

# **Engaging Freshman Engineering Students in the Entrepreneurial Mindset through Disruptive Technology Design Challenge Activity**

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# Engaging Freshman Engineering Students in the Entrepreneurial Mindset through Disruptive Technology Design Challenge Activity

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**Abstract** – The freshman engineering discovery courses currently running at Marquette University – Opus College of Engineering offer engineering design challenge activities for new engineering students to experience the engineering design process and to simultaneously practice an entrepreneurial mindset. A six-week long design challenge activity is scheduled for a group of student teams (seven to nine students per team) to conceptually design disruptive products for the underprivileged. After introducing samples of existing products and/or services related to the disruptive technologies to the students, they practice to identify additional existing disruptive products/services in our society or market, and continue to conceptually design the future (potential) various disruptive products or processes related to the given theme of the project through the disruptive technology design challenge activity. At its core, disruptive technologies are strongly linked to the entrepreneurial mindset defined by the 3C’s of Curiosity, Connections and Creating value.

*Index Terms* – disruptive technologies, engineering design challenge, entrepreneurial mindset, freshman engineering students

## INTRODUCTION

It has been recognized that there are two major categories of technology or innovation development [1-2]: innovations that are sustaining and those that are disruptive. Sustaining technologies are products and/or services that target high-end customers and offer improved performance over previous offerings. In contrast, disruptive technologies target low-end customers through products/services that are simpler, more convenient, and often less expensive than competitors.

Both of these approaches to technology development are important for the marketplace; however, the majority of the undergraduate (including freshman) engineering curriculum focuses on the development of sustaining technologies (i.e., improving performance or adding new features). While there is little doubt that the development of such skills are important for engineering students and their future employers, there is a significant need to educate and develop engineering students and engineers that are also adept at identifying and producing disruptive technologies.

The freshman engineering discovery courses developed and currently running at Marquette University – Opus College of Engineering offers various engineering design challenge activities for new engineering students to experience the engineering design process while establishing an entrepreneurial mindset. A six-week long disruptive technology design challenge activity is scheduled for a group of student teams (seven to nine students per team) to conceptually design disruptive products and/or processes for the underprivileged.

During the first session, sample products and/or services related to the disruptive technologies were selected and introduced for the students to understand and recognize the basic characteristics or fundamentals of the disruptive products/services. During the second session, a group of students (three to four students per team) works to find and identify additional existing and available disruptive products/services in our society and marketplace, in which they are asked to (hypothetically) consider and identify the elements of the entrepreneurial mindset (defined by the 3C’s of curiosity, connections and creating value [3]) included and involved in the identified products/services. Table I shows the expected students’ primary outcome and example behaviors in order for them to properly practice and build the entrepreneurial mindset [3].

TABLE I  
STUDENT PRIMARY OUTCOME AND EXAMPLE BEHAVIORS  
WITH ENTREPRENEURIAL MINDSET [3]

STUDENT OUTCOME	EXAMPLE BEHAVIORS
ENTREPRENEURIAL MINDSET	<b>CURIOSITY</b> DEMONSTRATE constant curiosity about our changing world EXPLORE a contrarian view of accepted solutions
	<b>CONNECTIONS</b> INTEGRATE information from many sources to gain insight ASSESS and MANAGE risk
	<b>CREATING VALUE</b> IDENTIFY unexpected opportunities to create extraordinary value PERSIST through and learn from failure

After running two introductory sessions of disruptive technologies with the identified currently existing and available products/services in the marketplace, a group of

students (seven to nine students per team) perform a four-week long disruptive technology design challenge project to conceptually design various disruptive products and/or process related to the theme of the project. At its core, disruptive technologies are strongly linked to the entrepreneurial mindset defined by the 3C's of curiosity, connections and creating value.

