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Fostering and Establishing an Engineering Entrepreneurial Mindset through Freshman Engineering Discovery Courses Integrated with an Entrepreneurially Minded Learning (EML) Pedagogic Approach

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***Abstract* – It is recognized worldwide that first-year engineering education is critical for new entry-level engineering students to obtain a clear vision and direction for their future. The engineering discovery courses developed at Marquette University – Opus College of Engineering offers freshman engineering students the opportunity to discover and explore their potential through various course topics, contents and activities integrated with entrepreneurially minded learning (EML). As a result, the students are able to develop and explicitly show their value as future engineers by gathering and assimilating information to discover opportunities or insights for further action. This is the first step that new engineering students take in fostering and establishing an engineering entrepreneurial mindset. The primary outcomes obtained by implementing the EML in the Freshman Engineering Discovery courses are shown in this paper.**

Index Terms – freshman engineering students, entrepreneurial mindset, entrepreneurial minded learning, freshman engineering discovery courses

INTRODUCTION

Higher education should be a transformative experience for students. A few years of studying and experience in college can lead to a lifetime of success. During school years, engineering students develop technical and professional skills. But beyond those skill sets, education and experience in engineering school can potentially transform a student's mindset. It was discovered that freshman engineering students frequently re-examine their values and motivations during their first year in college [1]. Thrown into unfamiliar situations with a new environment and expectations, undergraduate engineering programs become a crucible in which engineering students have an opportunity to think about the way they think; this is called metacognition [2-3]. Thus, it seems that the higher-educational institutes such as engineering schools are responsible for the students to develop both their skillset and mindset that would be influenced by a variety of teaching methods or pedagogical approaches.

Entrepreneurially minded learning (EML) is an emerging pedagogy that emphasizes discovery, opportunity identification, and value creation [4-5]. The EML builds upon other widely accepted pedagogical methods. In order for new/freshman engineering students to consistently develop their engineering skills and foster an engineering entrepreneurial mindset, they need to be exposed to more opportunities to practice and explicitly express their creativity through various engineering course works, activities and related experiences.

The main objective of the two-semester long *Freshman Engineering Discovery* courses developed and currently running at Marquette University – Opus College of Engineering is to provide new engineering students a vision as successful world-class engineering students in the future, equipped with both proper engineering skillset and mindset. In order to meet the objective, this course adapted an entrepreneurially minded learning (EML) pedagogy, complementarily stacked alongside other pedagogical approaches such as the problem-based and project-based learning.

The author's previous works [6-8] describe the details about the *Freshman Engineering Discovery* courses that have been running for more than eight years at Marquette University – Opus College of Engineering. After introducing the entrepreneurially minded learning (EML) as one of the pedagogical approaches along with the engineering entrepreneurial mindset defined by the Kern Entrepreneurial Engineering Network (KEEN) [4-5], this paper describes how the *Freshman Engineering Discovery* courses have been integrated with the EML. And it also shows the primary outcomes obtained by implementing the EML in the courses, supported by some students' course performance results obtained from various evaluation forms and rubrics (such as reports, presentations and posters) as direct and indirect measures of how the students are able to foster and build their engineering entrepreneurial mindset during their freshman year.

ENTREPRENEURIALLY MINDED LEARNING (EML) WITH ENTREPRENEURIAL MINDSET

There are various and different types of college-level courses that the students should study to get proper credits for graduation. Some of them are either engineering-related (such as mathematics and science courses) or core engineering courses within each disciplinary area while others are non-engineering courses such as English, History or Psychology as well as many others. Course instructors may adapt or use specific pedagogic methods related to the course contents and scope. Table I summarizes various traditional pedagogic methods and their emphases [4-5].

TABLE I
VARIOUS TRADITIONAL PEDAGOGICAL METHODS AND THEIR EMPHASES

Subject-Based Learning (**SBL**)	Students learn in a variety of settings, but the focus is on mastery of domain knowledge.
Experiential Learning (**EL**)	Students learn through direct experience in a domain (learn by doing).
ProjecT-Based Learning (**PTBL**)	Students learn domain and contextual knowledge from an instructed approach utilizing multifaceted projects as a central organizing strategy.
Active/Collaborative Learning (**ACL**)	Students learn through peer interaction.
Case-Based Learning (**CBL**)	Students learn domain knowledge and decision-making processes employed by experienced professionals in a historical case.
ProbleM-Based Learning (**PMBL**)	Students determine the information, strategies, and domain knowledge required to solve the problem.

