AN ENHANCED LEARNING ENVIRONMENT FOR MECHANICAL ENGINEERING TECHNOLOGY STUDENTS: AN ENERGY TRANSFORMATION

by

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Dedicated to my wife Laura, for all of her encouragement and patience. To my parents, Steve and Janice for their endless love and always believing in me. And to my brothers, Nathan and Daniel for all of their support.

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LIST OF ABBREVIATIONS

ANOVA – Analysis of Variance

CITI – Collaborative Institutional Training Initiative

CLOO – Core Learning Outcome Objective

CSV – Comma Separated Value

ESC – Energy Systems Credential

ET – Engineering Technology

HVAC – Heating, Ventilation, and Air Conditioning

IAB – Industrial Advisory Board

IRB – Institutional Review Board

MET – Mechanical Engineering Technology

PCA – Principal Component Analysis

SAS – Statistical Analysis System

SCS – Statistical Consulting Service

SPSS – Statistical Package for the Social Sciences

STEM – Science, Technology, Engineering, and Mathematics

GLOSSARY

The following is a list of definitions that will help explain key information contained within this Thesis proposal. Some of the key words or phrases contain self-reported definitions, while others are cited definitions from related published literature.

Active Learning – Can include group problem-solving worksheets, personal responses, and workshops (Freeman, 2014).

Applied Learning Environment – An environment that increases student potential to learn by using activities or active learning to influence and motivate them (Drew, 2011).

Blooms Taxonomy – Is a method of organizing learning goals which allows instructors to create resources that encompass learning goals (Anderson, 2001).

CATME – Is an online peer grouping and peer evaluation tool that can be used to help facilitate team member contributions within group activities (Loignon, 2017).

Competency Based Learning – CBL is a way of allowing learners to demonstrate the mastery of a set of competencies within a specific area of study (Ford, 2014).

Course Specific Survey – Survey given to students within each of the courses in the Energy System Credential. The survey is given at the end of energy specific activity to measures their perception of the activity and how they felt it impacts them (Operational).

Credential – Is a student awarded reward for the completion of a single activity or series of activities through going above and beyond (Operational).

ESC – Energy Systems Credential is a program being developed at Purdue University SOET to help transform the learning environment for students (Operational).

ESC Badge – Badges that students earn through demonstration of their mastery of skills within each specific course of the Energy System Credential program (Operational).

ESC Number – Numbers which are non-identifiable given to students to track the students longitudinally through earning the credential and their degree completion (Operational).

General Survey – A survey given to the students at the start of their first semester in the program, as well as the end of each academic year. Survey tracks student knowledge of various forms of energy as well as their perception of energy (Operational).

Intrinsic Scaffolding - Is providing the support that a student's needs to learn by means of viewing, combining, and weighting relationships (Jackson, 1998).

Likert Scale – Is a way to reduce the number of options within surveys to prevent student confusion (Chyung, 2017).

Scaffolded Learning – Process by which students are given all of the necessary tools to achieve a level of understanding of well-defined learning objectives (Trif, 2015).

Social Learning - Is the way a student is able to learn and absorb large amounts of information by watching others do, this can include project based or team based learning environments (Trif, 2015).

Style of Learning – The way that students are best able to learn from a psychological standpoint (Lucietto, 2017).

Team Based Learning – The use of small groups to help students become more engaged throughout the learning process (Sweet, 2012).

Transformation – Is a change from what was being done in the past, a way of revamping the classroom environment (Operational).

ABSTRACT

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The desire to produce a learning environment which promotes student motivation, collaboration, and higher order thinking is common within the higher education system of today. Such learning environments also have the ability to address challenges' Mechanical Engineering Technology (MET) students face entering the workforce. Through the vertical and horizontal integration of courses, this research presents how a scaffolded learning environment with a centralized theme of energy can increase motivation and conceptual retention within students. The integration of courses allows students to systematically translate their competency of concepts between energy based courses through experiential learning. The goal of this work is to develop a competency based learning model where students earn a professionally recognizable credential. The credential is earned through demonstrating their mastery of industry desired skills at a level that goes above and beyond the stock curriculum. The result is a more continuous curriculum that enhances multi-disciplinary problem solving while better preparing MET students for the workforce.

CHAPTER 1. INTRODUCTION

1.1 Introduction

The main goal of this research was to improve higher education to help engineering technology graduates address challenges they will see upon graduation and entering the workforce. Today's workforce tasks students to be not only be experts within their respective field upon graduation, but also possess the skills to problem solve in areas unrelated to their studies. To equip students for such workplace environments, institutions often look at ways to teach multi-disciplinary concepts to students through the use of applied learning environments (Freeman, 2014).

To address the specific needs seen by employers of engineering technology graduates, a transformation of the mechanical engineering technology (MET) curriculum was pursued. The goal of the transformation was to enhance student understanding and thinking and to provide students the tools needed to solve complex multi-disciplinary problems. In this work, energy was identified as the common theme embedded into most science, engineering, and technology courses. This work intends to highlight energy and its transformation from one form to another to allow students to move between courses and disciplines using a common variable and unit equipping students with the knowledge and experience needed to succeed in a diverse workplace.

In order to achieve this goal, new active learning environments, which engineering technology inherently uses, (Drew, 2011) had to be sought to better engage and motivate students. The proposed learning environments looked to vertically and horizontally integrate required courses within the MET curriculum while focusing on a centralized theme of energy throughout. Figure 1.1 illustrates how the courses in the MET department were able to be horizontally integrated by color and vertically integrated through the common energy focus of the ESC. Integrating the environment this way utilizes key concepts seen within Bloom's Taxonomy (Anderson, 2001). Students will vertically progress through courses within the ESC program, where the horizontal integration challenges the students through process within that specific topic, thus leading towards higher order thinking (Anderson, 2001).

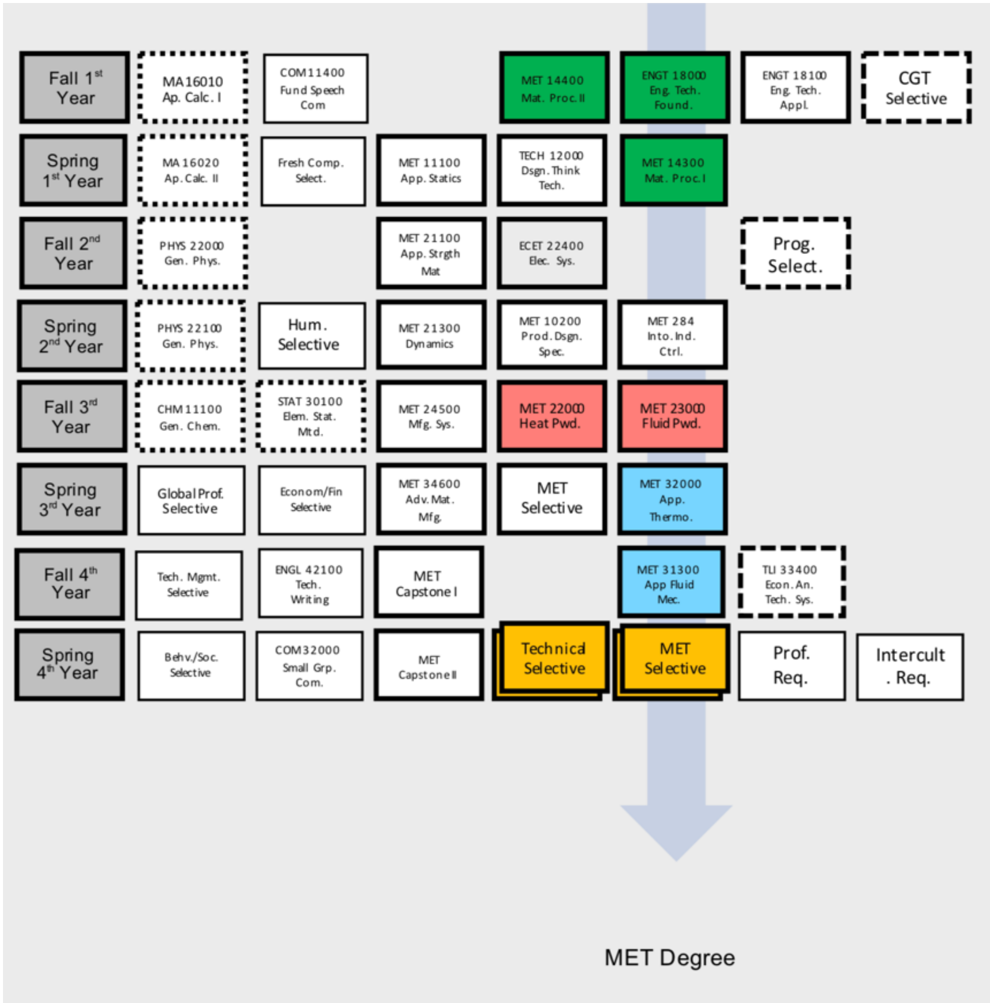


Figure 1.1 ESC Horizontal and Vertical Learning

The understanding of basic energy usage in topics such as fluid mechanics, thermodynamics, heat transfer, electricity, manufacturing processes, engines, heating and ventilation systems, utilities, hydraulics, and pneumatics through an experiential learning approach allows students to gain a deeper understanding of the subjects and the application of topics (Kolb, 2001). Through interactive activities, students will follow the six stages of cognitive process dimension (Anderson, 2001). As Anderson et al. (2001), explains:

