Incorporating Design Thinking into the First-year Engineering Curriculum

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Abstract

The goal of the common first-year engineering program at our university is to prepare students to succeed in upper level engineering curricula. This is achieved through the process of solving open-ended multidisciplinary engineering problems in an active, engaging, learning environment, while gaining exposure to different engineering majors and career options. The focus is the development of problem-solving, computational, and communication skills. Through active, collaborative teamwork, students apply engineering methods to "real world" problems. While there are a number of Innovation and Entrepreneurial (I&E) experiences available to our first-year engineering students, they are all extra-curricular in nature. By directly introducing students to key I&E tools and methodologies in the first-year engineering courses, we are fostering and encouraging an entrepreneurial mindset, allowing and better preparing students to take advantage of the available I&E opportunities and potentially increasing the pipeline of student inventors and innovators.

Historically, in this the first-year engineering courses, students work in teams to develop solutions to prescribed problems. In a pilot initiative for the Fall 2017 sections of ENG1102: Engineering Modeling and Design, our goal was to allow students the opportunity to self-identify problems they would like to address in an effort to expose them to concepts in innovation, creativity and entrepreneurial mindset. For this pilot study, our approach was to integrate a series of instructional modules in Design-Thinking methodologies into the curriculum for ENG1102 to help students: 1) employ empathy to identify problems of interest; 2) explore ideation techniques to generate innovative solutions, and 3) to practice low-resolution prototyping as a means to test their solutions, gather feedback and iterate on their designs. In this paper, we will share the results of our pilot initiative including assessment efforts to measure change in students' curiosity & exploration, attitudes toward creativity, creative self-efficacy and creative identity, as well as feedback from the student participants.

Background

At our university, we are focusing efforts toward creating a cohesive and well-defined Innovation and Entrepreneurship (I&E) ecosystem that actively integrates curricular and extra-curricular activities with applied commercialization and startup business development activities. A newly created Innovation Center for Entrepreneurship was formally established in the fall of 2015 with support from alumni who share in our vision for a well-defined base of support for I&E activities. Funding provided by this group of alumni has allowed for the staffing of two part-time co-directors who are actively working with a passionate group of faculty, staff, and students to bring the ecosystem to life. Key initiatives to date have included the *Introduction of a Lean Start-up Curriculum,* development of a new course in *Design Thinking Methodology*, implementation of a new 4,000 square foot *Makerspace* with associated programming and pop-up workshops, development of a new *Minor in Innovation & Entrepreneurship*, a *Guest Speaker Series*, and a campus-wide *Innovation Fest* held in October, 2017.

There are a number of I&E experiences available to our engineering and business students, including pitch competitions, access to the Makerspace and support resources through our new Innovation Center for Entrepreneurship. These activities are all extra-curricular in nature and require that individual students seek these opportunities of their own initiative. This project brings together faculty from this Innovation Center with faculty from the Department of Engineering Fundamentals who instruct the first-year engineering program. This project directly introduces students to key I&E tools and methodologies in the first-year engineering program and allows these students to work collaboratively across disciplines to develop innovative solutions. By doing this, we believe we can better foster and encourage an entrepreneurial mindset and better prepare students to take advantage of the available I&E opportunities. We hope that early exposure to these tools in their academic careers will increase the pipeline of student inventors and innovators.

Part of the mission of the First-Year Engineering Program at Michigan Tech is to enable students to succeed in upper level engineering curricula through the delivery and administration of an innovative first-year engineering curriculum. Hallmarks of the first-year engineering program at Michigan Tech include technology-rich, discovery-based learning as well as a teaching/learning environment in which diversity in its broadest sense is valued. This is achieved through the process of solving open-ended multidisciplinary engineering problems in an active, engaging, learning environment, while gaining exposure to different engineering majors and career options. All calculus-ready students who matriculate in our engineering programs begin their first year completing two common fundamentals courses: ENG1101 (Engineering Analysis and Problem Solving) and ENG1102 (Engineering Modeling and Design). Students who are ready for pre-calculus complete a three-course sequence: ENG1001 (Engineering Problem Solving), ENG1100 (Engineering Analysis), and ENG1102. Approximately 1000 students enroll in these courses each year.