Most instructors who teach entry or introductory-level engineering courses may use and/or adapt the subject-based learning (SBL) and/or the problem-based learning (PMBL) approaches for the students to study and build proper domain knowledge related to the course topics. Some instructors who teach upper-level core engineering courses may adapt and/or use the project-based learning (PTBL) and/or the case-based learning (CBL) for the students to practice applying the engineering fundamentals in order to solve real-world actual problems. Some instructors who teach the senior-level engineering courses such as senior capstone design course and elective courses may adapt and/or use the project-based learning (PTBL) and/or experiential learning (EL) for the students to apply their knowledge and experience that have been built throughout their engineering courses and related activities.

However, it has been recognized that most engineering students hesitate to deploy or explore their vision and potential as future engineers, mainly due to lack of experience in building or establishing their own engineering entrepreneurial mindset through taking various engineering courses [1].

The entrepreneurially minded learning (EML) teaching method has been advocated by KEEN [4-5] in order to help engineering students foster and develop an entrepreneurial mindset. Importantly, the EML builds upon other widely accepted pedagogical methods. Thus, this approach can be complementarily stacked alongside others. Table II summarizes the EML's emphasis. It also shows how the EML method is linked with others through or by adding the key element of entrepreneurial mindset.

TABLE II
EMPHASIS OF THE EML METHOD OR APPROACH

Entrepreneurially Minded Learning (**EML**)	Students learn to create value by gathering and assimilating information to discover opportunities or insights for further action.

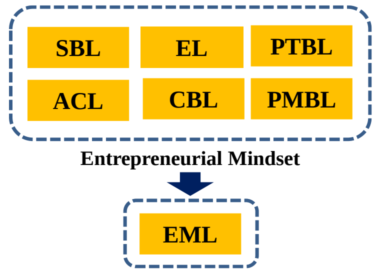


Table III shows the entrepreneurial mindset defined by KEEN in which three keywords, 3C's (*Curiosity - Connections - Creating Value*) were created for educators to use/follow as a guideline in order to provide the students an entrepreneurial mindset. It is also suggested that the students (properly educated/trained with the 3C's shown in Table III) must possess an entrepreneurial mindset coupled with engineering thought and action expressed through collaboration and communication founded on values. Table III also shows the expected students' primary outcome and example behaviors in order for them to properly practice and build the engineering entrepreneurial mindset [4-5].

TABLE III
STUDENT PRIMARY OUTCOME AND EXAMPLE BEHAVIORS WITH ENTREPRENEURIAL MINDSET

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

IMPLEMENTATION OF THE EML AND ITS PRIMARY OUTCOMES

I. Freshman Engineering Discovery 1

The course, *Freshman Engineering Discovery 1*, is offered every fall semester for freshman engineering students at Marquette University – Opus College of Engineering. It consists of one lecture for a one-hour period (on Monday) and two studio classes (on Tuesday and Thursday) for a four-hour period per week. Table IV describes the overall structure and topics of the course.

TABLE IV
FRESHMAN ENGINEERING DISCOVERY 1 – OVERALL COURSE STRUCTURE AND TOPICS

Engineering Graphics Fundamentals & Computer-Aided Design (CAD) Practice	Introduction to Engineering and Engineers & Multidisciplinary Department Module Sessions
Graphics & CAD Team Project – Poster Exhibition & Competition	

Introduction to engineering and engineers and department module sessions. The new engineering students in this course are primarily introduced on how to use and follow a set of rules and guidelines to experience the field of engineering and to understand the roles and responsibilities of an engineer. This is accomplished through various class and lab activities such as Fermi's problem solving exercises, scientific/engineering (US and SI) unit systems and their usage through various types of sample engineering problems.

