Using Design Thinking Principles to Develop New Community-centered Engineering Educational Initiatives for High School Students

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Introduction

The pathways of a typical high school student towards careers in engineering are fraught with obstacles; chief among them is a misconception that engineering is a singularly technical pursuit devoid of human interests. Design Thinking is a very valuable enabler to attract high school students to engineering[1]. Design thinking facilitates inspiration, evokes ideation, and provides pathways for implementation and evaluation. This emerging discipline blends sensibility and processes, to match people's needs with what is technologically feasible.

During 2016, the College of Engineering and Science at the University of Detroit Mercy developed and delivered a prototype two-week Design Thinking Summer Camp (DTSC) intended to engage high school students from across the community in human-centered design activities and, in the process, lay out a vision of how an engineering education can be leveraged to create products and services that affect and improve peoples lives.

The paper is a work-in-progress and presents a successful pilot of a new community centered engineering educational initiative. Five specific areas associated with launching this pilot prototype two-week DTSC are presented including:
1. Processes, methods and techniques used to develop new curriculum.
2. Pedagogy, instructional concepts, activities, outcomes and environments.
3. Developing effective collaboration and community partnership models.
4. Review of results, outcomes and assessment techniques employed.
5. Insights and details on how to improve and develop high school STEM programs.

Processes, Methods and Techniques

The ability to offer cutting edge innovation, creativity and design curricula was made possible by a ten-year investment on the part of the faculty at the University of Detroit Mercy. The five faculty members who developed and piloted the DTSC have combined to develop five new courses in Innovation and Entrepreneurial Design Thinking and modified several others with new content. Further, they have taken part in hands-on workshops, professional development networks, and a series of professional conferences.

The DTSC objectives were:
1. Introduction and overview of design thinking principals and concepts.
2. Exploration of how design thinking can be applied to drive innovation.
3. Insights into design thinking techniques, tools and processes.
4. Participation in interactive collaborative design thinking exercises.
5. Obtaining new insights and knowledge related to engineering education.

Pedagogy, instructional concepts, activities, outcomes and environments

This interactive program provided an introduction to the methods, tools, techniques, and frameworks associated with design thinking. Through a series of hands-on exercises and team activities, participants engaged in the process of redesigning the four-year high school experience. Curriculum, pedagogical methods, facility layout, community engagement and school culture included areas of engagement.

Student learning outcomes focused on developing the abilities to:
1. Identify the five stages of the Design Thinking process.
2. Carry out a basic ethnographic study to identify a customer need.
3. Transcribe a customer need into a value proposition and problem definition.
4. Apply basic structured innovation techniques to develop creative concepts.
5. Create basic proof of concept prototypes.
6. Test proof of concept prototypes with potential customers.

The DTSC included 70 hours of student faculty contact hours over the course of a two-week period. A large classroom was set up as a design studio and stocked with ample supplies and equipment and student teams set up their own design workspaces.

The curriculum was presented in a series of modules that required the students to actively engage and participate in a series of DT tools, techniques and methods associated with addressing the opportunity to redesign the high school experience. DTSC participants were required to engage, under supervision, with external stakeholders such as parents, siblings, kin, neighbors, friends and teachers.

The student-centered interactive curriculum was organized into eight classroom modules and two field trips. Each daylong session had a specific theme as outlined below.

<u>Week 1</u>
Day 1 - Introduction, Overview and The Five Stages of Design Thinking
Day 2 - Empathy, Discovery and Landscape Mapping
Day 3 - Framing and Defining Problems as Opportunities
Day 4 - Ideating Part 1: Making Sense of Findings and Framing Opportunities
Day 5 - Design Thinking In Action Fieldtrip

<u>Week 2</u>
Day 6 - Ideating Part 2: Refining, Visualizing and Re-Empathizing
Day 7 - Experimenting and Building to Bring Your Ideas to Life
Day 8 - Prototyping and Preparing Your Portfolio and Presentation
Day 9 - Presentations, Stories, Partnerships and Networking
Day 10 - Field Trip to History Museum

The five stages of Design Thinking were aligned with the following engineering and science education principles to help students understand the connections and apply them during the DTSC experence.

DT Stages	**Engineering and Science Education Principals**
1. Empathizing	Developing deep & insightful perspectives (people & technology)
2. Defining	Divergent & convergent thinking to define problems/opportunities
3. Ideating	Brainstorming, shaping, selecting & developing potential solutions

4. Prototyping	Designing, testing, iterating, refining concepts, process & solutions
5. Testing	Continuous short cycle innovation processes to improve design

The DTSC integrated a series of engineering and science education concepts with Design Thinking principals as detailed below. This provided students with an opportunity to engage in a series of five specific concepts related to engineering and science education.