This paper presents some of students' performance and outcomes obtained by running the disruptive technology design challenge activity through which the students are able to foster and develop an entrepreneurial mindset. The author's previous works [4-8] describe the details about the Freshman Engineering Discovery courses that have been running for more than ten years at Marquette University – Opus College of Engineering. In those courses, the entrepreneurially minded learning (EML) pedagogical approach has been explicitly adapted and used to foster freshman engineering students' entrepreneurial mindset defined by the Kern Entrepreneurial Engineering Network (KEEN) [3].

### SESSION 1: INTRODUCTION TO SUSTAINING AND DISRUPTIVE TECHNOLOGIES AND TYPES OF CUSTOMERS WITH ENTREPRENEURIAL MINDSET

The first introductory session is prepared for the students to learn about the sustaining and disruptive technologies and to be able to distinguish and identify the differences or characteristics between them. It is well known that sustaining technologies with their products/services primarily serve established companies, as their primary business model will involve making a better product that can be sold for higher profit margins.

In contrast, it is known that disruptive technologies with their products/services target low-end customers through products/services that are simpler, more convenient, and often less expensive than competitors. It was found that there are four common fundamentals or characteristics on the disruptive products/service - (i) usually cheaper, (ii) almost as good (if possible), (iii) serve customers that established companies do not care due to low margin, and (iv) improve over time [1-2]. Some of established companies are often significantly affected by disruptive technologies, sometimes to the point of collapse, when they fail to identify disruptive competitors to their marketplace.

Therefore, hiring employees that are skilled in disruptive technologies may allow established companies to recognize potential disruptors earlier and adjust their business model accordingly. Also, engineers trained in disruptive technologies are ideal for leading the development of new technologies in companies of all sizes and levels of establishment since they are skilled in connecting with customers and creating value.

These skills arise from the distinct nature of disruptive technology development, which starts with identifying customers that are over-served, under-served, or not served at all by existing products/services. This shift in mindset

allows companies to identify new opportunities that might normally be overlooked in a traditional sustaining business model, which can lead to product/services that have the greater chance for success.

The under-served customers usually like the products/services that they are using, and they are attracted to improvements/upgrades that may develop over time. The sustaining technologies may address their needs. The over-served customers usually like some aspects of products/services that they are using, and they would prefer a streamlined/simpler version at lower cost. The disruptive technologies may address their needs. The not-served customers currently are not using the products/services, and they could become part of market if product/service were substantially changed. The disruptive technologies may address their needs.

Table II shows the summary of different customers' behaviors for two sample/example products/services selected for the session 1. It can be seen that the sustaining technologies and their products/services commonly target to the under-served customers, while the disruptive ones for both the over-served and not-served customers because of existence of a room or gap for over- and not-served customers to be interested in new or disruptive products/services to meet their needs.

TABLE II  
DIFFERENT CUSTOMERS' BEHAVIORS FOR EXAMPLE PRODUCTS/SERVICES SELECTED FOR THE SESSION 1

Example 1: Cable/Satellite Entertainment		
Under-Served Customers	Over-Served Customers	Not-Served Customers
<ul style="list-style-type: none"> <li>◆ Like lots of channels</li> <li>◆ Have no problem paying for channels they don't actually watch</li> <li>◆ Will pay more for extra packages (e.g., movie, sport channels, etc.)</li> </ul>	<ul style="list-style-type: none"> <li>◆ Like a handful of channels</li> <li>◆ Do not want to pay for other channels they are not watching</li> <li>◆ Might be interested in an extra package, but would rather have just that (rather than an expensive add-on)</li> </ul>	<ul style="list-style-type: none"> <li>◆ Are not able or willing to pay for cable/satellite package</li> </ul>
Example 2: Power Tools		
Under-Served Customers	Over-Served Customers	Not-Served Customers
<ul style="list-style-type: none"> <li>◆ Contractors who work every day with their tools</li> <li>◆ Want rugged, long-lasting, high power instruments</li> <li>◆ Are willing to pay extra for quality since it is their livelihood</li> </ul>	<ul style="list-style-type: none"> <li>◆ DIY enthusiasts who do many projects around their house each year</li> <li>◆ Want a handful of critical tools, but not everything under the sun</li> <li>◆ Quality is somewhat important to them.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Homeowners that just want to hang a picture frame and be done with it</li> <li>◆ Want something lightweight, low-cost, and quality is not very important</li> <li>◆ Only going to use once or twice per year</li> </ul>