The course we focused on for this project is ENG1102, the last engineering course in the sequence, which focuses on engineering problem solving in the context of the design process. The core purpose of this course is to provide a broad introduction to engineering as well as to equip students with basic engineering skills that will be used throughout their careers. In this course, students form teams and are provided an engineering challenge for which they need to develop a solution. We believe that by incorporating education in key concepts of the design thinking into these courses, and by also allowing students to identify problems of interest to them (and to the broader community) for their team projects, that we can effectively increase the I&E mindset of our students. The majority of students who typically take the ENG1102 course in the fall are the students who took the ENG1001/ENG1100 track. Other students in the class are transfer students or students who took ENG1101 but are off the typical track due to scheduling reasons. A total of 111 students, from which 28 teams of three to four students per team were formed and participated in this pilot study.

In the pilot sections taught during the Fall 2017 semester, students were introduced to the design thinking process through a series of interactive workshops where they could apply the phases of empathy, define, ideation, prototype, and test, and then were encouraged through assignments to apply these concepts to their own projects. There was a total of 28 engineering teams that

designed, built, and tested an iterative series of prototypes as they worked toward a final solution due at the end of the semester. Teams consisted of three to four engineering students. Pre/post assessment was conducted in an attempt to measure the impacts of this pilot on students' curiosity & exploration, attitudes toward creativity, creative self-efficacy, and creative identity. The findings from this assessment are discussed in the results section.

Overview of Pilot Design Thinking Curriculum

In our pilot initiative to introduce design-thinking to the first-year engineering curriculum, we created a series of 1-hour modules, each of which introduced a component of the design thinking process – empathy, define, ideate, prototype and test. The design-thinking methodology was chosen for its human centered design and innovative problem-solving approach. Utilizing a variety of sources for design-thinking curricula, including the Stanford d-school [1] and Ideo.org [2], these modules were designed to facilitate a brief introduction to each phase of the process followed by a practical application of each. Hands-on mini-projects and activities were incorporated, allowing students the opportunity to experiment with the process prior to its application to their projects. For example, we used a quick and simple activity about ice cream within a class setting to illustrate the overall design thinking process. To practice empathy, students paired up to interview each other about their experiences eating ice cream. After creating a list of student-identified challenges and needs around ice-cream, two or more of the pairs worked as a team to define a specific problem or challenge they wanted to address, and then brainstorm 30 or more possible solutions (ideate). By using a nominal group voting technique, teams selected their "top" idea and created a simple prototype. Two teams then paired up to "test" each other's solution by sharing their prototype and gathering feedback on their design.

Each of the 1-hour design-thinking modules was designed to help students learn and practice the process before applying it to their own design projects. In these pilot sections, students were free to identify problems or opportunities of interest to them for their design project, and then work as a team to develop an innovation solution. Students were encouraged to identify a problem/opportunity by creating a "bug list" of things on/around campus that they found challenging or frustrating, as well as by interviewing other members of the campus community to gain empathy for challenges faced by others. In addition to completing the design-thinking modules, a set of assignments were developed that required students to demonstrate how each of the design-thinking components were integrated into their semester project. Examples of these assignments include:

- a problem statement assignment where teams had to "define" the problem they were designing for, with a summary of the observation and interviewing used to gain empathy for the user.
- a list of ideas for solutions to the problem statement as generated through the ideation phase, and the methods used to evaluate these ideas in order to select their team's "top" idea that they wished to develop further.
- a 2-minute pitch delivered in class to share their team's challenge and proposed solution.
- a description of at least three prototypes of increasing complexity created by the team with a summary of testing conducted on each prototype and how the results of that testing informed the subsequent prototype.

Survey Methods

In order to assess the effects of this design project with the implementation of design thinking on students, we used several different measures. The complete survey is included in the Appendix. To begin, we used the Engineering Design Self-Efficacy Survey (EDSE) to determine changes in students' self-efficacy, motivation, outcome expectancy, and degree of anxiety when performing several engineering design tasks. [3] For each task, the student was asked to record a number on a scale from 0 to 100. For example, on design self-efficacy, students were asked to rate their degree of confidence to perform the task (0 = cannot do at all; 50 = moderately can do; 100 = highly certain can do). These tasks include a) conduct engineering design, b) identify a design need, c) research a design need, d) develop design solutions, e) select the best possible design, f) construct a prototype, g) evaluate and test a design, h) communicate a design, and i) redesign.