Cognitive Process1: To remember

- To remember is to retrieve relevant knowledge from long-term memory. (p. 67)

Cognitive Process2: To understand

- To understand is to construct meaning from instructional messages, including oral, written, and graphic communication. (p. 67)

Cognitive Process3: To apply

- To apply is to carry out or use a procedure in a given situation. (p. 67)

Cognitive Process4: To analyze

- To analyze is to break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose. (p. 68)

Cognitive Process5: To evaluate

- To evaluate is to make judgments based on criteria and standards. (p. 68)

Cognitive Process6: To create

- To create is to put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure; inventing a product. (p. 68)

1.2 The Problem

Synergy amongst energy based courses, and optimization of student interaction with industrial partners is near inexistent within today's educational system. Course cohesion, along with bridging the gap between students and industry allows students to obtain the applicable skills desired in engineering based industries (Industrial Advisory Council Meeting, 2017). Student feedback, placement information, as well as feedback from Industrial Advisory Boards and their current needs is how this will be achieved. The grand challenge being addressed in this work is development of a curriculum that allows students to see the connections between their courses and allows them to think and design across disciplines to solve problems.

Engineering technology students thrive within learning environments that are not regularly seen in today's educational system. Furthermore, the application of energy related concepts that are learned within the classroom are not always clear. Unfortunately, these pitfalls are both contributing factors in students being ill-equipped for entering the workforce. The skill gap that is being recognized by employers of STEM graduates consists of both hard and soft skills that are required by the employers (McGungale, 2018). Additionally, the lack of industrial partnerships as seen through advisory boards with industrial partners has further contributed to not fully preparing students for life outside of academia. Knowing what industrial partners want, can better prepare course developers to meet the needs of employers within technical fields. By placing an emphasis on energy concepts and developing project based and team based learning activities, a more continuous curriculum can begin to be take shape, thus instilling experiential learning within students that can be translated into various industries.

1.3 Significance

The findings of this study will demonstrate that by transforming the MET curriculum and using energy as the common theme to integrate courses, a learning model can be produced fostering higher order thinking and multi-disciplinary problem-solving skills. This enhanced learning environment will not only increase the learning potential of students but also better equip them for life after graduation.

The research allows instructors to provide a foundation for students within the MET program to become more involved in course content and further their knowledge beyond the "stock" course curriculum. The world and technology are continuously changing, and the way that students are taught must also change. Traditional lecture type learning environments do not work for all students. Even when this type of environment does work, students are not being exposed to ways of applying the knowledge being gained within a real-world environment. In addressing this problem we are also addressing the 13th Engineering Grand Challenge which is dedicated towards the advancement of personalized learning (Engineering, 2013).

1.4 The Purpose

The research will examine how the learning environment for mechanical engineering technology students can be improved within energy related courses to impact student learning potential. The focus of the research looks at how students currently view their learning environment as well as their competency and outlook on energy topics. The study looks to evaluate such data at various points along a student's academic career in pursuit of not only their degree but also a professionally recognized credential.

To achieve an advanced learning environment, data must be collected and support claims on how students perceive the environment within energy based courses, such as fluid dynamics and thermodynamics. In changing the current student learning environment, the opportunity will be given to students to enhance their comprehension, retention, and application of knowledge (Anderson, 2001). The study also has the potential to further understand the differences that academic standing and gender have on how students perceive their learning environment.

1.5 Research Questions

The active pursuit of two research questions throughout the course of this research will help lead our team to find an improved solution to provide graduates with the skills they need to be successful in their future careers. The two questions are of equal importance, and will allow the research team to quantify the student learning experience.

- Does active learning impact the motivation to learn of engineering technology students within energy related courses?
- Do energy focused activities improve perceived student understanding of energy concepts?

A series of questions from one of two surveys administered to the students will produce data which is directly linked to these research questions. Each of the two research questions have one or more hypotheses that are directly correlated with it. Bench-mark testing using data collected will individually determine if the hypothesis is satisfied or not. The following null hypotheses are based off the first research question "Does active learning impact the motivation to learn of engineering technology students within energy related courses?".

> H_0: There is no interrelation between active learning activities and the motivation of MET students.

The second research question "Do energy focused activities improve perceived student understanding of energy concepts?" can also be tested using the same method of developing a null hypothesis and testing it based off of the data that is directly related. The following hypothesis is driven from the second research question.

H_0: Energy focused activities do not improve the perceived understanding within energy concepts.

1.6 Assumptions

Several assumptions were made while conducting the proposed research. It was important to ensure that all assumptions were reasonable and correct to prevent drawing false conclusions prematurely based off these assumptions by fellow researchers or readers. The following list consists of the assumptions which were made:

- Participants will pursue the Energy Systems Credential.
- The participants involved will be incentivized to perform better on activities than those who are not.
- The enhanced active learning environments will help participants who are both involved and not involved in the energy transformation.
- The participants will have a better understanding of how to apply the knowledge gained through coursework in a real world environment.
- The survey tool being used will prompt reliable responses.
- The participants will fully understand the survey questions.
- The participants freely and honestly provided answers based off of their personal views and competencies.
- The survey responses are not a response based off perception of the instructor, or their grade received on the project or course.

1.7 Delimitations

The project as a whole is designed to improve the student understanding and motivation within the Purdue University MET program. Currently a divide exists between what is being taught within the classroom and the desires of industry based off of this knowledge gained (Garrick, Chan, Lai, 2004). By introducing students to a transformed learning environment the hope is that students will better understand how to apply skills learned in various industrial settings.

To encourage student participation on surveys, closed-ended Likert based scales were used predominantly with some open-ended or short answer type questions. As the energy based courses being used within this study are related to the MET curriculum, the population of interest is only students from the MET department. However, the use of a similar educational model within other engineering technology departments will require little change.

1.8 Limitations

Several aspects are present that will also limit the research. The true participation in the ESC is one of these limitations. While the transformation of the courses happens regardless of student participation, the students are not required to pursue any individual course badges. This also has the ability to impact the number of survey responses. The students in each of the courses are asked to take the course specific surveys, however all surveys are voluntary response. Deploying the course specific surveys is done by the respective instructors for each course. Therefore, the deployment of the survey is contingent on faculty being proactive and seeing the benefit of the ESC. The shifting of faculty members over time has the ability to impact this, unless it is written into the required curriculum for each involved course.

Additionally, a major limitation to the project is that students must maintain a non-identifiable code so that the research team can monitor individual student progress over time and group the data obtained through numerous surveys. The code will help identify where students improve most. This also allows researchers to track the improvement trends for each individual student without being able to identify them. Lastly, students must also take part in the energy transformation program for all four years of their undergraduate career to earn the full ESC. Participation less than the full four years can result in students earning specific course badges, but not the ESC which may impact individual survey results.

1.9 Summary

Within this chapter the ESC transformation was introduced as well as information on what the transformation might look like. A major pull away from this chapter is that energy is everywhere and impacts our lives on a daily basis. For graduates of the MET program, energy is an unceasing characteristic, present in nearly every engineering technology job. Still, it can be seen that synergy amongst energy-based courses is lacking within the current plan of study for MET courses here at Purdue. There is a disconnect between employers and graduates of the MET program, and this transformation will help bridge that gap. Helping students to understand how energy is used in multiple fields and using this knowledge to link these disciplines and concepts allows students to apply this knowledge to solve real-world problems.

Additionally, energy is the fundamental tool that allows for the translation of topics currently taught within discrete courses to be transferred between courses. This allows for students to work on projects which encompass all forms of energy within a singular design with confidence. The result of this is the ability to advance the student learning model of MET students at Purdue University and elsewhere. This chapter also defined the research questions for the study as well as their respective hypotheses.

CHAPTER 2. REVIEW OF LITERATURE

2.1 Methodology of the Review

2.1.1 Key Concepts

Throughout the description of the problem there are several concepts that can be extracted. The concepts within the problem description act as tools for discovering articles related to the subject matter. The key words were extracted from the concepts illustrated within the description of the problem. Through using this strategy, searches kept a narrow focus so they produce exactly what the research is looking for. The key words used can fully define the problem that is being addressed through the research.

2.1.2 Key Words

Enhanced Learning Environments, Motivation, Applied Learning, Experiential Learning, Continuous Curriculum, Bloom’s Taxonomy, Vertically and Horizontally Integrated Curriculum, Scaffolded Learning

2.1.3 Concept Map

Using the key words drawn from the problem description, a concept map is able to be created. A concept map shows the relationship that key words may have with other key words. The result of producing a concept map shows how key words branch off of a single concept. The single concept when performing this task was student learning potential. This in essence is the root issue that is being improved upon. In doing this, all key words will be branched off a single concept, in a sense the root problem.