At the end of the introductory session 1, six sample examples of currently existing disruptive products/services (see Table III) are selected for a group of students (three to

four per team) to practice creating or developing the elements of the entrepreneurial mindset (defined by the 3C's of curiosity, connections and creating value) by hypothetically assuming or pretending that they were disruptors of the products/services shown in Table III. Table IV shows a list of keywords (related to the 3C's) developed by the students' teams.

TABLE III  
SAMPLE EXAMPLES OF EXISTING PRODUCTS/SERVICES WITH IDENTIFIED DISRUPTORS

Sample/Example Products/Services	Typical/Identified Disruptor(s)
[1] Cable/Satellite Entertainment Services	Netflix, Hulu, Roku, etc.
[2] Power Tools	Black & Decker, etc.
[3] Personal Computers	Dell Computers
[4] Lab-based Glucose Testing	Portable Blood Glucose Monitors
[5] Commercial Airlines	Southwest Airlines
[6] Portable Cameras	Smart Phone, i-Phone, etc.

TABLE IV  
SAMPLE OF STUDENTS' WORK – LIST OF KEYWORDS RELATED TO THE 3C'S OF ENTREPRENEURIAL MINDSET INVOLVED IN THE SELECED PRODUCTS/SERVICES

EXERCISE [1]: Cable/Satellite Entertainment with NETFLIX, HULU, ROKU, etc.	
Curiosity	Demand / Watch past shows / Work around schedule / Go beyond physical media / One Provider
Connections	On any device / Built on success of Blockbuster / Still billed monthly / subscription / TV not always practicable / Offers suggestions based on previous choices / People always have their phone.
Creating Value	Low cost / Increased convenience / Fraction of the cost / Easier to watch / Wide demographic / Creates original shows / New shows / Countless selections
EXERCISE [2]: Power Tools with Black & Decker	
Curiosity	People work for themselves / Make more simple / Cater to new users / Cheap / Don't need specialized tools
Connections	DIY/simple projects / Not willing to pay for fancier tools / Still complete basic tasks / Don't want to hire professional / Better speed of work
Creating Value	Low cost & DIY / Light weight / Affordable / No compromised features / Low-end options
EXERCISE [3]: Personal Computers with Dell Computers	
Curiosity	Simple & cheaper / Customizable / Navigable / Limited choices / Target all computer users
Connections	Same software & OS / Simplicity & compatibility / High performance
Creating Value	Customizable / Cheaper / Simple / Frugal / Accessible
EXERCISE [4]: Portable Blood Glucose Monitors	
Curiosity	No need transportation / Long time to produce results / Simple, easy to use & safe / Portable / Accurate
Connections	Do it themselves & simple / Hospitals are busy / Same process as hospitals / Affects large amount of population / Control over own body
Creating Value	Small, easy, portable & accurate / Self-evaluating, time-efficient / Rewards for frequent flyers
EXERCISE [5]: Commercial Airlines with Southwest Airlines	
Curiosity	Low cost, more convenient / Need no hidden fees
Connections	Cheaper / Appeal to more people / Same routes
Creating Value	Cheaper, more routes & less time / Less stressful

EXERCISE [6]: Portable Cameras with Smart Phone & i-Phone	
Curiosity	Easier to use & right away / Compact, portable & everywhere / Too bulky & more accessible
Connections	Immediately see results / More settings / No more bulky cameras / Price point static
Creating Value	Easier to use / No need to develop pictures / Downsize / Easier transport / Smaller / Better sensors / Better pictures / Built into smartphones / Storage / Store memories / Quality pictures / More versatility / Less stressful

It can be seen that the students are able to clearly understand the characteristics or fundamentals of the disruptive products/services. And they also experience identifying and developing the key elements of the entrepreneurial mindset defined by the 3C's related to the development of those disruptive products/services shown in Table IV.