We measured creativity using several different instruments to measure various aspects of creativity: creative identity, creative role expectancy, the perceived value of creativity, an individual's resistance to change, disposition towards curiosity, and attitudes towards creativity. The creative identity scale is a 5-item scale that measures how creativity is perceived as part of an individual's personal image. The more important being creative is to a person's self-image, the higher they will score on these questions. Research suggests that this may be more predictive of creativity than creative self-efficacy. [4] A person who identifies as more creative might be more prone to searching out opportunities to be creative and enjoy these activities. Creative role expectancy uses three questions that measures a student's perception of the role of creativity in their academic course work. [5,6] The perceived value of creativity scale is comprised of three questions developed by researchers at Penn State. This scale measures how individuals perceive creativity is valued in their personal and professional environments. [7] These three scales are measured on a 5-point Likert scale with 1 = Strongly Disagree and 5 = Strongly Agree.

The Resistance to Change Scale (RTC) is a 17-item survey that measures four subscales regarding an individual's reluctance to change. The first factor, Routine Seeking (RS), measures the extent one seeks out stable routines. Emotional Reaction (ER) measures an individual's response to change. Those individuals who are more anxious about change, would be more resistant to pursuing creative options. Short-term Thinking (STT) tests whether an individual focuses on short term costs of change versus the long term benefits. Finally, Cognitive Rigidity (CR) measures how strongly an individual holds onto their viewpoints. [8] This scale has been negatively correlated with creativity. In other words, a student who is more resistant to change would be less likely to pursue or enjoy opportunities to be creative.

The Curiosity and Exploration Inventory (CEI) is positively correlated with creativity. This survey measures an individual's disposition to be curious. This 7-item survey has two subscales: Exploration and Absorption. The Exploration subscale measures if an individual has a tendency to pursue novel and challenging activities. The Absorption subscale measures how likely an individual is to become absorbed in these activities. [9] Lastly, the Zampetakis and Moustakis Scale (Z & M Scale) is an 11-item survey with four subscales which measure attitudes towards 1) own creativity, 2) university environment, 3) family environment, and 4) pursuing

entrepreneurial intentions. [10] These three scales were also measured on a 5-point Likert Scale with 1 = Strongly Disagree and 5 = Strongly Agree.

The last three scales (RTC, CEI, and Z&M scales) were used in the first-year engineering program in the past to assess changes in creativity over the course of the first-year in engineering. Comparing these results to the pilot project will allow us to determine if the changes observed are more greater, less than, or equal to changes typically observed within the first-year engineering students at the end of ENG1102.

These surveys were administered as a single instrument through Survey Monkey at the beginning of the semester (pre) and after they had submitted their final design report at the end of the semester (post). A total of 87 students consented to the research and completed both the pre and post-test for a response rate of 78.4%. As this combined survey had a total of 72 questions, it is important to consider the effects of survey fatigue as this will affect a) how many students complete the survey and b) how seriously the students complete the survey. This appears to be a concern as the survey averaged a 62% completion rate, which would indicate that students are not answering all the questions. These students were, however, included in the analysis for the scales they had fully completed. In addition, several students did not complete the surveys seriously as evidenced by inconsistently answering opposing questions. For example, students answered “I often change my mind” and “I don’t change my mind easily” by agreeing to both or disagreeing with both when opposing responses were expected. A total of 19.5% (n=17) of the surveys were removed due to evidence of survey fatigue, giving a final sample of 70 students.

Pilot Assessment Results

In order to determine the effects of the design thinking instruction and project with respect to our various measures, we used a paired t-test to determine changes in each measurement scale. The results from the Engineering Design Self-Efficacy Survey (EDSE) are summarized in Table 1 below. Between 67 and 70 students completed the pre/post tests for each of the four separate scales. As you can see, the students felt significantly more confident in their abilities to perform all of the tasks with the exception of redesign. In addition, students felt significantly more confident in their ability to be successful on all of the tasks with the exception of researching a design need and evaluating and testing a design. There were no significant differences in their motivation to perform the various tasks or their level of anxiety when performing these tasks.

Table 1. Engineering Design Self-Efficacy Survey Results (EDSE) (Fall 2017)