For the department module sessions, each department (biomedical, civil and environmental, electrical and computer and mechanical engineering at Marquette University – Opus College of Engineering) provides the students with an overview of their departments and areas of practice, along with appropriate research works and activities. Through this type of department module session, the freshman engineering students are able to recognize the multidisciplinary perspectives of engineering fields.

In order to assess the students' learning from the department module sessions, the students are asked to fill in the survey form shown in Table V in which four evaluation items connected to the three keywords of the 3C's are used. It can be seen that the average scores for the items #1 and #2 (*Curiosity* and *Connections*) are a bit lower than those for the items #3 & #4 (*Connections* and *Creating Value*). This is due to the fact that many new or entry-level engineering students are not well familiar with the areas and topics selected and introduced by each department, but their explicit participation in the class and lab activities allow them to learn more about the multidisciplinary characteristics of engineering and engineers.

TABLE V
STUDENTS' LEARNING OUTCOMES WITH THE 3C'S FROM THE DEPARTMENT MODULE SESSIONS

Evaluation Survey Used for Department Module Sessions				
Poor [1]	Below Average [2]	Average [3]	Above Average [4]	Good [5]

No.	Evaluation Items	Average Score
[1]	Selected Areas, Topics and Scope (w/ ***Curiosity***)	**3.8 (76%)**
[2]	Interest and Challenge (w/ ***Curiosity*** & ***Connections***)	**3.9 (78%)**
[3]	Contents and Activities (w/ ***Connections*** & ***Creating Value***)	**4.3 (86%)**
[4]	Effective Learning (w/ ***Creating Value***)	**4.2 (84%)**

Engineering graphics fundamentals and computer-aided design (CAD) practice. The project-based learning (PTBL) approach described in Table I has been used in this course for the students to study and practice the topics of engineering graphics fundamentals and computer-aided design (CAD) through the use of the textbook developed by this author [9]. The PTBL approach allows students to create a series of 3D solid (component and assembly) models during lab classes every time they practice CAD modeling by using the routines and/or methods that they have used to create previous 3D solid models. Furthermore, the students are asked to create and summarize their own 3D solid modeling steps for all the 3D solid objects selected and assigned for homework.

The class project model, gear pump system with seven independent components, has been selected for the students to create all components/parts every time they practice CAD modeling and assemble them to create a complete assembly model and drawing as shown in Figure 1. Through this type of PTBL method, the students build confidence in using/applying the most commonly used methods and/or routines for creating a 3D solid model along with professional engineering drawing documents.

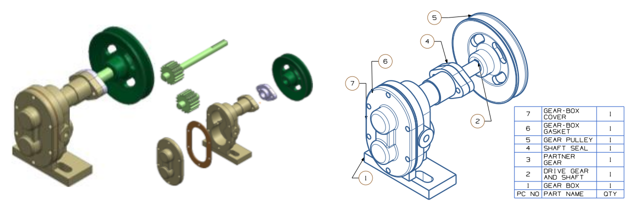


FIGURE 1
CLASS PROJECT MODEL – GEAR-PUMP SYSTEM; COMPONENT AND ASSEMBLY MODELING AND ASSEMBLY DRAWING

Graphics/CAD team project – poster exhibition and competition. After completing the object modeling practice mentioned above, the students are asked to form teams of about twenty students. Total of eight to ten design teams are established for the graphics/CAD team design project for modeling four or five different real objects. Each team member is assigned to create four to five components/parts of a real object assigned to the team. All team members are expected to measure the geometric dimensions of the parts/components of the object, create hand sketches of the components, and create 3D solid models and document drawings within about four weeks of work.

Figure 2 shows the organizational diagram of the graphics/CAD team project where the roles of each team member and leader are indicated and show how they work together. Thus, throughout this team project, the students naturally learn how to work together and recognize the importance of each member.

In the past years, various types of real objects, such as machines, devices, equipment and buildings located in the Marquette University campus, were selected for the graphics/CAD team project in order for the new engineering students to become familiar with their new environment and campus.