## SESSION 2: INVESTIGATING AND IDENTIFYING ADDITIONAL DISRUPTIVE PRODUCTS/SERVICES WITH ENTREPRENEURIAL MINDSET

After the preliminary introductory session 1, the students were asked to investigate and identify the additional disruptive products/services existing and available in the marketplace, and simultaneously to generate/create the key elements of the 3C's related to the identified disruptive products/services. Table V shows the samples of students' works, in which it shows identified disruptees and disruptors of various products/services. Figure 1 shows a student's presentation slides, in which it includes the fundamentals of disruptive products along with the entrepreneurial mindset involved in the disruptive products.

It is apparent that the students are able to find and identify various types of disrupted products/services and the corresponding disruptors. It definitely stimulates and motivates the students to actively participate in the disruptive technology design challenge activity to practice conceptually designing potential/future new disruptive products/services.

TABLE V  
SAMPLE OF STUDENTS' WORKS – LIST OF IDENTIFIED DISRUPTIVE PRODUCTS/SERVICES

Selected Disrupted Products/Services	Identified Disruptors
Traditional Home Cooked Meals	Fast Food Chains such as McDonalds, Burger King, Taco Bell, etc.
Navigational Processes such as maps and GPS system	Smart Phone Navigation System
Traditional Expensive Manufacturing Techniques	3D Printing Prototype Models
Telephone Voice Message System	Cell Phone Texting Message
Traditional College	Online Courses/Classes
Traditional Department & Grocery Stores	Amazon.com
The Local Library	Google Wikipedia
Music Streaming (e.g., Apple Music, Using CD's, Cassettes, etc.)	App Spotify, Youtube, Soundcloud, Pandora, etc.
Subway, Taxies, Public Busses, etc.	Citi Bikes

Laptop PCs	Tablets
Traditional Vacuum Cleaner	Roomba
Old-Fashioned Maps (e.g., Road Maps, Mapquest, etc.)	Global Positioning Systems (GPS)
The Whiteboard/Chalkboard	The SmartBoard
Web Browsers (e.g., Microsoft Internet Explorer)	Google Chrome/Firefox
Makeup Products	Sephora App
Traditional Money Sharing Services (e.g., Regular Bank, Western Union, etc.)	Online Money Sharing Services (e.g., Venmo, Square Cash, PayPal, etc.)
Traditional (Video) Gaming (e.g., Nintendo, Sega, etc.)	Mobile (Handheld) Gaming

### Traditional Vacuum Cleaner

<b>Under-served</b> <ul style="list-style-type: none"> <li>• Likes a very clean house</li> <li>• No problem paying extra for a better vacuum</li> </ul>	<b>Over-served</b> <ul style="list-style-type: none"> <li>• Want to clean through cheaper means</li> <li>• Does not have much time to focus on cleaning</li> </ul>	<b>Not Served</b> <ul style="list-style-type: none"> <li>• People who do not clean their homes at all because they are homeless, dirty, or lazy</li> </ul>
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### Disrupter: Roomba

- Takes up less space
- Cheaper
- Hands-free (Convenient)
- Less time needed to clean home



### Three C's

- **Curiosity:** People will always need to clean their homes, but is there a simpler way to vacuum?
- **Connections:** Autonomous machines and advanced AI brought inspiration to the idea of the roomba.
- **Creating Value:** The elderly and weak do not need to push heavy equipment or hire cleaners to keep their homes tidy.