Task	**Degree of Confidence** (Post-Pre (p))	**Motivation to Perform** (Post-Pre (p))	**Perception of Success** (Post-Pre (p))	**Degree of Anxiety** (Post-Pre (p))
Conduct engineering design	**10.0 (0.000)**[a]	3.9 (0.100)	**9.4 (0.000)**[a]	0.6 (0.856)
Identify a design need	**5.9 (0.026)**[b]	1.1 (0.567)	**7.4 (0.001)**[a]	2.1 (0.468)
Research a design need	**8.8 (0.003)**[a]	1.4 (0.647)	5.5 (0.059)	0.1 (0.962)
Develop design solutions	**6.4 (0.011)**[b]	2.8 (0.184)	**7.1 (0.001)**[a]	-0.2 (0.963)
Select the best possible design	**6.6 (0.013)**[b]	-1.9 (0.453)	**5.0 (0.024)**[b]	1.0 (0.800)
Construct a prototype	**7.1 (0.007)**[a]	-1.4 (0.539)	**5.3 (0.010)**[a]	3.9 (0.301)
Evaluate and test a design	**7.1 (0.011)**[b]	-0.9 (0.734)	4.4 (0.062)	-0.7 (0.838)
Communicate a design	**5.8 (0.027)**[b]	0.3 (0.913)	**7.0 (0.002)**[a]	-2.9 (0.463)
Redesign	4.9 (0.075)	-1.4 (0.631)	**6.4 (0.006)**[a]	-1.1 (0.726)

[a] $p<0.01$, [b] $p<0.05$

The changes in the students' creative identity, creative role expectancy, and perceived value of creativity are shown in Table 2 below. As shown, the creative identity scale is the only scale that approaches significance (p=0.078).

Table 2. Creativity Scale Results for Fall 2017 ENG1102 Design Project

Scale	**N**	**D Mean (Post - Pre)**	**p**
Creative Identity	69	0.82	0.078
Creative Role Expectancy	69	-0.42	0.274
Perceived Value of Creativity	68	0.07	0.802

[a] $p<0.01$, [b] $p<0.05$

Table 3 looks at the changes in the three comparison scales: RTC, CEI, and Z & M Scale. There were no significant changes in any of these scales. While there are no significant increases with

regard to entrepreneurial intentions, own creativity, curiosity or exploration, there were also no increases in resistance to change. This would seem to indicate that the design thinking instruction and this project maintained the students' current levels of creativity.

Table 3. Creativity Results for Fall 2017 Design Project

Scale	Factor	N	D Mean (Post - Pre)	p
Z & M	Own Creativity	68	0.26	0.228
	University Environment	70	-0.09	0.748
	Family Environment	70	0.19	0.583
	Entrepreneurial Intentions	70	0.41	0.116
	Total	68	0.76	0.318
RTC	Routine Seeking	66	0.12	0.791
	Emotional Response	66	0.77	0.094
	Short Term Thinking	70	0.10	0.780
	Cognitive Rigidity	67	0.09	0.849
	Overall	60	0.97	0.444
CEI	Exploration	67	0.07	0.815
	Absorption	70	0.00	1.000
	Overall	67	0.13	0.784

[a] $p<0.01$, [b] $p<0.05$

A direct comparison between a previous offering of ENG1102 (Fall 2010) and the offering with design thinking (pilot group) is shown in Table 4 below. It is important to note that there were no significant pre/post changes in these measures in the Fall 2010 group either. Therefore, this comparison was used to determine if the results shown in the design thinking group are representative of the typical ENG1102 population. Using an independent t-test, these results indicate a few significant changes, which would indicate that these populations are different. First, students in Fall 2010 appear to have a family environment that encourages creativity more so than the Fall 2017 group. In addition, it appears that the Fall 2017 group was more resistant to change as a whole than the Fall 2010 group.

Table 4. Comparison between ENG1102 Fall 2010 (n = 84) and Fall 2017 (n = 70) Post-test Results

Scale	Factor	**Fall 2010** (Mean ± SD)	**Fall 2017** (Mean ± SD)	p
Z & M	Own Creativity	9.1 ± 1.8	9.0 ± 1.6	0.841
	University Environment	14.5 ± 2.4	14.6 ± 2.0	0.824
	Family Environment	**13.5 ± 2.4**	**12.5 ± 3.1**	**0.030[b]**
	Entrepreneurial Intentions	**7.6 ± 2.4**	**6.8 ± 2.6**	**0.048[b]**
	Total	44.7 ± 5.6	42.9 ± 6.2	0.065
RTC	**Routine Seeking**	**14.2 ± 4.3**	**15.8 ± 4.1**	**0.016[b]**
	Emotional Response	**13.3 ± 4.2**	**14.9 ± 3.7**	**0.017[b]**
	Short Term Thinking	**11.9 ± 3.9**	**13.7 ± 3.3**	**0.004[a]**
	Cognitive Rigidity	13.6 ± 4.0	13.5 ± 3.3	0.906
	Overall	**53.0 ± 11.8**	**58.0 ± 10.6**	**0.008[a]**
CEI	Exploration	17.8 ± 2.8	17.3 ± 2.9	0.368
	Absorption	12.9 ± 2.4	12.7 ± 2.7	0.666
	Overall	30.6 ± 4.4	30.1 ± 4.8	0.490