To refine concept searches the key words that are used should be words that are infrequently used (Krippendorff, 2013). Krippendorff (Krippendorff, 2013) explains searching for relevant documents as a method of attempting to “cover” all aspects of a specific text seen in Figure 2.1, while using AND, OR, as well as NOT Boolean operators as seen in Figure 2.2.

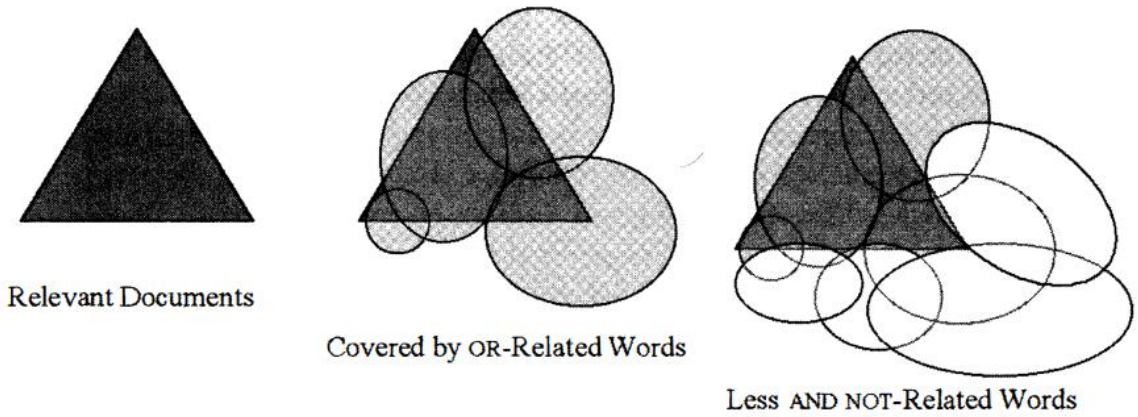


Figure 2.1 Approximation of a Query to a Set of Relevant Documents (Krippendorff, 2013)

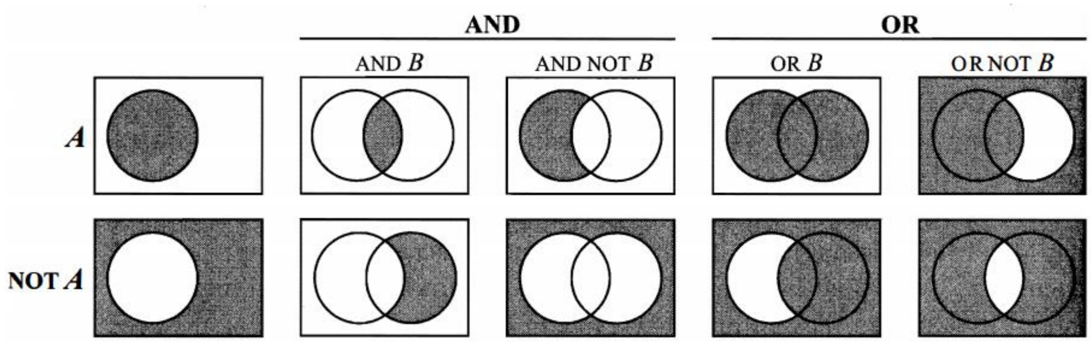


Figure 2.2 Effects of the Application of Boolean Operators (Krippendorff, 2013)

2.1.4 Search Strategies

Searching for relevant literature within this specific research area is very important. The predominant library databases used to preform searches were Engineering Village, IEEE Xplore, and Web of Science. When searching these three library databases a search strategy needed to be followed. Figure 2.3 shows a Venn diagram that was made to illustrate how the results of the searches will be prioritized.

The keywords listed are the initial search items. Papers that contain multiple keywords will be ranked higher than single use papers. The application of a filter was used to ensure that all of the gathered results were related to the key words as well as engineering education, or engineering technology education. This is a very important aspect as the problem that is being addressed ties directly to the described population. Lastly, a search filter will be used to find the highest quality paper, without eliminating others. The filter to do this process will be related to educational terminology. The terminology being sought after here is concepts, such as Bloom's Taxonomy, Likert Scale, Peer Evaluation, and scaffolded learning.

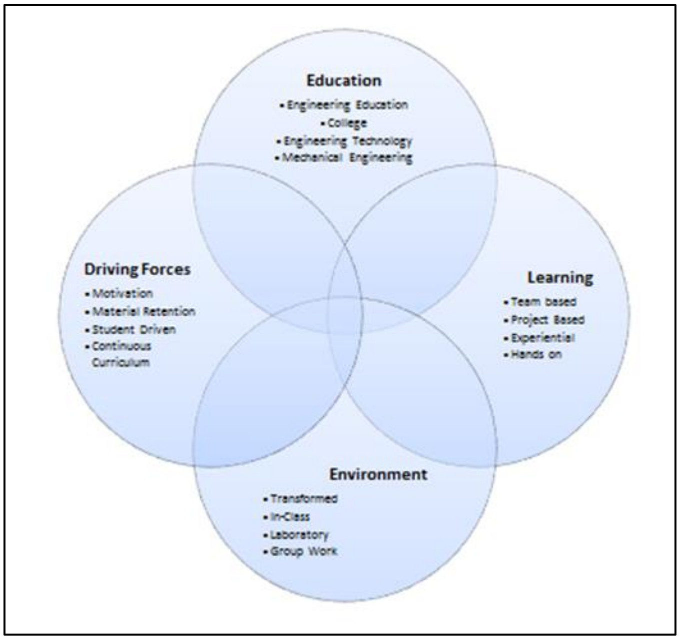


Figure 2.3 Search Strategy Venn diagram

2.2 Findings Pertaining to the Problem & Purpose

The ability to truly motivate a learner is needed in order to effectively convey course topics (Lawlor, 2016). A great way to do so is through using interactive activities as well a team approach to solving them (Alvarez-Bell, 2017). Research has shown that students within active learning environments score twice as high as students in traditional classrooms on tests that look at the conceptual understanding of course concepts (Prince, 2004).

Previous literature identified that exercising a flipped class-room environment is a way to incorporate interactive activities during class time while also having the ability to encourage teaming by students while working on such activities. The time used working on activities during the class time gives opportunities for the students to explore concepts more deeply (Kropp, 2016). The guidance from an instructor during this time allows students to ensure concepts are in tune with course outcomes (Kropp, 2016). Additionally, the utilization of strategies developed by other researchers, such as that outlined within Bloom's Taxonomy, can aid in the development of such activities to ensure they follow the progression of complexity and specificity (Anderson, 2001). The result is that students will be able to approach multi-disciplinary course activities with a greater likelihood of succeeding due to the way in which they perceive tasks (Moseley, 2005).

Competency based learning (CBL) is becoming common within higher educational systems. The concept of CBL was introduced in the 1960s to train elementary school teachers (Nodine, 2016), and by the 1970s it was beginning to be used for adult college students (Klein-Collins, 2012). The CBL that is seen within the educational system today is a way of allowing learners to demonstrate the mastery of a set of competencies within a specific area of study (Ford, 2014). The method that CBL follows strays from the traditional practices seen within higher education. Through the use of CBL, credits that students earn through competency mastery allow for the vertical and horizontal movement of the student within a degree program or even institution (Ford, 2014). Horizontal and vertical integration allows for vertically grow by taking more complex courses, in pursuit of their degree, while focusing on the various forms of energy (the centralized theme of the research) in horizontal progression. This flexibility allows for students to customize their career path, and have the ability to vertically integrate courses they are most interested in.

2.3 Findings from Pilot Study and Industrial Advisory Board

2.3.1 Pilot Study Findings

Prior to beginning the ESC, a pilot study was used as a preliminary student assessment. The pilot study had a focus on transforming two sequential thermodynamic courses from the MET department at Purdue University. The transformation looked to see how students can be provided with increased learning opportunities and how their attention as well as motivation could be impacted, all through a hands-on pedagogical approach (Reeve, 2014). A hands-on approach was pursued as active learning type environments can help improve student performance within the classroom (Freeman, 2014). Before the redesign, the two courses lacked continuity as separate text books were used for each, they applied unrelated projects, and course evaluations had no tie to each other. Continuity between courses allows students to see and understand ties between concepts as they grow in complexity. The pilot study focus included the incorporation of a singular electronic textbook (eBook) throughout the two courses, the incorporation of a common set of learning objectives, the inclusion of a common renewable energy theme throughout both courses, and implementing a modified scaffolded learning environment (Maynard, 2018).

The two courses take place during both the spring and fall semesters, and have a typical enrollment of 70 to 100 students. The first of the two thermodynamic courses goes over topics such as heat transfer and phase diagrams. The second thermodynamic course builds off concepts taught within the first and begins applying them to real world applications. Furthermore, the second of the two courses did not presently incorporate laboratory type activities whereas the first of the two did. Therefore, the instructors felt a way to transform the two courses and the students' perception of the two was through the incorporation of course projects. Instructors began looking at interactive activities based off of the real world applications being taught in the latter of the two courses. The data from this pilot study was all collected in the second thermodynamic course. The reason for only collecting energy activity data during the second course is that students within this course have a much greater understanding of thermodynamic concepts, and because the added activities are specific only to this course.