FIGURE 1

A STUDENT'S PRESENTATION SLIDES – IDENTIFIED DISRUPTIVE PRODUCT WITH THE 3C'S INVOLVED

## ENGINEERING DESIGN CHALLENGE ACTIVITY WITH DISRUPTIVE TECHNOLOGY

After two introductory sessions described in the previous two sections, a new group of students (seven to nine students per team) perform a four-week long disruptive technology design challenge activity with the theme of designing disruptive products or process for the underprivileged. Table VII shows the overall theme and the project guideline used for the disruptive technology design challenge activity.

Figure 2 shows the weekly schedule for the students to use and follow for the project. The key elements of the entrepreneurial mindset defined by the 3C's are properly included in the weekly schedule.

TABLE VII  
OVERALL THEME AND GUIDELINE USED FOR DISRUPTIVE TECHNOLOGY DESIGN CHALLENGE ACTIVITY

<b>OVERALL THEME:</b> "Designing Disruptive Products (Devices or System) or Processes for the Underprivileged" <b>DESIGN GUIDELINE:</b> <ul style="list-style-type: none"> <li>• Identifying &amp; selecting the problems/issues (w/ <b>Curiosity &amp; Connections</b>)</li> <li>• Generating/creating new concepts/ideas to solve the issues/problems with proper hand sketches (w/ <b>Curiosity &amp; Connections</b>)</li> <li>• Selecting/refining and finalizing idea/concept (w/ <b>Connections</b>)</li> <li>• Developing system working principles &amp; creating physical system (3D solid) virtual models (w/ <b>Connections &amp; Creating Value</b>)</li> <li>• Performing a basic/proper engineering and cost analysis/calculations of the selected objects with some degree of entrepreneurial aspect to the products/system (w/ <b>Connections &amp; Creating Value</b>)</li> </ul>
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CONNECTIONS			
CURIOSITY		CREATING VALUE	
<b>WEEK #1</b> <ul style="list-style-type: none"> <li>♦ Problem Identification</li> <li>♦ Ideation (1)</li> </ul>	<b>WEEK #2</b> <ul style="list-style-type: none"> <li>♦ Ideation (2) &amp; Refinement</li> <li>♦ Analysis (1)</li> </ul>	<b>WEEK #3</b> <ul style="list-style-type: none"> <li>♦ Analysis (2) &amp; Assessment</li> <li>♦ Project Executive Summary</li> </ul>	<b>WEEK #4</b> <ul style="list-style-type: none"> <li>♦ Presentation Evaluation</li> </ul>

FIGURE 2

WEEKLY SCHEDULE FOR DISRUPTIVE TECHNOLOGY DESIGN CHALLENGE ACTIVITY

A simple six-step engineering design process [7] (i.e., problem identification, preliminary ideas/concepts, refinement, analysis, decision and implementation) has been used for freshman engineering students to use and follow for the design challenge project work.

While keeping the four characteristics or fundamentals of disruptive products/serves mentioned in the previous section, the additional design constraints (some of them are similar/same) are used for this activity as: the products or process should be designed as easy/simple to use, cheap to purchase (i.e., low-cost products), and does not require skill or education to use.

Table VIII shows some of students' work for the disruptive technology design challenge project. It is evident that the students and their design teams explicitly practiced the entrepreneurial mindset (defined by the 3C's of curiosity, connections and creating value) along with their imagination and creativity to generate/create a product to help the underprivileged in our society. Figure 3 shows sample/selected CAD models of the project, in which all design teams are required to create virtual CAD models related to their design products or processes. Also, all teams are required to properly address and demonstrate the products and/or system working principles in the final project reports and the presentation materials.