[a] $p<0.01$, [b] $p<0.05$

Student Feedback

At the end the term, the Fall 2017 ENG1102 pilot group was given a Design Thinking Feedback Survey. The survey used a five point Likert scale. Figures 1-3 show the results of the survey. One of the main goals of design thinking is to focus on the needs of the user. Students self-evaluated that the design thinking process helped them obtain that goal. Students also feel they would be able to apply these concepts on future design projects. In written comments, several students often referred to creativity and thinking outside the box concerning the design thinking class sessions. The students found the entrepreneurial project worthwhile, although they would recommend providing more focus for the design project topic.

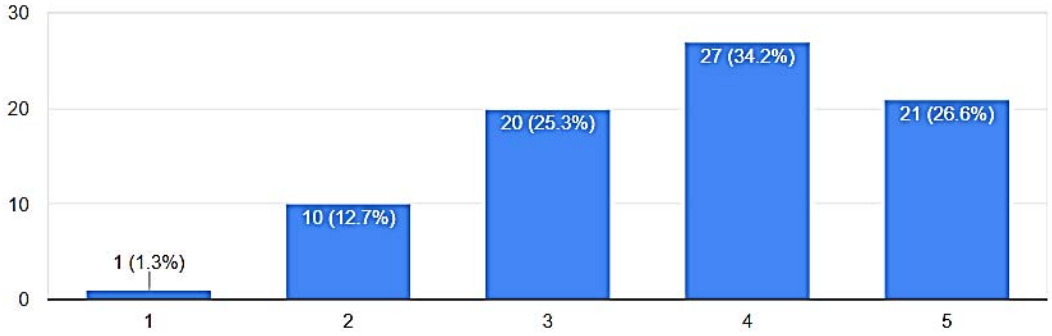

Figure 1. Fall 2017 ENG1102 student response to "The Design Thinking process helped our team to focus more intentionally on the needs of the user". 1 = Strongly Disagree, 5 = Strongly Agree, n = 79. Mean = 3.7 SD =1.0

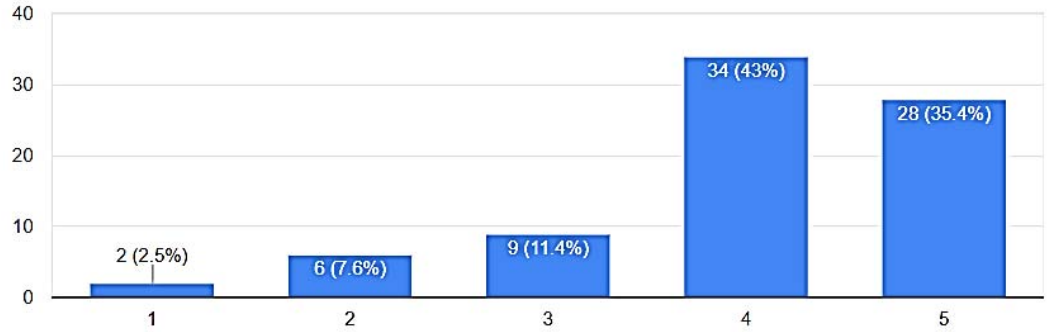

Figure 2. Fall 2017 ENG1102 student response to "I feel that I understand how to apply the Design Thinking process to future projects". 1 = Strongly Disagree, 5 = Strongly Agree, n = 79. Mean = 4.0, SD = 1.0

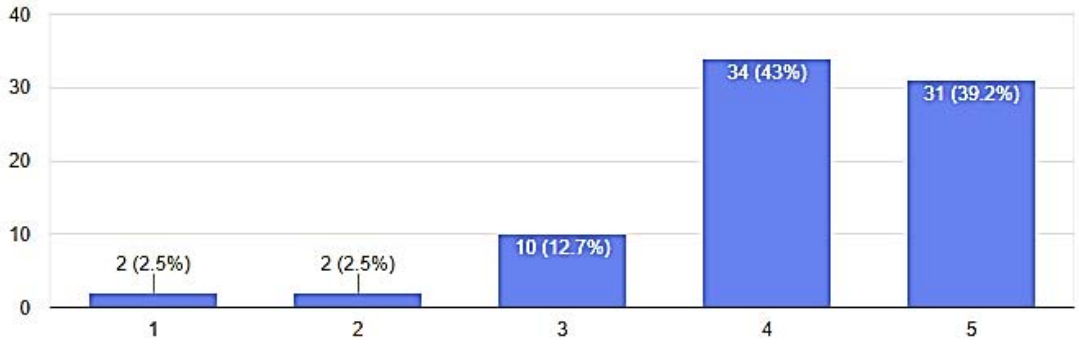

Figure 3. Fall 2017 ENG1102 student response to "Overall, the Entrepreneurial design project was worthwhile", 1 = Strongly Disagree, 5 = Strongly Agree, n = 79, Mean = 4.2, SD = 0.9