Within the second of the two courses students learn about concepts encompassing renewable energy. Some of the concepts that are covered include solar energy, hydroelectric, biomass, and wind. The concepts are learned by the students through lectures, the new class projects, and through the completion of the Introduction to Renewable Energy Certificate which is offered through Solar Energy International (Solar, 2018). The activities implemented for the second thermodynamics course consisted of two projects. The first of the two projects has a focus on solar energy while the second, focuses on power cycles and Stirling engines. Maynard et al., described project details as:

Project 1 Focus: Solar Energy (NREL, n.d.)

- Tasks (on small solar panels): Measure Current, Voltage, Power Output
    - Measurement Configurations: Parallel & Series, Various Angles, Various Lighting Environments
- Secondary Task: Charge Cell Phone

- Reason for Task: Demonstrate Utility of Solar Energy, Functionality of Panels, Design Criteria Needed, Better Understand Energy Transfer
- Knowledge Application: Analyze Data from PV Array Designed/Maintained on Campus
- Student Learning Takeaways: Improved Team Communication/Interaction, Electrical Circuit Design, PV Array Functionality, Increased Problem Solving Skills, Power Losses, and Characteristics of Light-Based Energy.

Project 2 Focuses: Power Cycles & Stirling Engines

- Task: Design a System to Raise Material of Known Weight (quarter or dime)
  - Energy Source: Tea Light Candle
- Secondary Task: Written Technical Bulletin
  - Reason for Task: Explain Process and Measurements of Energy Conversion
- Deliverables: In-class Demonstration & Oral Presentation Describing their machine's their Energy Conversion Mechanism
- Student Learning Takeaways: Further Improved Team Communication/Interaction, In-Depth Look at Energy Sources and their Qualities, Energy Conversion Processes, Losses within Energy Conversion, and System Efficiencies.

The students were administered surveys at the beginning and end of each of the technical project assessing specifics relating to the project. Upon completion of both of the technical projects, the students were given a post overall assessment which asked questions about the incorporation of the technical projects as a whole (Maynard, 2018). The data collected was then analyzed based off of questions pertaining to the pilot studies research question.

The first technical project was aimed at aiding the understanding of concepts surrounding renewable energy. Students were first asked to rate their knowledge of renewable energy then to rate their understanding of solar energy. The questions utilized a 10-point Likert scale where students reported a score of (0) equates to no knowledge/understanding, and (10) to expert. Figure 2.4 compares pre and post survey response data regarding their understanding of solar energy for all students who took the course during the fall 2016 and spring 2017 semesters. Here the students self-reported their perceived mean understanding level of μ=5.309 before the project, to a mean understanding level of μ=6.760 upon completion.

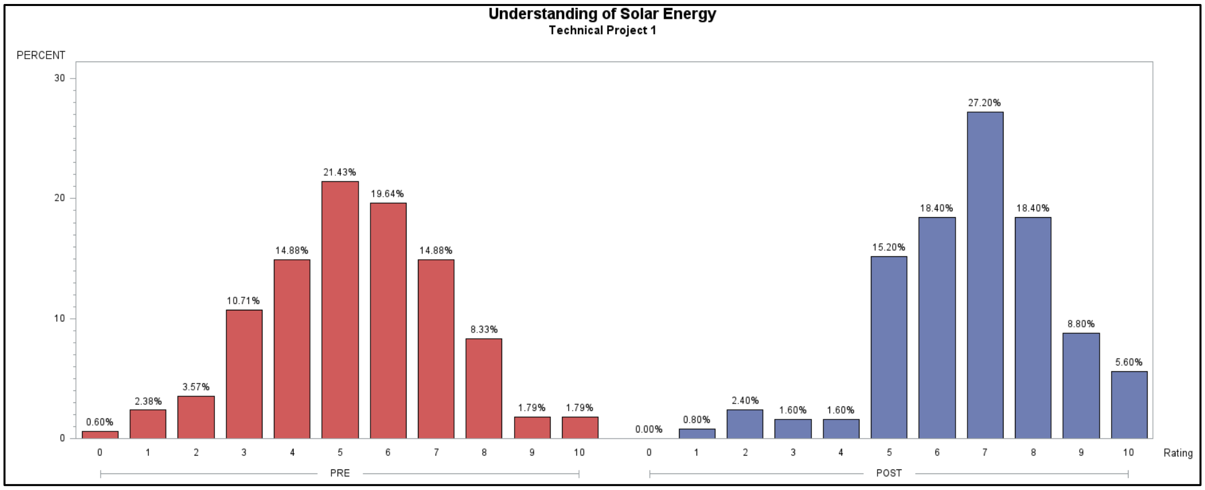


Figure 2.4 Pilot Data on Student Perceived Understanding of Solar Energy

The second technical project was centered on the concept of energy conversion. Here the students were asked to indicate their perceived level of knowledge regarding energy conversion Figure 2.5 and to rate their understanding of heat and work Figure 2.6. Both questions utilized the same 10-point Likert scale as before. The student results showed they felt their knowledge not only increased, but reported that understanding of heat and work as a whole increased from μ= 6.251 to an understanding level of μ=6.8476.

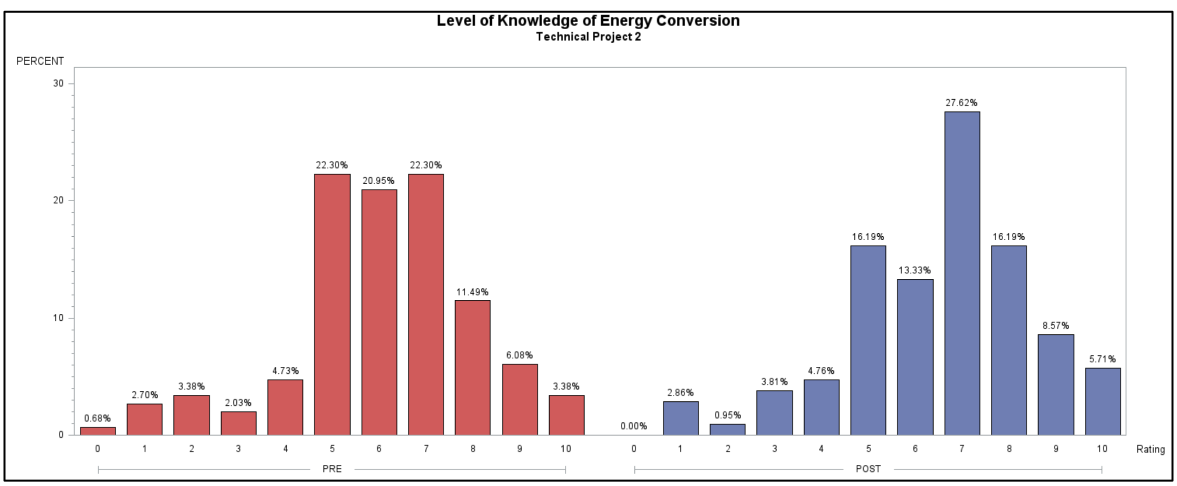


Figure 2.5 Pilot Data on Student Perceived Knowledge of Energy Conversion

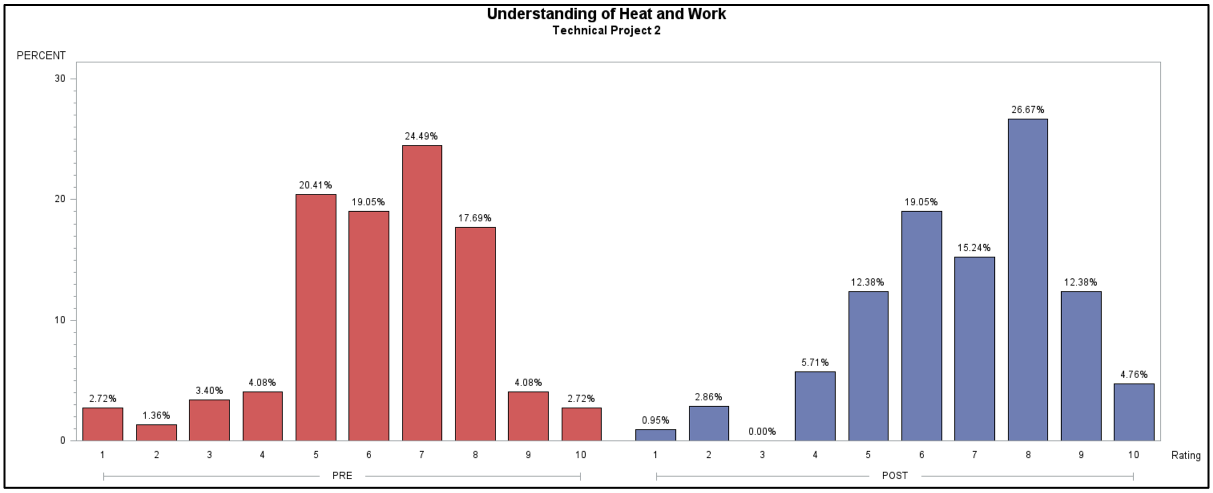


Figure 2.6 Pilot Data on Student Perceived Understanding of heat and work

The overall outcome of the pilot study supported the theory that students do desire an improved learning environment which incorporates an active learning approach. The survey taken after the students completed all activities associated with the technical projects reinforced this theory. When asked how students would rate their level of class participation/interaction in Figure 2.7 below the mean response of all students was μ=6.028 having a standard deviation of only σ=2.341. Their participation/interaction was assessed on a 10-point Likert scale with (0) being no participation and (10) being they felt they were always participating. Furthermore, when students were asked if they felt the real world examples enhanced their learning over 64% of the class reported that the real world projects definitively enhanced their learning. The distribution of responses for if their learning was enhanced can be seen in Figure 2.8.