TABLE VIII  
DISRUPTIVE TECHNOLOGY DESIGN CHALLENGE PROJECT –  
SAMPLES OF STUDENTS' WORKS

Project Title or Product Name	Product/System Description
GOGO TENT	Designing an inexpensive, highly portable single person tent for residents dealing with homelessness.
ZEER POT FILTRATION SYSTEM	Designing the Zeer pot water system to help many hot, dry countries in Africa and the Middle East accessing to the refrigeration and filtration systems
PUFF N' STUFF	Designing a jacket that can function both as a means of storage and as a variable climate control system for homeless people - a comfortable sleeping area, staying warm, carrying and storing personal items, and more.
POWER WHEEL	Designing the product <i>Power Wheel</i> that makes wheel chair maneuverability easier and less expensive with a battery attached to some wheels that could be connected to an existing wheelchair, at home charger included
WATER ON WHEELS	Designing a bike with a large water canister on the back, that can easily transport the water from the source to the community (e.g., Ethiopia)
MENSTRUATION UNDERGARMENTS	Designing an innovative reusable menstruation undergarment for specifically, women in regions of Africa such as Kenya
A MODULAR HOUSING FOR NATURAL DISASTER	Designing an inexpensive, modular tent system to house families of four displaced from their homes following natural disasters
PLANT PODS	Designing/creating a self-contained potato growing pods for people (especially the African Country of Malawi)
ADAPTIVE MEDICAL TAPE	Designing a bandage that can be used to provide a secure and clean area for the wound to heal saves lives of those who are far away from hospitals or treatment centers
THE BACKET	Designing/creating a multipurpose bag that serves as a sleeping bag/blanket and large jacket that can be worn as a backpack to provide warmth and comfort to the homeless population
MAGNETIC ZIPPER	Designing a product for people (with limited finger dexterity from diseases, such as Parkinson's disease) often struggle with attaching and zipping on their jackets - for these individuals to perform this task with ease
THE SPIN CYCLE LAUNDRY MACHINE	Designing a (man-powered) device that can use a reduced amount of water to complete a cycle of laundry for people in the developing country of Morocco
THE KACHOW CHAIR	Designing a more effective and potentially cheaper wheelchair, which will be more efficient in movement and also more comfortable for people who suffer from long-term injuries or diseases that affect the body from the waist down
BRICKHOUSE TORNADO SHELTER	Designing a more financial and physical accessible tornado shelter (collapsible, portable, and mostly impenetrable by common debris) that will improve the current use of shields

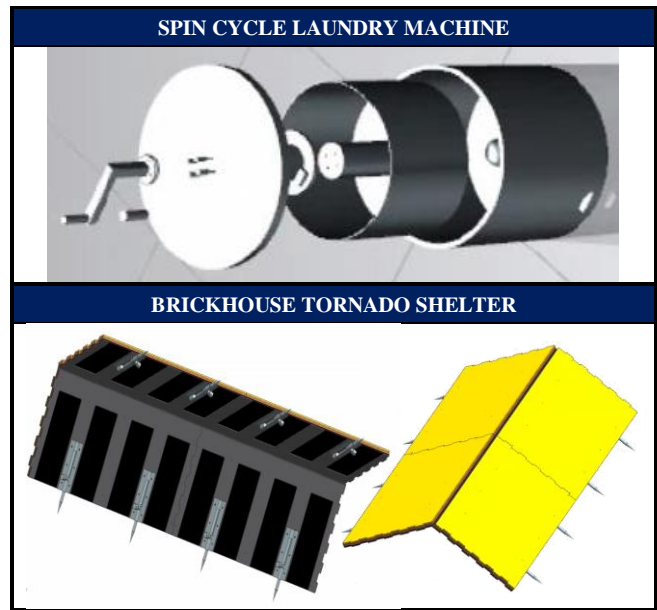


FIGURE 3  
SAMPLE CAD MODELS OF FRESHMAN DISRUPTIVE  
TECHNOLOGY DESIGN CHALLENGE PROJECT

The overall performance of the design team's work is evaluated by the final team project report and team oral presentation, in which some degree of entrepreneurial aspect of their design products should be properly included and demonstrated. Table IX shows the guideline for the design team to consider and include in their final work – project report and oral presentation. This form is also used as the presentation evaluation rubric for the evaluators or judges that consist of peer evaluators (i.e., the students in the same class section) and engineering faculty/staff members and upper-level engineering students. It is shown that evaluation items #2 through #5 are connected and related to the key elements of the 3C's of an entrepreneurial mindset.