DTSC Engineering and Science Education Concepts, Activities and Outcomes

Concepts	Activities	Outcomes
Student Lab Workbooks (Design Notebooks)	Organizing tasks, recording data, framing experiments, capturing ideas, visualizing	Individual artifact similar to a lab notebook that students developed during camp
Experiments and Prototypes (Ideating and Testing)	Team exercises requiring application of physics, geometry and mathematics	Creation of prototypes that require persistence through failure and experimentation
Team Design Projects (Reports and Presentations)	Defining design problems, conducting research, testing concepts, communicating	Working in teams, defining problems, field research, presenting and writing
Laboratories and Studios (Designing and Testing)	Building models, defining specifications, testing and measuring outcomes	Used materials, tools and technology to create and test hypotheses and models
Field Trips & Networking (Theory Meets Practice)	Working sessions with engineers and scientists in labs, studios and offices	Mentoring and coaching with practicing engineers, scientists and designers

Developing effective collaboration and community partnership models

Central to the success of the pilot DTSC was the development of a series of collaborative community partnerships. This included the University, the College, alumni, local business community and urban and suburban school districts.

Faculty worked with a local corporate foundation to develop a budget and received a grant of $25,000 to support the development and delivery of the prototype DTSC. Based upon results of the prototype program, the foundation indicated that they would be receptive to a second round of funding to support the continued development and delivery of future DTSCs.

Faculty also established a working relationship with a local design firm that has been operating in the area for over 80 years. Working with the partners of the firm, they reviewed the curriculum and received input related to exercises, methods and techniques being used in practice. The design firm also agreed to host the DTSC participants for a one-day session at their facilities. This hands-on session provided students with valuable insights and examples of how design thinking is being applied in practice.

Furthermore, faculty arranged for a second one-day session at a large indoor and outdoor history museum complex that holds National Historic Landmark status. Through a personalized interactive guided tour, DTSC participants explored science, history, creativity and innovation through living models, prototypes, inventions and stories associated with success, failure and human collaboration.

University administrators and faculty also worked closely with local urban and suburban school districts, and regional faith-based high school systems to form partnerships, secure teacher support and recruit students. Fourteen school districts agreed to participate in the program.

Review of results, outcomes and assessment techniques employed.

Sixteen students (6 female and 10 male) participated in the DTSC prototype program. Of the participants, 12 were African American, 3 Hispanic and 1 Caucasian. DTSC participants consisted of three primary clusters, urban (7 students), suburban (7 students), and international (2 students). Seventy-five percent of the DTSC participants were from public schools, and twenty-five percent from private institutions.

Parents were encouraged to engage through session visits and exchange with faculty and staff. Throughout the two-week DTSC, parents interacted with faculty on a regular basis and many attended the final DTSC student presentations.

DTSC participants achieved the following outcomes associated with the introduction and fundamental development of basic design thinking skills and competencies:
1. Leading and collaborating in cross-functional team environments.
2. Gathering, integrating and interpreting information and knowledge.
3. Ideating and experimenting to identify opportunities and solve problems.
4. Prototyping and reframing problems as opportunities to improve people's lives.
5. Evaluating and refining how you look at human interaction and technical systems.
6. Integrating and reframing of a High School's educational offerings and outcomes.
7. Presentation of new prototypes, ideas, and human centered design concepts.

The DTSC participants were queried for direct feedback in the form of a five point Likert scale questionnaire (5 being the highest and 1 the lowest). The questions were intended to gauge the student's satisfaction with the experience. A more appropriate assessment program modeled after the state of the art is planned for future offerings[3]. The following table provides a summary of their responses:

DTSC Participant Evaluations*

Item	5	4	3	2	1
Because of this summer camp, I can now employ Design Thinking to solve problems.		4.25			
I now believe that Design Thinking is an important and beneficial skill for a high school student.		4.20			
The camp has met my expectations.			3.60		
I would highly recommend this camp to others.			3.80		
I am more likely to pursue a course of study in engineering or computer science as a result of this camp.			3.40		
The instructors did a good job teaching and managing the camp.		4.00			
The support staff was helpful and courteous.		4.80			

The field trips were interesting and fun.			3.90		

*N = 16 | 5 = highest 1= lowest

Direct Student Feedback

One student wrote: "Design Thinking is an exciting and innovative way to create a better solution than what was obvious." Another student singled out empathy as an enabler for better customer understanding: "Overall great experience, I learned a lot about empathy and how it ties into design and critical thinking." Design process and teamwork were a focus of a third student's remarks: "Through my time at this camp I am beginning to understand the process of creating opportunities out of problems, and working effectively and efficiently as a team."

Insights and details on how to improve and develop high school STEM programs

Overall, this pilot offering of a two-week high school DTSC was well received by the student participants, parents and the host institution leading to plans for another offering during the summer of 2017. The feedback from the participants and other key stakeholders led to the following insight for improving future offerings:

- Expand the recruitment process to include a larger number of schools.
- Incorporate more on-campus facilities such as labs, maker spaces and libraries.
- Select a topic that requires the creation and development of tangible prototypes.
- Invite guest speakers and subject matter experts to campus as guest speakers.
- Request parents take more responsibility related to policies and procedures.
- Recruit teachers from local high schools to champion and participate.
- Raise the bar on recruiting and offer performance and need based scholarships.

Conclusions

A successful two-week pilot of a design thinking summer camp (DTSC) was offered in 2016 to sixteen high school students. Students were tasked with redesigning the high-school education experience, which proved to be a daunting task, and led to some consternation. Despite these difficulties, the feedback was fairly positive and a second offering is planned for 2017 albeit with a more accessible project.

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