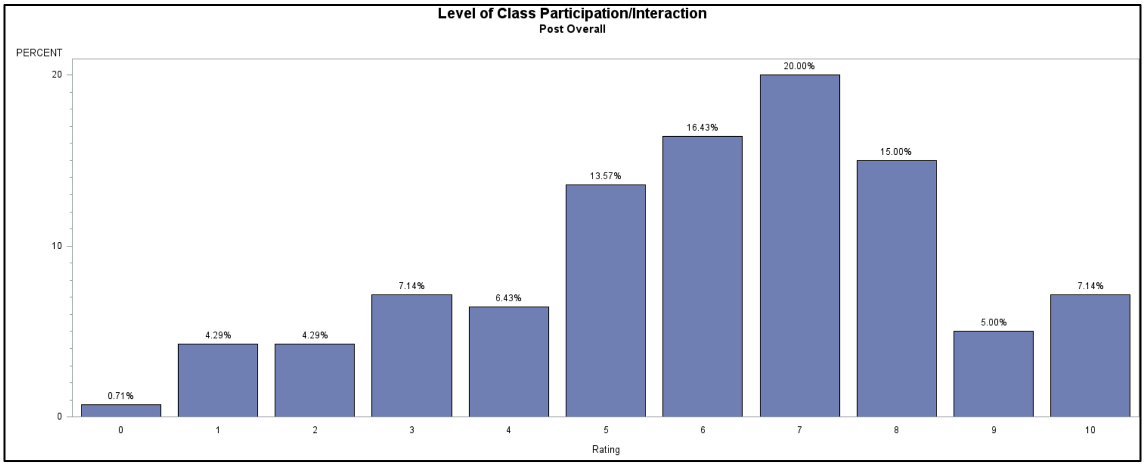


Figure 2.7 Pilot Data Overall Level of Class Participation

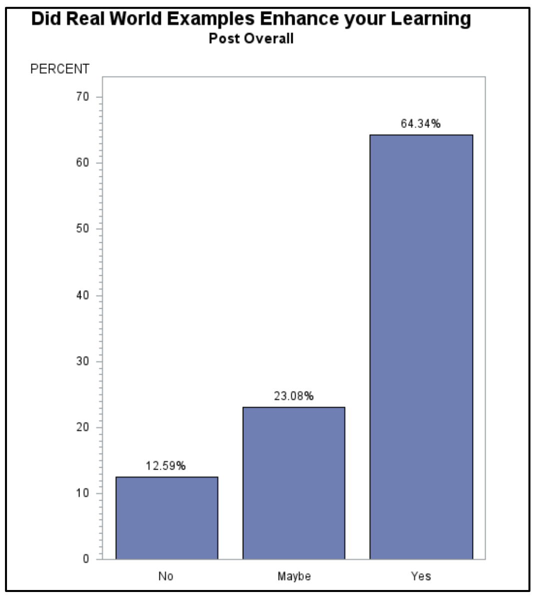


Figure 2.8 Pilot Data on the Enhanced Learning due to Real World Examples

2.3.2 Industrial Advisory Board Findings

The divide between students and industry was even greater than initially believed, as companies can easily educate their own more easily than trying to change how universities are educating to meet continual change (Garrick, Chan, & Lai, 2004). An Industrial Advisory Board (IAB) allows employers to have feedback on what they see as needs for future MET employees. Hosting a workshop with the IAB allowed for the research team to get the direct input, from employers, on strengths and weaknesses seen within recent MET graduates. The IAB was asked several questions pertaining to this topic. Table 2.1 shows findings that were noted by industrial partners of the MET department.

Table 2.1 IAB Workshop Responses

Questions	Separate Company Responses			
What are critical components to an energy systems certificate?	• Understanding the energy fundamentals across several energy disciplines	• Validation of learning and visual separation of student achievement • Industry relevant exercises and projects	• Energy supply and demand, including balancing how they are managed	• Problem solving, critical thinking, communication, multidiscipline approach • Shows student has initiative, went above and beyond
What would make an energy certificate valuable to and recognized by industry?	• Additional requirements (extra-curricular) • Beyond a basic degree • Measurable difference	• Recipients must be able to demonstrate competence in the field • Clear info on how concepts were applied (what was physically done – hardware, software, in lab and projects)	• Higher level thinking systems • Something extra in classes (capstone), direct industry interaction through activities, grade requirements (ex. B or better)	• Badge requirements must be above and beyond normal course requirements • Applied outside the classroom – like internship • With a capstone
How might we collaborate with you and your company on this effort?	• Develop a project or Rube Goldberg project showing a broad yet deep understanding of several energy disciplines	• Internships • Activities applied to industry problems • Provide drawings or other materials as teaching aids	• Share curriculum to increase understanding maybe research projects	• Capstone projects • Internships • Coordinate focus groups

Studying literature from (McGunagle, 2018) revealed that the top three skills desired by employers, in order are: the ability to effectively communicate orally and listen, skills revolving around creative thinking and problem solving, and experience in the application of skills learned. The skills listed were also found as a result of the IAB workshop. New STEM graduates may lack hard technical skills desired by companies, but companies are more worried about the lack of soft skills seen amongst graduates like communication, problem solving, and team work as these skills need to be present from day one (McGunagle, 2018).

2.4 Summary

From the pilot study, based off of student feedback and instructor observations, it is evident that the two semesters of courses were lacking continuity. This study aimed to integrate the two, both horizontally and vertically. The results that were seen from the databases, the pilot study, as well as through the IAB indicate a need that is supportive of the research area. These sources supported that an integrated energy curriculum can influence the learning of students if applied correctly. Sources also support that within vertically and horizontally integrated courses, activities can improve student understanding of concepts. While the studies support these claims, many focused on other disciplines. Very few of the studies actually looked at how this can be done for engineering technology students.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Introduction

In order to collect information from students, surveys must be distributed to see where improvements can be made to the curriculum presently and for the future. The data must not only provide answers to the research questions, but must also allow researchers to make changes to the structure of multiple courses. Within the ESC there are a series of fourteen badges which can be awarded. These fourteen badges are each represented by a specific course. In order to earn the full ESC, students must earn the associated ESC badges within seven courses which they are required to take per the MET curriculum. The remaining badges work towards a focus within HVAC systems, utilities, mechanics, manufacturing, or transportation. Figure 3.1 shows the core courses involved in the ESC as well as the title and progression of each badge in route to the ESC.

The design of the activities for each of the energy based courses was done by current faculty members teaching each specific course. Within each of these courses an energy related assignment, which is based on a current course learning outcome objective (CLOO) will be implemented and assessed using rubrics. The CLOOs were determined utilizing objectives outlined within Bloom's Taxonomy to establish pedagogical interchange and to ensure the hierarchy of cognitive skill is followed (Anderson, 2001).