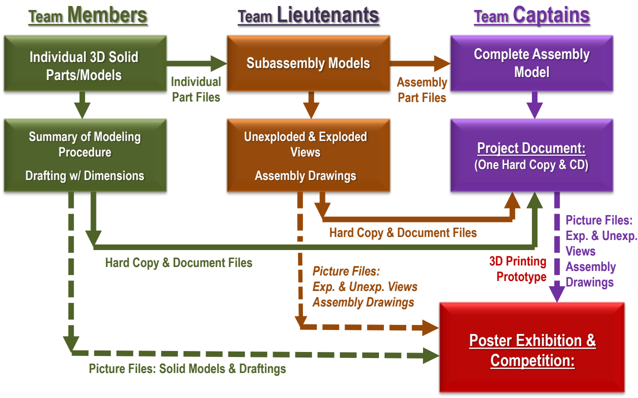
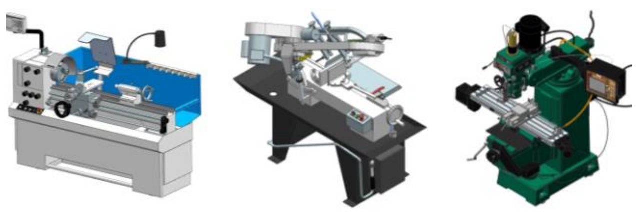


FIGURE 2
ORGANIZATION CHART FOR THE GRAPHICS/CAD TEAM PROJECT



(a) Clasuing Lathe (b) Horizontal Band (Well) Saw (c) Trak K3 Mill

FIGURE 3
SAMPLE MACHINE MODELS USED FOR THE CAD TEAM PROJECT

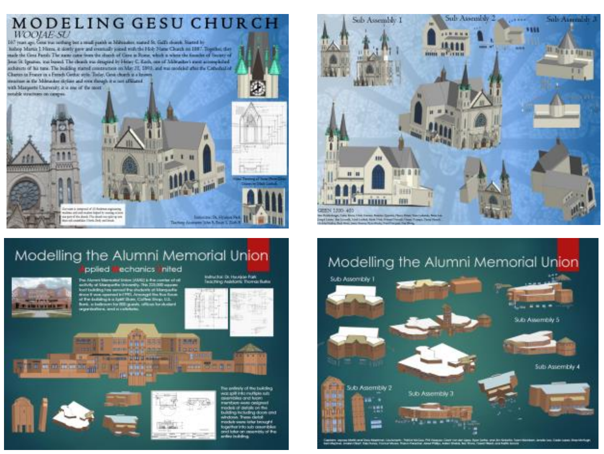


FIGURE 4
SAMPLE WORKS OF THE FRESHMAN GRAPHICS/CAD TEAM PROJECT – POSTER EXHIBITION AND COMPETITION

Figure 3 shows some of the complete assembly models created by CAD teams within about four weeks of work. Each team prepares two-page posters that include the overall CAD modeling procedure of the assigned models; the hand sketches of the individual parts with their measured dimensions and the corresponding 3D CAD models, the subassembly and complete assembly CAD models. Figure 4 shows some of the complete project posters – modeling Marquette University campus buildings.

Table VI shows some of students' learning outcomes or perspectives obtained from the graphics/CAD team project, in which the three keywords from the 3C's of the entrepreneurial mindset are connected to each item in order to assess how well the students experience the entrepreneurial mindset.

TABLE VI
SUMMARY OF LEARNING OUTCOMES OBTAINED FROM THE GRAPHICS/CAD TEAM PROJECT

- **Problems** encountered (such as matching part dimensions) overcome through teamwork (w/ ***Curiosity*** & ***Connections***)
- **Communication** through a hierarchy (team captains and lieutenants) (w/ ***Connections***)
- **Time management** to meet deadlines (w/ ***Connections***)
- **Delegation** of roles and responsibility to contribute to the whole (w/ ***Connections***)
- **Collaboration** and sharing different techniques (w/ ***Connections***)
- **Application** of engineering graphics fundamentals & CAD modeling techniques (w/ ***Connections*** & ***Creating Value***)

During the graphics/CAD project poster exibition and competition event, engineering faculty/staff members and the upper-level engineering students are invited to judge the team project posters. Table VII shows the simple rubric used by the judges to evaluate the project posters. It includes three simple evaluation items connected/related to the three keywords from the 3C's, along with the minimum and maximum evaluation points obtained from the poster judges. It can be seen that all design teams scored well above average on their team project work. Therefore, it is believed that this type of teamwork activity or project helps and motivates the students to foster and develop their engineering entrepreneurial mindset.