Conclusions and Future Work

This pilot study has been a learning experience with many positive outcomes and lessons learned. We were able to successfully introduce Design-Thinking into the ENG1102 design process with a series of one-hour modules. Feedback from students will allow us to improve the content and presentation of these materials for future courses. A summary of the survey data suggests that students showed gains in their confidence and perception of success on completing design tasks. The data also suggests that students who go into engineering now are less likely to have entrepreneurial intentions than in the past, are receiving less encouragement from their families to pursue creative endeavors, and are more resistant to change. If this is the case, it becomes more critical to encourage creativity in the university environment and activities such as design thinking become drivers for change in this mindset.

In general, the positive results from this pilot will lead the way to a next phase of the project. The initiatives that we plan to pursue as a result of lessons learned through this pilot will focus on improvements that we can test in a second pilot planned for Fall 2018. We learned a great deal through this pilot initiative and, as with any design thinking initiative, we are using information gained through our prototype/test phase to iterate on our design. This has allowed us to identify several key initiatives that we would like to explore to advance our efforts with the goal of introducing a permanent curricular offering. Key initiatives are identified below:

- ✓ Create a combined section(s) of the first-year engineering and business courses that will allow students to still learn the core content needed in each course, but will also allow them to come together for common sessions on the design thinking and lean start-up processes while working together on an interdisciplinary project team to develop innovative solutions to problems of interest to them.
- ✓ Refine the curriculum based on lessons learned during the pilot phase to optimize the design-thinking workshops, to incorporate training in lean start-up methodology, and to identify areas in which the curriculum for the first-year engineering and business courses can be merged without sacrificing the integrity of the core content.
- ✓ Allow students the flexibility to identify the problems they would like to solve, but within pre-identified theme areas such as the popular themes of student life, outdoor activities, and personal convenience products, along with more globally focused themes such as the environment, assistive technologies, and healthcare.
- ✓ Train additional faculty in the design-thinking and lean start-up methodologies by offering a “train-the-trainer” faculty workshop, to be facilitated by faculty who have completed Stanford’s Teaching & Learning Studio training on design thinking, and Steve Blank’s Lean Launchpad training.
- ✓ Incorporate use of the makerspace more deliberately into the curriculum for prototyping and testing students’ design projects.
- ✓ Refine assessment methods and continue assessment of the impact of the addition of the new curriculum
- ✓ Identify needs/challenges associated with scaling this approach to all FYE courses and refine/revise course materials as appropriate.

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This survey looks at your views regarding creativity and entrepreneurship in the design process. This survey should only take 10- 15 minutes.

* 1. To obtain credit for completing this survey, enter the following information.

Enter your first and last name

Enter your MTU email address (userid@mtu.edu)

Enter your ENG1102 Section number

2. Please select one of the statements below that best fits your view:

- ◯ Success in mathematics is based on an intellectual gift.
- ◯ Success in mathematics can be achieved through hard work.

3. Would you say you are more interested in:

- ◯ People and Relationships
- ◯ Things and Gadgets

4. For each statement below, please rate your level of agreement according to how you generally feel.

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
As a group member working on a project, I am often positively judged by my teammates for the ideas I have.	○	○	○	○	○	○
I try novel approaches despite the possibility of failure.	○	○	○	○	○	○
I can easily come up with many different ideas.	○	○	○	○	○	○
In my engineering coursework, I learn that there is more than one solution to a problem.	○	○	○	○	○	○
In my engineering coursework, I am encouraged to evaluate problems in innovative ways.	○	○	○	○	○	○
In my engineering coursework, the faculty encourage students to produce and employ new ideas.	○	○	○	○	○	○
My family members easily adapt to changing circumstances.	○	○	○	○	○	○
My family members always come up with new ideas for making their life easier.	○	○	○	○	○	○
I am comfortable sharing any ideas with my family	○	○	○	○	○	○
I'll probably start my own business in the future.	○	○	○	○	○	○
I can see myself as an entrepreneur.	○	○	○	○	○	○
I am often very creative in how I think about things.	○	○	○	○	○	○
I am often very creative when solving problems.	○	○	○	○	○	○
I naturally approach problems by trying to think "outside of the box"	○	○	○	○	○	○
When working with a group, I often have ideas that the group chooses to adopt.	○	○	○	○	○	○
I prefer assignments in which I am free to solve a problem or complete a task in novel ways.	○	○	○	○	○	○
I think that other students are much better at thinking "outside of the box" than I am.	○	○	○	○	○	○
I consider myself the type of person who will make novel contributions to the field of engineering	○	○	○	○	○	○
I enjoy learning about abstract concepts or theories	○	○	○	○	○	○
I often find myself deep in thought about an idea that one of my professors brought up in class	○	○	○	○	○	○