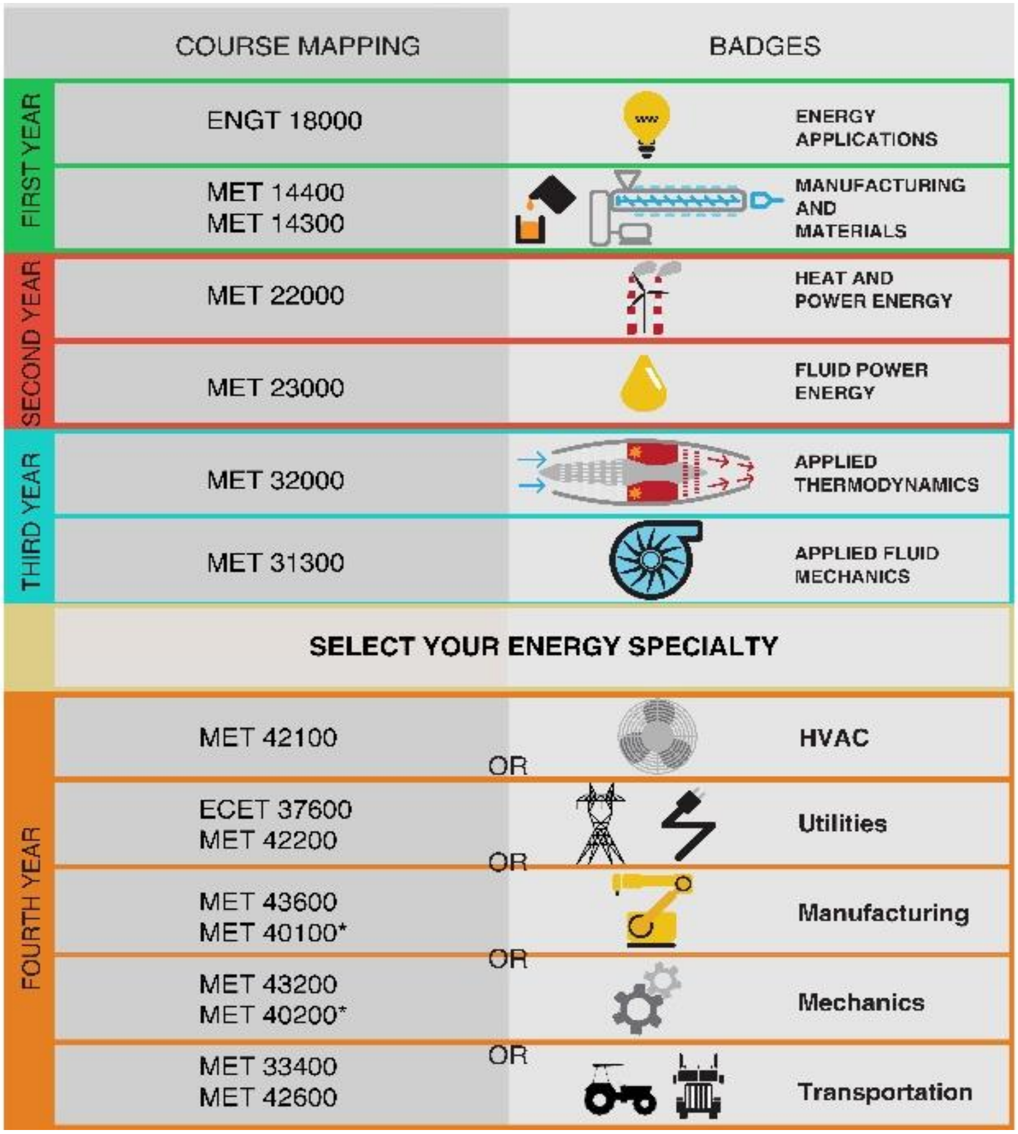


Figure 3.1 ESC Course and Badge Map

In order to make effective changes to each of the required courses, students will be administered surveys at the end of each of their academic years within the MET program, as well as when they first arrive in the program. The survey, which they will take a total of five times, is going to be referred to as the ESC general survey. In addition to the general survey, students will be tasked with the completion of a course-specific survey at the end of each course involved within the transformation. The course specific survey is required by students who wish to receive their badge from that specific course. The general survey is required by all those wishing to receive the full ESC.

3.2 Research Mode/Type/Approach

The data being collected will consist of both Quantitative and Qualitative data. The Quantitative data will be obtained by analyzing the results of student reported surveys and drawing statistical conclusions about the transformation of the courses and about how students perceived their learning experiences. The Qualitative data will be collected through short answer responses on both surveys. The questions that utilize Likert scales to assess the student's experiences within the classrooms provides most of this quantitative data. The general survey also contains knowledge-based questions that will be used to help answer the research questions.

All survey data from the students will be collected anonymously through Qualtrics. Students participating in the transformation are required to complete surveys to remain in the program; however, by incentivizing non-participating students to complete surveys, the research team is capable of utilizing multiple different research designs to measure responses between the variable of ESC participation (Lappe, 2000). Students are tracked to ensure completion through the use of a non-identifiable ESC number which is assigned to the students within their freshman engineering technology course. To analyze the large amounts of data from independent surveys, the use of statistical software packages is needed. The statistical software programs that will be used are SAS as well as SPSS. Furthermore, guidance from the statistical consulting service or SCS, here at Purdue University will be used for guidance while running different statistical tests. All surveys to be administered can be seen within appendix A.

3.3 Experimental Design

Due to the differences between surveys there are two separate designs being practiced through the implementation of this research. The student participation in the program itself is voluntary, but to earn the credential, survey responses are not voluntary. This allowed for students who did not wish to participate in earning the ESC but still took surveys act as a control group (Sekaran, 2010). The reason for no formal control group is that students cannot receive unfair advantages to advance their personal education within the classroom. Meaning this research cannot transform the learning environment within the classroom for some students, while omitting others.

The use of a Quasi-experimental design uses students who are enrolled in the class, but not in the energy credential program as the control group. A Quasi-experimental design looks to see if the treatment of the pursuit of the ESC influences factors that are being assessed (Creswell, 2009). Furthermore, as students can choose to participate in the ESC program or not, the Quasi-experimental design is satisfied as individuals are not randomly assigned to groups. The design itself was selected because of the ability to use the comparison data from each class and be able to compare those results. The further comparison of the results over time for course specific survey, as well as tracking an individual student as they progress through the program and analyze their progress in a systematic, long term philosophy utilizes a longitudinal design study (Reeve, 2014). Due to the ESC program being new, the results of this longitudinal study will be done in future works.

3.4 Population and Sample

3.4.1 Description of Population

The population being studied within the energy system transformation consists predominantly of Mechanical Engineering Technology students from Purdue University. All general survey respondents were within the students' freshman year. The general survey data is made of SoET students as they are required to take ENGT 18000 Engineering Technology Foundations. This causes survey data for students from majors outside of the MET department to be collected. The phenomena of having non-MET student data will only regularly occur within the freshman course but can occur whenever non-MET students elect to take a MET course. Historically within the MET population, the students range in age from 17 to 30 years old, and slightly over 90% of the students identify as male (Lucietto, 2016).

Through the initiation of the ESC the General survey data indicated that 184 students took part in the survey. Of those 184 students, 80.86% identified as male and 18.52% identified as female. The cumulated responses from all the course specific surveys indicated that 89.52% identified as male, and 7.86% identified as female.

3.4.2 Sampling Method

The sampling type that is being used for this study is volunteer response sampling. While not the ideal method for quantitative data, the research setting only allows for this type of sampling without creating unfair/unequal student learning opportunities. The sampling method is also due to the nature of this study and in dealing with human subjects within the classroom. Studies like this are required to receive Institutional Review Board (IRB) approval to ensure that through the course of the research there is little to no risk for participants involved. Information about the IRB exemption that was awarded is discussed in further detail later within chapter 3. The surveys are given to all students within each of the described environments through an online hyperlink. Therefore, students can choose to respond regardless of if they are actively seeking the ESC or even just a single badge. This opportunity allows students to receive individual badges from a course and demonstrate their competence within that specific area (Klein-Collins, 2012). Furthermore, all students participating are able to indicate their response to the activities being measured regardless of degree program.

3.4.3 Parameters

The students involved in the study are MET students and must be actively enrolled at Purdue University West Lafayette. The implementation of the ESC is able to be done at statewide locations as well; however, it is being launched only at the West Lafayette campus at this time. Students are also required to complete a series of seven badges from required courses that are distributed from freshman to senior year of the program. The student population responding to the surveys does not include all students enrolled in the course; rather it is based on their interest in the ESC. Student participation involving the energy based activity is required by all students enrolled in the course as each has been built into the course curriculum.

Within each of the badges, students are required to complete the ESC activity which is added to each of the courses included in the credential program. The list of courses can be seen in Figure 3.1.1. The student must score a minimum of 80% on ESC activities within required courses to remain in the program as well as complete the required survey. The level of completion required comes as a result of observing what employers of MET graduates would like to see as means of students with the ESC setting themselves apart from others. The minimum score requirement demonstrates the students' proficiency in each specific energy related topic. In addition to each project activity, students are also required to complete all surveys associated with the ESC program.

3.4.4 Sample Size

The student population sample size has the ability to fluctuate over time. Currently the MET program has approximately 150 students per graduating class who have the option to take part in this research. Additionally, within the freshman year of students, participation could be as high as 300 students. This is a result of all freshmen being required to take the freshman engineering technology course ENGT 18000 prior to choosing a specific degree path.

It is anticipated that enrollment numbers into the ESC program will increase as students and faculty become more aware of the program. This is an aspect that cannot be guaranteed. The pilot study revealed that MET students' self-reported high levels of interest in transformed classrooms with a centralized focus of energy. Maynard et al., supports this claim, explaining that:

> One student said "It was interesting to apply concepts we learned ourselves and not have to follow a set of instructions. We had guidelines and we did what we could with them." Others suggested that the hands-on experiences in "real time" were effective in teaching and reinforcing practical concepts… (p. 5)

Given the current enrollment trends (Lucietto, 2016), the sample size can be as large as 700 subjects consisting of MET students over a four-year span. The estimated future sample size does not account for students who may take longer than four years to complete their program. The current sample sizes observed within the ENGT 18000 course are from the Fall 2018 and Spring 2019 academic semesters, as well as all other course involved with the ESC that have run since the launch of the program. This can be seen within Table 3.1.

Table 3.1 Sample Sizes

Survey	**Course Number**	**Year**	**Academic Term**	**Participated**	**Survey Completion**	**Completion Percentage**
General Survey	ENGT 18000	2018	Fall	134	124	93%
Course Specific	ENGT 18000	2018	Fall	117	73	62%
Course Specific	MET 14400	2018	Fall	8	6	75%
Course Specific	MET 23000	2018	Fall	86	83	97%
Course Specific	MET 42600	2018	Fall	62	53	85%
General Survey	ENGT 18000	2019	Spring	50	47	94%
Course Specific	MET 32000	2019	Spring	48	40	83%

3.5 Variables

3.5.1 Independent

Within the focus of the ESC, the independent variables are variables that will influence the results gathered from the survey questions which assess the research questions (Creswell, 2009). The independent variable being measured from the first null hypothesis is the use of active learning activities. The second independent variable being assed is the use of energy focused activities as a common theme.