TABLE VII
EVALUATION RUBRICS FOR THE GRAPHICS/CAD TEAM PROJECT POSTERS

Evaluation Rubric Used for Graphics/CAD Team Project

Poor [1]	Below Average [2]	Average [3]	Above Average [4]	Good [5]

No.	Evaluation Items	Score Min	Score Max
[1]	Identifying the assigned model parts and creating basic hand sketches of the assigned model parts (w/ **Curiosity**)	**4.5 (90%)**	**4.8 (96%)**
[2]	Creating 3D solid models & draftings of individual components or parts of the model (w/ **Connections** & **Creating Value**)	**4.3 (86%)**	**4.9 (98%)**
[3]	Creating subassembly & complete assembly models with exploded and unexploded views (w/ **Connections** & **Creating Value**)	**4.5 (90%)**	**4.9 (98%)**

II. Freshman Engineering Discovery 2

This course is offered every spring (or second) semester, consisting of one lecture for one one-hour period (on Monday) and two lab classes (on Tuesday and Thursday) for a four-hour period per week. Table VIII shows the overall structure and topics of the course in which various class activities are included.

Engineering computing with MATLAB® and its applications. In order for freshman engineering students (or entry-level college students) to efficiently practice MATLAB® during the lab class hours, the MATLAB® lab manual has been developed by this author [10]. It includes self-study guides and sample example problems. The manual guides the students on how to properly enter MATLAB® basic commands and codes in order to produce the numerical and graphical results required.

TABLE VIII
FRESHMAN ENGINEERING DISCOVERY 2 – OVERALL COURSE STRUCTURE AND TOPICS

Engineering Computing with MATLAB® & Its Applications	Engineering Problem Solving Practice
	Engineering Design Process with Design Challenge #1
	Engineering Design Process with Design Challenge #2
Design Challenge #2 – Poster Exhibition & Competition	

After practicing the MATLAB® basics and the corresponding programming algorithms, the students start using/applying the MATLAB® basics to solve some useful engineering and scientific problems by selecting and using proper numerical methods such as solving system linear equations, interpolation and curve fitting, nonlinear equations and numerical integration and differentiation. These numerical methods or techniques are very useful for the students in their engineering courses.

Engineering problem-solving practice with energy term project. During the engineering-problem solving module session in this course, the students are primarily introduced to simple engineering problem-solving steps or procedures (as shown in Figure 5) while they study the selected engineering topic – basic modes of heat/energy transfer (i.e., conduction, convection and radiation). In this course, the analogy between heat flow/transfer and electric current flow [11] has been introduced and used to practice engineering problem solving.

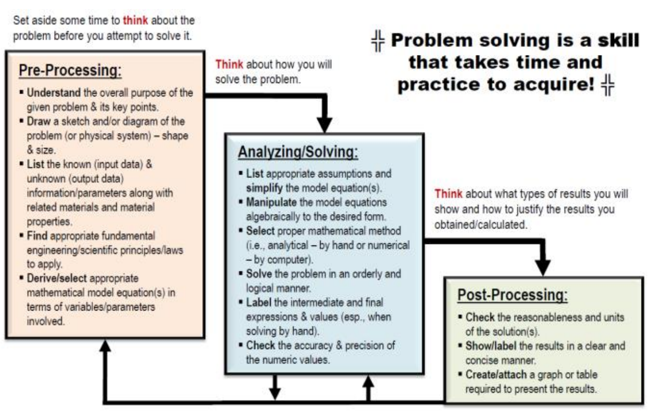


FIGURE 5
GENERAL ENGINEERING PROBLEM-SOLVING PROCEDURE USED IN THE COURSE

After studying basic fundamentals on heat transfer such as heat conduction, convection and radiation with proper forms of thermal resistances, the students are able to consistently analyze and solve various types of energy/heat system example problems.