TABLE IX  
GUIDELINE AND EVALUATION RUBRIC USED FOR DISRUPTIVE  
TECHNOLOGY DESIGN CHALLENGE PROJECT

Project Evaluation Criteria & Equivalent Grade Point				
Poor [1]	Below Average [2]	Average [3]	Above Average [4]	Good [5]
No.	Evaluation Items	Score		
		Min	Max	
[1]	Appearance			
[2]	Clarity of Problem Statement (w/ <i>Curiosity</i> )	4.5 (90%)	4.8 (96%)	
[3]	Preliminary Ideas & Proposed Solutions (w/ <i>Curiosity &amp; Connections</i> )	4.2 (84%)	4.9 (98%)	
[4]	Refinement & Analysis (w/ <i>Connections &amp; Creating Value</i> )	4.3 (86%)	4.6 (92%)	
[5]	Validity of Final Concepts (w/ <i>Creating Value</i> )	4.4 (88%)	4.7 (94%)	
[6]	Handling Questions			
[7]	Overall Presentation (Preparation & Organization)			

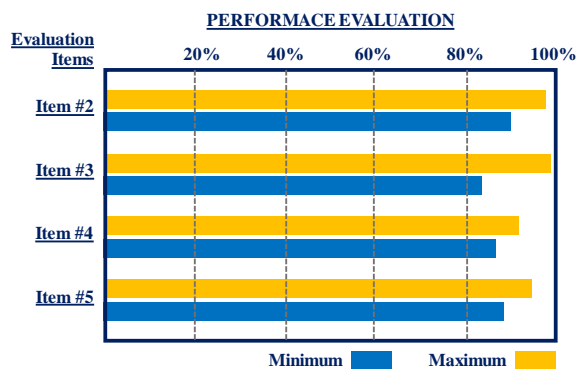


FIGURE 4  
STUDENTS' PERFORMANCE ANALYSIS RESULTS (THE 3C'S) OF  
DISRUPTIVE TECHNOLOGY DESIGN CHALLENGE WORK

Table IX and Figure 4 show design challenge project work performance analysis results obtained from the evaluation items #2 through #5, in which the distributions of the minimum and maximum scores (from all design teams) for each evaluation item are obtained to analyze and assess the students' learning outcomes from the disruptive technology design challenge activity in the course. The overall performance of the students' work in terms of fostering their entrepreneurial mindset through this type of design challenge activity is very high. And it was found that the overall performance and the evaluation scores obtained from this disruptive technology design challenge activity are about 5-10% higher than those obtained from the design challenge project without having the introductory disruptive technology sessions [4].

### SUMMARY AND CONCLUSIONS

The *Freshman Engineering Discovery* courses developed and currently running at Marquette University – Opus College of Engineering are designed to create engineering students that are curious about the world around them, unafraid to challenge existing methods, able to identify unexpected opportunities for growth, and eager to seek out innovative solutions to challenging problems. In order to meet these goals of the two-semester long courses, the entrepreneurially minded learning (EML) pedagogical method along with others has been explicitly implemented.

It should be noted that the development of disruptive technologies is not tied to one discipline within engineering. Rather, it is a universal approach to technology development that has potential to be both exciting and ground-breaking in its impact on the mindset of emerging engineering students.

The primary outcomes obtained by implementing a six-week long disruptive technology design challenge activity show that many new engineering students are able to use and express their imagination and creativity. Also it was found that the overall performance analysis results obtained from the disruptive technology design challenge activity with having the introductory disruptive technology sessions are high, resulting in engaging the new engineering students in the entrepreneurial mindset.

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