Additionally, within quantitative research there are additional independent variables called control variables which need measured as they can potentially influence the dependent variables (Creswell, 2009). These unique independent variables can be found within demographic or even personal variables (Creswell, 2009). The first control variable within this research looks to see if student participation in the program as a whole, or even a specific badge can influence the outcome. The second control variable looks to see if gender has any potential impact on the dependent variables.

3.5.2 Dependent

The dependent variables within a study are being measured. Dependent variables are the outcomes as a result of the independent variables and are often referred to as response variables (Creswell, 2018). Many dependent variables can be measured from the study; however, the ability to answer the research questions results in testing only two of these dependent variables. The first response variable being measured is the motivation of engineering technology students within energy focused courses. The second dependent variable being analyzed is the perceived understanding of energy concepts.

3.6 Treatment

The treatment being administered is the transformed class environment within fourteen energy focused courses contained within the MET department. Seven of these transformed courses are required by all students per the MET curriculum. This class transformation is the incorporation of a centralized energy theme within energy based courses, the addition of specially designed activities that apply course concepts to real world projects in each of the courses, the distribution of surveys to measure their perceived and actual knowledge longitudinally, and a more interactive competency-based structure.

The treatments associated with the ESC are administered to each of the participating courses as a whole. Therefore, the activities and likewise the treatments will be administered to all students in each of the courses. While not ideal, there is no way to pull aspects out of a restructured course for some students and keep them in place for others.

The restructured courses will incorporate a more project, team, and experiential based learning environment. The transforming of the courses to utilize an experiential based learning environment allows students to gain knowledge within a specific area by being capable of fully grasping the concepts being taught (Kolb, 2001). Within the ESC at least one activity will be conducted during the semester that creates such a learning environment. The emphasis of non-technical skills is also placed within many of these activities requiring peer communication, technical writing skills, as well as presentation skills.

3.7 Instrumentation

3.7.1 Development

As an aspect of the development of the ESC program the need is vital to create an evaluation procedure as part of the program. One component of this evaluation process is the development of class specific instruments that can be used to analyze a specific predetermined classroom energy activity. The evaluation of the activity increases not only the energy activity, but also the understanding of each component and how each component works together for student success in understanding energy and its application. A quantitative, Quasi-experimental, instrument was developed to measure motivation, application, and interest.

One portion of the development of the evaluation process required the creation of an IRB protocol with the University. As part of the creation of this protocol, the research was applied to be Category 1 research. Category 1 research is conducted as normal educational practices within an educational setting. This category is designed for educational studies that are exempt and are part of the normal classroom experience.

An important part of development for the classroom specific evaluation survey for the energy credential program is the creation of the qualitative research design for the study. After research on different types of quantitative research designs, the use of case study research design was selected. One reason for the selection of case study is because of the ability to use this technique in various classrooms in small groups to be able to answer questions like "how" and "why" student interest in energy credential is impacted (Baxter, 2008). As part of the research design, observations were chosen as the method for gathering data. Observations were selected because "the target for observation is the event or phenomenon in action" (Tuckman, 2009). The use of a developed observation protocol focuses on "(1) relationships between the behaviors of the various participants, (2) motives or intentions behind the behavior, and (3) the effect of the behavior on outcomes or subsequent events" (Tuckman, 1999).

The quantitative survey was developed in a Quasi-experimental design with the use of those who are enrolled in the class, but not in the energy certification program as the control group. This design was selected because of the ability to use the comparison data from each class and be able to compare those longitudinally throughout the years. Part of this research design analysis of the data will be focused on using t-test and multiple group regression (ANOVA) as well as factor analysis. Each of these will give the opportunity to look into the correlational data between the control group and the energy certificate program and evaluate for significance for each of these.

The use of an interface for students to track their progress towards earning the full ESC was also constructed. This interface allows students to view badges they have previously earned and which ones are still needed to complete their credential. The platform used for this interface after evaluating the functionality of several others was Passport. Passport is a Purdue University developed and supported platform that is used for badging. Within Passport, private groups can be made, where "learners" are able to track their personal progress on activities, submit content for badges, and access supplemental learning content provided by instructors. The following figures include images of the designed student interface. Figure 3.2 is a screen capture that shows the main ESC group page where students are able to view information as well as access the general survey. Figure 3.3 shows the roadmaps that students are able to follow, and Figure 3.4 shows other badges students are able to navigate towards from the main group page.

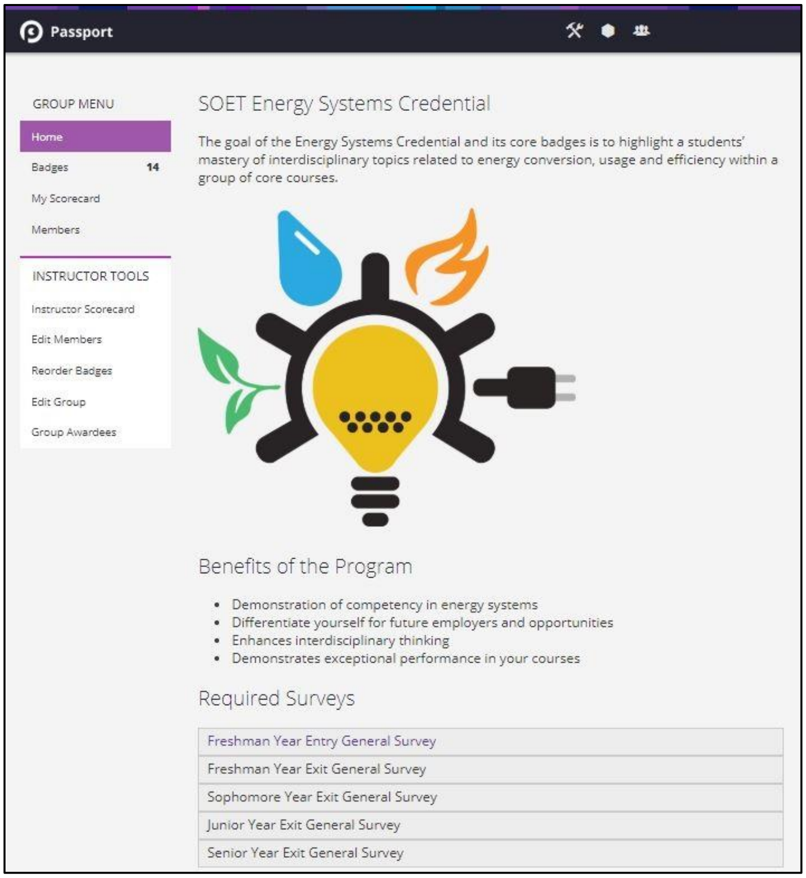


Figure 3.2 Passport Screenshot ESC Home Page (Studio, 2019)

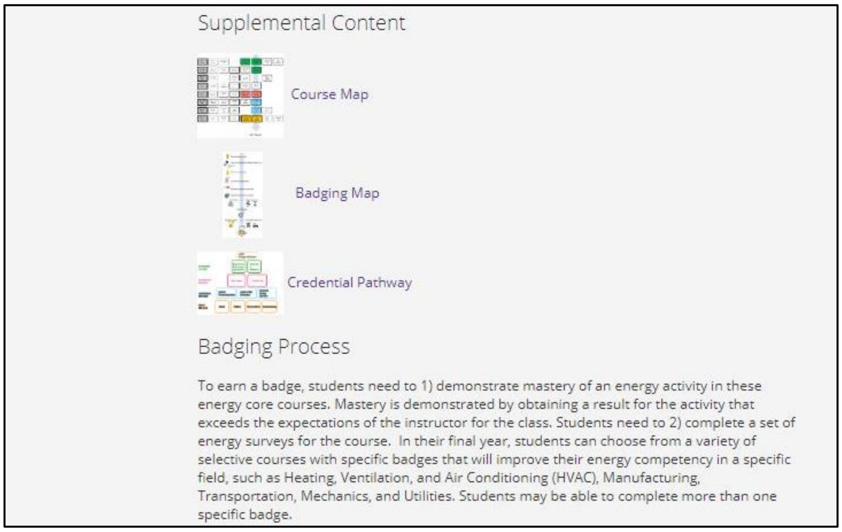


Figure 3.3 Passport Screenshot ESC Pathway Information (Studio, 2019)