The author's previous work [8] describes in detail how the student teams work on the class energy term-project for a two-week period with the theme of analyzing and estimating energy/heat amount or usage, system efficiency and energy usage cost. Each project team was asked to find and identify the object or problem from Marquette University campus, such as the dormitory, cafeteria, classroom, library, etc. Table IX shows some of the students' works on the energy term project.

TABLE IX
ENERGY TERM PROJECT – SAMPLES OF STUDENTS' WORKS

Project Title	Problem Statement with Objective or Goal
CARPENTER TOWER HEAT TRANSFER	Performing an analysis of the heat loss and energy cost of one floor in M. Carpenter Hall, utilizing the data of the six coldest months of the year
HEAT LOSS FROM O'DONNELL	Calculating the amount of heat loss and the heat needed to be produced to maintain a comfortable temperature in O'Donnell Hall and estimating the corresponding yearly electricity cost of maintaining a proposed ideal temperature
CARPENTER DOUBLE HEAT COST	Estimating total amount of heat loss due to a number of windows, wall, and door and energy cost to maintain a temperature of 21°C in a standard Carpenter room when the hallway is 20°C and the outside is -7°C

Table X shows the guideline and evaluation rubric used for the team energy term project in which three keywords of the 3C's defined for the entrepreneurial mindset are integrated to the evaluation items. Each project team presents their work during class hours. Engineering faculty/staff members and engineering students are invited to evaluate the students' project works using the evaluation rubric provided in Table X.

TABLE X
GUIDELINE AND EVALUATION RUBRIC USED FOR THE ENERGY TERM PROJECT

Project Evaluation Criteria & Equivalent Grade Point				
Poor [1]	Below Average [2]	Average [3]	Above Average [4]	Good [5]

No.	Evaluation Items	Score Min	Score Max
[1]	Appearance		
[2]	Clarity of Problem Statement (w/ ***Curiosity***)	**2.4 (48%)**	**3.6 (72%)**
[3]	Analysis Procedure (w/ ***Curiosity*** & ***Connections***)	**3.7 (74%)**	**4.2 (84%)**
[4]	Analysis Results (w/ ***Creating Value***)	**4.0 (80%)**	**4.3 (86%)**
[5]	Handling Questions		
[6]	Overall Presentation (Preparation & Organization)		

Table X also shows the performance analysis results of all project teams, in which the minimum and maximum scores are shown for the evaluation items #2 - #4. It can be seen that a large gap between the maximum and minimum scores for evaluation item #2 exists and the average score for the evaluation item #2 is relatively lower than those for the evaluation items #3 and #4. It can be considered that many project teams selected similar topics (i.e., buildings or rooms) for their energy term projects. However, the evaluation scores for the items #3 and #4 are relatively higher than those of item #2 because many teams confirmed using/applying the heat/energy fundamentals for the project work.

Engineering design process with team design challenge #1. There are various resources and references related to the engineering design process [12-14]. In this course, a simple six-step engineering design process [7] (i.e., problem identification, preliminary ideas/concepts, refinement, analysis, decision and implementation) has been used for the freshman engineering students to use and follow for the design challenge works.

The theme used for design challenge #1 relates to an issue about helping the underprivileged (i.e., underrepresented and underserved). Table XI shows the theme for design challenge #1 work and the corresponding guideline for the students and their teams to follow and finish the project within a four-week period.

TABLE XI
OVERALL THEME AND GUIDELINE USED FOR DESIGN CHALLENGE #1

OVERALL THEME: "Designing Innovative (or Useful/Valuable) Products (Devices or System) or Processes for the Underprivileged" **DESIGN GUIDELINE:** • Identifying & selecting the problems/issues • Generating/creating new concepts/ideas to solve the issues/problems with proper hand sketches • Selecting/refining and finalizing idea/concept • Developing system working principles & creating physical system (3D solid) virtual models • Performing a basic/proper engineering and cost analysis/calculations of the selected objects with some degree of entrepreneurial aspect to the products/system

