africa, up to 75% of the population is illiterate. According to Barbara Garner of the World Education Organization, "It's the lack of resources"—specifically access to books and lighting—rather than the lack of interest in education that contributes to these numbers. After validating this with the community, Design that Matters translated this need into a detailed problem description for engineering and business students to address in their university courses and research. The objective has been to design and build a rugged, lightweight, low-power projection system, which uses a microfilm cassette to store up to 10,000 images at a fraction of the cost of paper books, and employs a state-of-the-art optics system to project an image large enough for the entire classroom to read.

The design concept was developed in Spring 2002 by a team of undergraduate students taking a DtM-lead seminar at the MIT Media Lab. In Fall 2002, a second undergraduate team in an MIT Mechanical Engineering senior capstone design course picked up the project, developing the first working prototype. In Spring 2003, students from the course continued the development of the projector through senior thesis projects [3-7], culminating in a six-week field test in West Africa the following summer.

In Fall 2003, development of the projector moved to the University of Cambridge in England, where students in the Sustainable Development program researched opportunities for local production of content, and Worcester Polytechnic Institute, where electrical engineering students are tackling the redesign of a robust battery-charger circuit and a more efficient LED driver circuit [8].

In 2004, DtM is working with volunteer professionals and students at MIT and the University of Cambridge to tackle problems related to systems integration and design-for-manufacture. DtM is also working with World Education to organize an extended pilot study of the device this fall, as a prelude to large-scale deployment among World Ed's literacy programs in Mali and Guinea in 2004.

**Program Study**

In Fall 2003, Design that Matters began a pilot test of our design challenge portfolios in senior-level courses at five college engineering programs. The test followed a proof-of-concept phase conducted at MIT in Fall 2002, during which 60% of students offered DtM or alternatives products chose DtM. As DtM headed into pilot testing, many questions about the proof-of-concept phase remained unanswered:

- Why did 60% of students choose to work on DtM design challenge portfolios?
- Why did 40% of students opt for an alternative design project?
- What factors (product attributes, professors, information gathering, perceived hazards, user experience) influenced choices by instructors and students?

In Spring 2003, Design that Matters, with the assistance of a graduate student team from MIT Sloan, conducted a study to better understand the results observed during DtM's proof-of-concept phase. This study involved collecting the following data:

- interviews with students at MIT who had worked on DtM design challenges through the Fall 2002 mechanical engineering senior capstone course
- surveys of mechanical engineering sophomores at MIT who were headed into the same senior capstone design course
- interviews with engineering faculty at both MIT, Purdue, University of Massachusetts at Lowell and the University of Colorado at Boulder

There were four key objectives to this analysis:

- To understand student needs in connection with their capstone experience
- To understand students’ perception about the capstone experience and its value to them
- To identify areas where current performance of the curriculum product falls short
- To describe the decision process of a student in selecting a problem on which to work in his or her capstone course.

**Methodology**

Student analysis followed several steps:

1. **Data Analysis #1:** Reviewed and analyzed existing surveys administered by the MIT Public Service Center to students enrolled in MIT’s mechanical engineering capstone course (See Appendix 1 for results of analysis)

2. **Survey #1 Design and Distribution:** Designed an interview guide for one-on-one interviews with students who recently completed MIT's mechanical engineering capstone course. We received 20 responses from 120 prospects and...
interviewed all six willing to be interviewed, including two who indicated negative sentiments about their course experience (See Appendix 2 for interview guide).

3. Data Analysis #2: Performed a Voice-of-the-Customer analysis to confirm the integrity of results from Data Analysis #1 and acquire more dynamic understanding of the student perspective (See Appendix 1 for results from Data Analysis #1 and #2).

4. Survey #2 Design and Distribution: Designed a 10-minute online survey that collected the following types of data: (1) Usage intent, (2) conjoint analysis rankings and (3) demographic information. The target audience for this survey was students on track to take 2.009, including students currently enrolled in 2.007 and 2.008. We sent the survey to over 100 students and received 40 completed surveys (See Appendix 3 for interview template).

5. Data Analysis #3: We performed a cluster analysis to segment our responses into 10 customer segments (See Appendix 4 for dendrogram). We then performed a conjoint analysis on the data to understand the utility for each product feature of a hypothetical capstone project within the different clusters (see Appendix 6 for results). We also performed a simple regression analysis to understand students' expectations for projects on a relative basis.

FINDINGS

Analysis of Likelihood to Choose a Service-Oriented Project

We began the Survey #2 analysis simply by estimating likelihood for students to choose a service-oriented project like those provided by DtM. They indicate that service-oriented projects create a favorable initial impression with students that will prompt them to take a closer look at the option. Students, when asked whether they'd choose a project that could enhance health or education in an underserved community, responded in the following way:

<table>
<thead>
<tr>
<th>TABLE 1: STUDENT SURVEY RESPONSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>I would definitely choose this project</td>
</tr>
<tr>
<td>I would seriously consider this project</td>
</tr>
<tr>
<td>I might consider this project</td>
</tr>
<tr>
<td>I would not consider this project</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
</tbody>
</table>

We began the Survey #2 analysis simply by estimating likelihood for students to choose a service-oriented project like those provided by DtM. They indicate that service-oriented projects create a favorable initial impression with students that will prompt them to take a closer look at the option. Students, when asked whether they'd choose a project that could enhance health or education in an underserved community, responded in the following way:

Demographic Analysis

A quick analysis of our demographics obtained from Survey #2 shows a fairly typical MIT student population. A majority of students expect to pursue master's degrees and work in the manufactured industrial sector. Community service work is rare but not non-existent among these students. Roughly 50% of respondents are members of the Greek system and 23% are female. Surprisingly, all respondents indicated they are U.S. citizens.