5. For each statement below, please rate your level of agreement according to how you generally feel.

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I prefer assignments that are given with clear instructions for completion rather than those in which I am free to decide how to complete them	○	○	○	○	○	○
I look forward to the opportunity to apply engineering concepts in novel ways to solve problems.	○	○	○	○	○	○
I often get frustrated when trying to solve an ill-defined problem	○	○	○	○	○	○
The classes I enjoy the most are those that really challenge my viewpoints.	○	○	○	○	○	○
I don't like to be impulsive, especially when it comes to problem solving.	○	○	○	○	○	○
I get anxious when confronted with an assignment that I don't feel prepared to complete.	○	○	○	○	○	○
When solving a problem, I try to focus on the most relevant issues.	○	○	○	○	○	○
When solving a problem, I appreciate the opportunity to be innovative.	○	○	○	○	○	○
I often think about how common engineering problems could be solved using more sustainable methods	○	○	○	○	○	○
If I am struggling to conceptualize something, drawing a picture of it helps	○	○	○	○	○	○
I can't wait to apply new concepts after learning about them in class	○	○	○	○	○	○
I generally consider changes to be a negative thing.	○	○	○	○	○	○
I'll take a routine day over a day full of unexpected events any time.	○	○	○	○	○	○
I like to do the same old things rather than try new and different ones.	○	○	○	○	○	○
Whenever my life forms a stable routine, I look for ways to change it.	○	○	○	○	○	○
I'd rather be bored than surprised.	○	○	○	○	○	○
If I were to be informed that there's going to be a significant change regarding the way things are done at work, I would probably feel stressed.	○	○	○	○	○	○
When I am informed of a change of plans, I tense up a bit.	○	○	○	○	○	○
When things don't go according to plans, it stresses me out.	○	○	○	○	○	○
If one of my bosses changed the performance evaluation criteria, it would probably make me feel uncomfortable even if I thought I'd do just as well without having to do any extra work.	○	○	○	○	○	○

6. For each statement below, please rate your level of agreement according to how you generally feel.

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
Changing plans seems like a real hassle to me.	○	○	○	○	○	○
I feel that creativity is a competency that employers look for in engineering graduates.	○	○	○	○	○	○
Often, I feel a bit uncomfortable even about changes that may potentially improve my life.	○	○	○	○	○	○
When someone pressures me to change something, I tend to resist it even if I think the change may ultimately benefit me.	○	○	○	○	○	○
I sometimes find myself avoiding changes that I know will be good for me.	○	○	○	○	○	○
I often change my mind.	○	○	○	○	○	○
I don't change my mind easily.	○	○	○	○	○	○
Once I've come to a conclusion, I'm not likely to change my mind.	○	○	○	○	○	○
My views are very consistent over time.	○	○	○	○	○	○
I hope to improve my creativity while at Michigan Technological University.	○	○	○	○	○	○
I would describe myself as someone who actively seeks as much information as I can in a new situation.	○	○	○	○	○	○
When I am participating in an activity, I tend to get so involved that I lose track of time.	○	○	○	○	○	○
I frequently find myself looking for new opportunities to grow as a person (e.g., information, people, resources).	○	○	○	○	○	○
I am not the type of person who probes deeply into new situations or things.	○	○	○	○	○	○
When I am actively interested in something, it takes a great deal to interrupt me.	○	○	○	○	○	○
Being creative is important to me professionally.	○	○	○	○	○	○
My friends would describe me as someone who is "extremely intense" when in the middle of doing something.	○	○	○	○	○	○
Everywhere I go, I am looking out for new things or experiences.	○	○	○	○	○	○
Being creative in my student work is an important part of who I am	○	○	○	○	○	○
There is an expectation that I do creative work in my classes.	○	○	○	○	○	○
Creativity is required in my daily work as a student	○	○	○	○	○	○