TABLE XII
DESIGN CHALLENGE #1 – SAMPLE OF STUDENTS' WORKS

Project Title or Product Name	Product/System Description
THERMAL INSULATION SHEET	Designing and using a thermal insulation sheet for small, underprivileged homes that need extra warmth during the cold months and extra cooling in the summer
QUINOA HYDROPONIC GREEN HOUSE	Designing an innovative hydroponic garden system to produce Quinoa Plants to help resolve the hunger deprivation in Comoros, a small country off the east coast of Africa
INTERCHANGEABLE MODULAR SHELTER	Designing modular homes as transitional housing options for people displaced by natural disasters and as long-term housing solutions for those who live in high poverty areas.

Before initiating design challenge #1 work, the students are asked to form a design team of seven to nine people. Each team selects team leaders, such as one team captain and one team secretary. The main role of the team captain is to lead and moderate the team's project and progress, while the team secretary schedules and records the team's work progress, along with producing intermediate and final work results.

Table XII shows some of students' work for design challenge #1. It appears that the students and their design teams used their imagination and creativity to generate/create a product (system and/or device) to help the underprivileged in our society.

The overall performance of the 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 XIII 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 lab 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 keywords of the 3C's of an entrepreneurial mindset.

TABLE XIII
GUIDELINE AND EVALUATION RUBRIC USED FOR DESIGN CHALLENGE #1

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/ ***Curiosity***)	**4.0 (80%)**	**4.8 (96%)**
[3]	Preliminary Ideas & Proposed Solutions (w/ ***Curiosity*** & ***Connections***)	**4.0 (80%)**	**4.8 (96%)**
[4]	Refinement & Analysis (w/ ***Connections*** & ***Creating Value***)	**3.8 (76%)**	**4.5 (90%)**
[5]	Validity of Final Concepts (w/ ***Creating Value***)	**3.5 (70%)**	**4.3 (86%)**
[6]	Handling Questions		
[7]	Overall Presentation (Preparation & Organization)		

Table XIII also shows design challenge #1 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 design challenge #1 activity in the course. It can be seen that the evaluation items #4 and #5 scored a bit lower than items #2 and #3. It can be considered that this may be due to the students' lack of explicit experience (and related engineering skills) in performing and implementing the (real) engineering design work with entrepreneurial mindset during their high-school education.

Engineering design process with team design challenge #2. After finishing design challenge #1, the students are asked to regroup their design teams for design challenge #2, to be performed for a period of six weeks. Table XIV shows the overall theme, potential project areas/topics and design guidelines used for design challenge #2 of this course. Since the design challenge #2 work requires each design team to build and test product prototypes and/or mock-ups, additional periods of time were given to the students

TABLE XIV
OVERALL THEME AND GUIDELINE FOR DESIGN CHALLENGE #2

OVERALL THEME: "Developing/Designing the System/Device Related to Energy & Water Sustainability" **POTENTIAL PROJECT AREAS/TOPICS:** • (General) energy and/or water savings, renewable energy, fuel resources and supply, etc. • Water production, maintenance, purification, etc. • Water and thermoelectric power interdependency **DESIGN GUIDELINE:** • Identifying the global water & energy related issues • Generating concepts (or ideas) - potential solutions • Developing an innovative solution & considering its impact on the energy/water issues • Designing/developing system/device & its working principle(s) with some degree of entrepreneurial aspect to the products/system • Developing virtual (UGS NX) models and building & testing (small-scale) prototype (mock-up) system/device • Finalizing the design project – report, presentation & poster

Table XV shows some of students' work for design challenge #2. It is once again apparent that the students and their design teams used their imagination and creativity to generate/create a product (system and/or device) related to the project theme, "*Energy and Water Sustainability*." It also shows that various types (and kinds) of multidisciplinary topics have been selected by the design teams.