Cluster Analysis

Our cluster analysis from Survey #2 produced a clear dendrogram, which we initially used to split the population into 10 clusters and then into eight segments after deciding to exclude the two smallest segments. The segments listed below attempt to capture the key aspects of each cluster:

- **The Engineer's Engineers** - This group wants projects that require them to apply all of their skills and innovativeness.
- **Helpers** - This group looks very promising for DtM. Helpers are interested in DtM-type projects and in helping the underserved and are more flexible about the type of work they do. These students require a strong connection to the users and want assurance their work will make an impact. Employment is a big concern. Notably, this segment is 80% female; no other segment is over 33% female.
- **Intrigued** - Intrigued students would seriously consider a DtM-type project and are not significantly differentiated on other dimensions. A well designed project could certainly capture their interest.
- **Smooth sailing** - Smooth Sailers are marginally interested in DtM-type projects and were primarily interested in projects with good advising support that would provide the most advantages for their job search. They are indifferent about helping the underserved and innovative projects.
- **Haters** - Haters want to be left alone. They are indifferent to advising, and aren't interested in DtM-type projects or helping the underserved. Haters don't care if their products get used. On other dimensions Haters are average.
- **Job-seekers** - This group isn't interested in DtM-type projects and don't care if their projects are applied. Their primary interest is their job search.
- **Helpers** - Helpers are interested in DtM-type projects and in helping the underserved and are more flexible about the type of work they do. These students require a strong connection to the users and want assurance their work will make an impact. Employment is a big concern. Notably, this segment is 80% female; no other segment is over 33% female.
- **Intrigued** - Intrigued students would seriously consider a DtM-type project and are not significantly differentiated on other dimensions. A well designed project could certainly capture their interest.
- **Smooth sailing** - Smooth Sailers are marginally interested in DtM-type projects and were primarily interested in projects with good advising support that would provide the most advantages for their job search. They are indifferent about helping the underserved and innovative projects.
- **Haters** - Haters want to be left alone. They are indifferent to advising, and aren't interested in DtM-type projects or helping the underserved. Haters don't care if their products get used. On other dimensions Haters are average.
- **Job-seekers** - This group isn't interested in DtM-type projects and don't care if their projects are applied. Their primary interest is their job search.
- **The Academic Helpers** - This group is interested in helping the underserved, but not interested in seeing their projects implemented. Applying all of their skills is a bigger motivator. This is a very promising segment for DtM, but unfortunately a small segment of the student population.
Regression Analysis

The expectations section from Survey #2 helped qualify needs and expectations of all students working on capstone projects that we identified in Data Analysis #1 and #2, regardless of their segment. Generally speaking, students have strong, optimistic expectations about their projects that drive their overall satisfaction with the experience. Students rated the following needs and requirements as highly desirable. These needs had low standard deviations (the scale was 1-5, where 5 indicated students “strongly agreed” with the statement):

<table>
<thead>
<tr>
<th>Need/Requirement</th>
<th>Avg. Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Teamwork Experience</td>
<td>4.80</td>
</tr>
<tr>
<td>Clear Understanding of Constraints and Requirements</td>
<td>4.73</td>
</tr>
<tr>
<td>Variety in Selection of Projects</td>
<td>4.56</td>
</tr>
<tr>
<td>Access to Resources Giving Feedback on Product</td>
<td>4.35</td>
</tr>
<tr>
<td>Innovative Projects to Work on</td>
<td>4.29</td>
</tr>
</tbody>
</table>

Conjoint Analysis

The rankings section of Survey #2 helped us start to understand how students would select a capstone project if presented several project choices. Students ranked project prototypes with five attributes hypothesized based on Analysis #2 to play a key role in their selections process. We learned that with a few exceptions the customer segment served by their project (e.g. US general consumer, industrial or underserved community) plays the leading role in student decisions.

RECOMMENDATIONS

Our analysis suggests a large potential student interest for service-oriented projects like those from DrM. However, several key issues must be addressed to better serve this interest. These issues include (1) project and process improvement, (2) continuity, and (3) corporate support.

- Projects and processes improvements (1) - Project offerings should be diverse in type and in the level of technology that the project will require. Also, faculty should offer a packet of information that includes consistent, organized and thorough information about the community’s need, people, culture, environment and resources, including a video whenever possible. Community contact is critical, so this information packet should be the next best thing to actual site visits.

- Projects and processes improvements (2) - Packets should include a roadmap with documented progress made by previous teams and additional milestones to project completion. The documented process should include specific points in which progress can be measured, including feedback from students, staff, partners and the community that the project is helping.

- Projects and processes improvements (3) - mechanisms that facilitates communication between students, faculty, and the community needs to be put in place to establish stronger ties between the stakeholders and offer a forum to answer any questions that the students and faculty may have. This could be in the form of an interactive website or scheduled conference calls, etc.

- Faculty should recognize the importance of continuity in projects they select for their students. Faculty should provide continuity for the communities their projects serve and identify a process to ensure that the communities are not left empty-handed and have the skills and resources required to ensure sustainability of the services received. We recommend that faculty formalize a processes in knowledge transfer and follow-thru by helping teams obtain patents and partnering with organizations that have the ability to pick-up the responsibilities of manufacturing and distribution of the product.

- Look to corporations for non-financial support. Local engineers can act as "design mentors" by working with students to develop their projects. They can also speak to the students about the value of low-cost, less complex, easy-to-maintain designs to help change their perceptions on high-tech versus low-tech projects.

ACKNOWLEDGMENT

The authors would like to thank Professors Woodie Flowers and David Wallace in MIT Mechanical Engineering for allowing us to survey and work with students in their course. We would like to thank the students in MIT course 2.009 for their enthusiastic contributions.

REFERENCES