7. Rate your degree of anxiety (how apprehensive you would be) in performing the following tasks by recording a number from 0 to 100. (0 = not anxious at all; 50 = moderately anxious; 100 = highly anxious)

	0	10	20	30	40	50	60	70	80	90	100
Conduct engineering design	○	○	○	○	○	○	○	○	○	○	○
Identify a design need	○	○	○	○	○	○	○	○	○	○	○
Research a design need	○	○	○	○	○	○	○	○	○	○	○
Develop design solutions	○	○	○	○	○	○	○	○	○	○	○
Select the best possible design	○	○	○	○	○	○	○	○	○	○	○
Construct a prototype	○	○	○	○	○	○	○	○	○	○	○
Evaluate and test a design	○	○	○	○	○	○	○	○	○	○	○
Communicate a design	○	○	○	○	○	○	○	○	○	○	○
Redesign	○	○	○	○	○	○	○	○	○	○	○

8. For each statement, rate your confidence on a scale from 0 (not at all confident) to 100 (highly confident).

	0	10	20	30	40	50	60	70	80	90	100
In general, my creativity is an important part of my self-image Jaussi, et al.	○	○	○	○	○	○	○	○	○	○	○
My creativity is an important part of who I am Jaussi, et al.	○	○	○	○	○	○	○	○	○	○	○
Overall, my creativity has little to do with how I see myself. Jaussi, et al.	○	○	○	○	○	○	○	○	○	○	○
My ability to be creative is an important reflection of who I am. Jaussi, et al.	○	○	○	○	○	○	○	○	○	○	○
Being creative is important to me personally.	○	○	○	○	○	○	○	○	○	○	○

9. Rate your degree of confidence (i.e. belief in your current ability) to perform the following tasks by recording a number from 0 to 100. (0 = cannot do at all; 50 = moderately can do; 100 = highly certain can do)

	0	10	20	30	40	50	60	70	80	90	100
Conduct engineering design	○	○	○	○	○	○	○	○	○	○	○
Identify a design need	○	○	○	○	○	○	○	○	○	○	○
Research a design need	○	○	○	○	○	○	○	○	○	○	○
Develop design solutions	○	○	○	○	○	○	○	○	○	○	○
Select the best possible design	○	○	○	○	○	○	○	○	○	○	○
Construct a prototype	○	○	○	○	○	○	○	○	○	○	○
Evaluate and test a design	○	○	○	○	○	○	○	○	○	○	○
Communicate a design	○	○	○	○	○	○	○	○	○	○	○
Redesign	○	○	○	○	○	○	○	○	○	○	○

10. Rate how successful you would be in performing the following tasks by recording a number from 0 to 100. (0 = cannot expect success at all; 50 = moderately expect success; 100 = highly certain of success)

	0	10	20	30	40	50	60	70	80	90	100
Conduct engineering design	○	○	○	○	○	○	○	○	○	○	○
Identify a design need	○	○	○	○	○	○	○	○	○	○	○
Research a design need	○	○	○	○	○	○	○	○	○	○	○
Develop design solutions	○	○	○	○	○	○	○	○	○	○	○
Select the best possible design	○	○	○	○	○	○	○	○	○	○	○
Construct a prototype	○	○	○	○	○	○	○	○	○	○	○
Evaluate and test a design	○	○	○	○	○	○	○	○	○	○	○
Communicate a design	○	○	○	○	○	○	○	○	○	○	○
Redesign	○	○	○	○	○	○	○	○	○	○	○

11. Rate how motivated you would be to perform the following tasks by recording a number from 0 to 100. (0 = not motivated; 50 = moderately motivated; 100 = highly motivated)

	0	10	20	30	40	50	60	70	80	90	100
Conduct engineering design	○	○	○	○	○	○	○	○	○	○	○
Identify a design need	○	○	○	○	○	○	○	○	○	○	○
Research a design need	○	○	○	○	○	○	○	○	○	○	○
Develop design solutions	○	○	○	○	○	○	○	○	○	○	○
Select the best possible design	○	○	○	○	○	○	○	○	○	○	○
Construct a prototype	○	○	○	○	○	○	○	○	○	○	○
Evaluate and test a design	○	○	○	○	○	○	○	○	○	○	○
Communicate a design	○	○	○	○	○	○	○	○	○	○	○
Redesign	○	○	○	○	○	○	○	○	○	○	○