TABLE XV
DESIGN CHALLENGE #2 – SAMPLES OF STUDENTS' WORKS

Project Title or Product Name	Product/System Description
H2FLOW	Designing water-flow tracking sensors within individual households in order to reduce and minimize water consumption and water usage cost
BOREAS WHEEL	Designing special horizontal wind turbines grounded on the sides and ends of airport runways to harness the wind energy occurring from taking off and landing planes
45 REVOLVER	Designing an electric-energy generating revolving door system using the solenoid within the door of a high-traffic structure

The overall team performance of the design challenge #2 is evaluated by the team project reports and posters which are displayed during the event, *Freshman Engineering Students Design Challenge #2 - Poster Exhibition and Competition*. Figure 6 shows sample final posters of two winning teams, in which the key elements in the engineering design process [7] (i.e., problem identification, preliminary ideas/concepts, refinement, analysis, decision and implementation) are included.

Table XV shows the guideline and evaluation rubric for the design challenge #2 work, in which five evaluation items are connected and related to the three keywords of the 3C's of entrepreneurial mindset. Engineering faculty/staff members and the upper-level students are invited to judge the project posters during the poster exhibition and competition event held at the end of the semester.

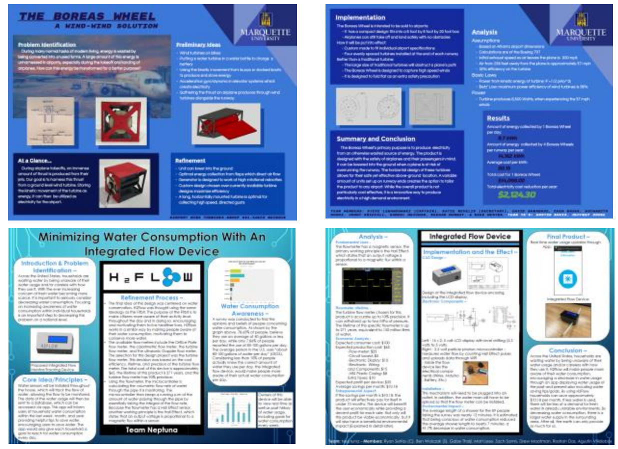


FIGURE 6
DESIGN CHALLENGE #2 – SAMPLES OF STUDENTS' WORKS

Table XV also shows the overall performance analysis results of the design teams. Since the students practiced and experienced the engineering design process with an entrepreneurial mindset through the previous design challenge #1 work, it was found that the students' motivation and performance on the design challenge #2 works was consistently improved.

TABLE XV
GUIDELINE AND EVALUATION RUBRIC USED FOR DESIGN CHALLENGE #2

<table>
<tr><th colspan="5">Project Poster Evaluation Criteria & Equivalent Grade Point</th></tr>
<tr><td>Poor
[1]</td><td>Below Average
[2]</td><td>Average
[3]</td><td>Above Average
[4]</td><td>Good
[5]</td></tr>
</table>

No.	Evaluation Items	Score Min	Score Max
[1]	Clarity of Problem Statement (w/ ***Curiosity***)	**4.5 (90%)**	**4.9 (98%)**
[2]	Proposed/Generated Ideas & Solutions (w/ ***Curiosity*** & ***Connections***)	**4.3 (86%)**	**4.8 (96%)**
[3]	System Model & Working Principles (w/ ***Connections*** & ***Creating Value***)	**4.0 (80%)**	**4.5 (90%)**
[4]	Validity of Final Concepts (w/ ***Creating Value***)	**3.9 (78%)**	**4.5 (90%)**
[5]	Outcomes and/or Consequences (w/ ***Creating Value***)	**3.8 (76%)**	**4.2 (84%)**
[6]	Handling Questions		
[7]	Overall Presentation (Preparation & Organization)		

SUMMARY AND CONCLUSIONS

The *Freshman Engineering Discovery* courses developed and currently running at Marquette University – Opus College of Engineering is 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.

The primary outcomes obtained by implementing the EML in the *Freshman Engineering Discovery* courses show that many new engineering students are able to use and express their imagination and creativity through various course topics, contents and activities which result in developing a vision to become a future engineer with an engineering entrepreneurial mindset. In order for them to further develop and foster their engineering skills and entrepreneurial mindset, they need to be exposed to many more opportunities to practice and explicitly express their creativity through various engineering course works, activities and related experiences.

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