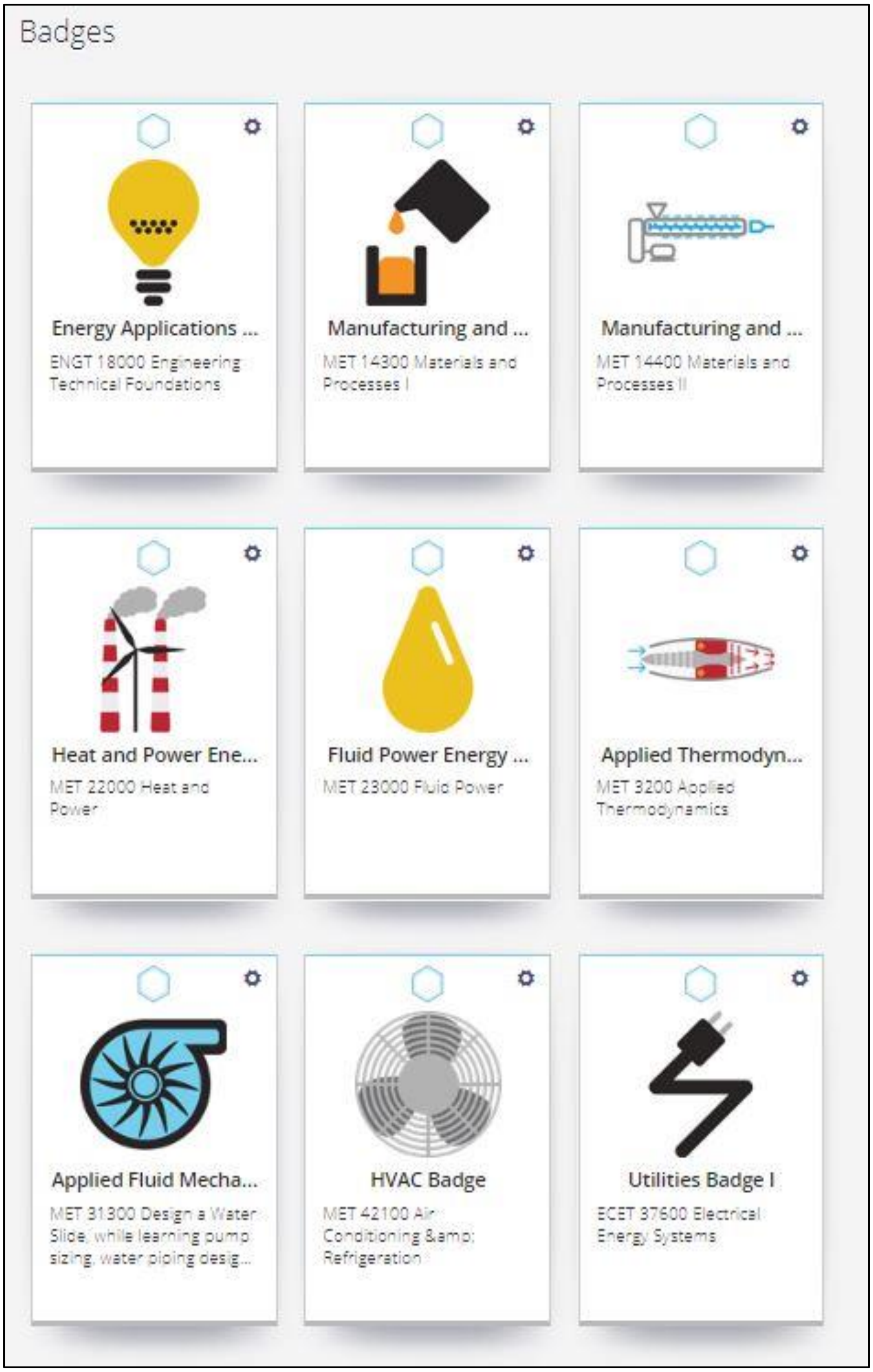


Figure 3.4 Passport Screenshot ESC Badges (Studio, 2019)

The instructors within each course involved in the energy transformation are able to modify challenges and grading rubrics for the given ESC activity. The following figure shows a challenge existing within one of the badges in passport. This is where students can view what is required of the challenge, submit the required documents Figure 3.5, and view the grading rubric Figure 3.6. When students submit content for completion of a badge, instructors are able to grade each of these activities directly from passport. Instructors are also able to download comma separated value (CSV) files which show scores for all students who submitted content.

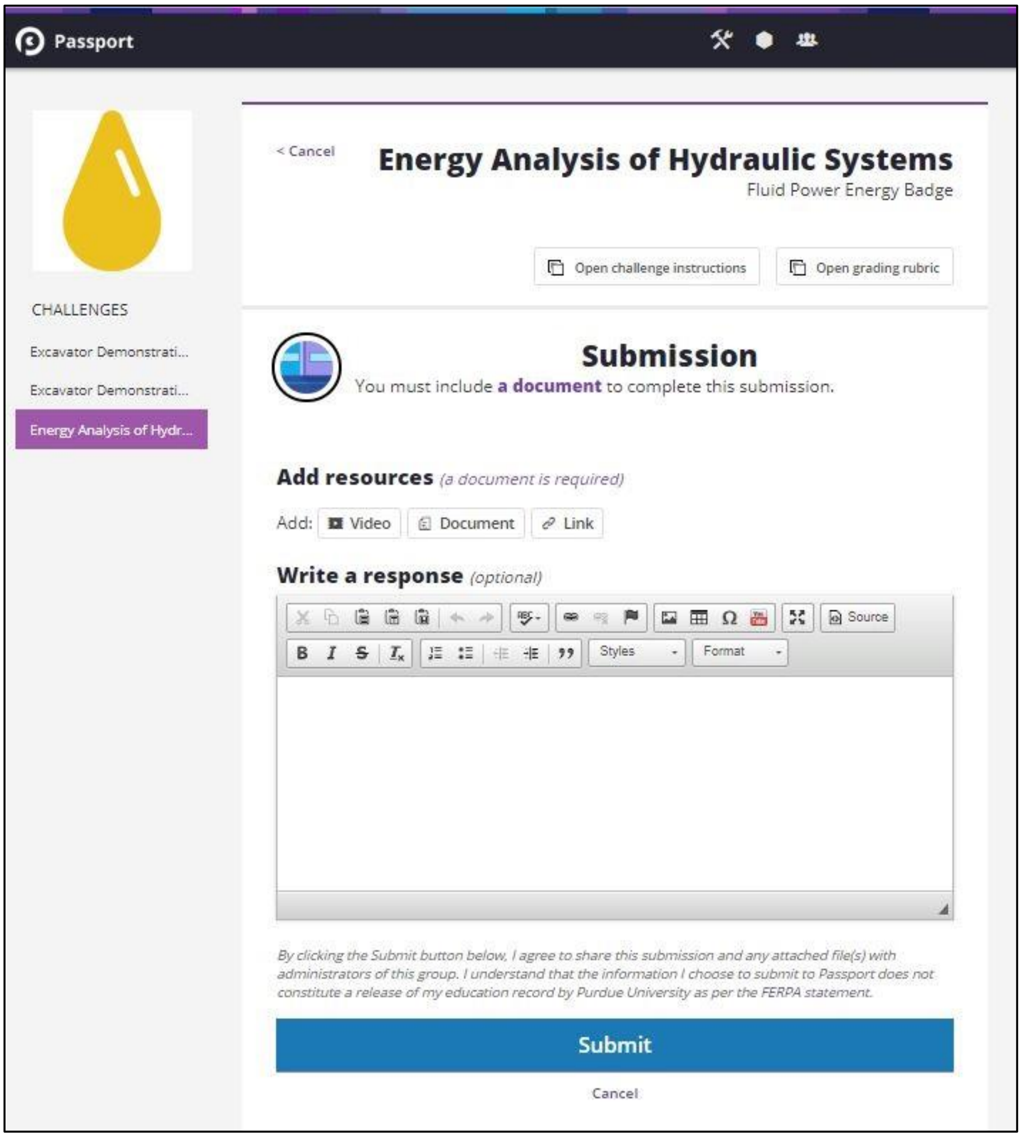


Figure 3.5 Passport Screenshot ESC Challenge Submission (Studio, 2019)

Grading Rubric

Criteria	Seriously Deficient	Lacking	Acceptable	Good	Exceeds Expectations
Identify sources and consumers of energy from energy conservation principles using the Bernoulli equation - Students are able to relate terms in the Bernoulli equation that contribute to energy gain or energy loss from a system	**1 point** None of the questions	**2 points** Question 4 or 6	**3 points** Questions 4 and 6 Correct only	**4 points** All questions but #1 and 14	**5 points** All questions 1,4,6,13,14
Calculate energy losses due to laminar and/or turbulent flow in pipes, tubes or hoses - Students can choose the correct equation for flow regime and determine Head loss from the equations	**1 point** None of the questions	**2 points** Only 9 correct	**3 points** 9-10 correct but not 11	**4 points** Failed by just a rounding error or conversion of units	**5 points** Questions 9-11 correct
Estimate energy and power losses due to friction and leakage of hydraulic and pneumatic cylinders, valves, motors and pumps - Use the hydraulic power formula and efficiency to determine the losses and convert between power and energy units	**1 point** None of the questions	**2 points** None of the questions are correct	**3 points** Question 12 is correct but Q1 is incorrect	**4 points** Question 1 is correct and 12 is incorrect by rounding error or units conversion	**5 points** Questions 1, 12 and 14 are correct

Figure 3.6 Passport Screenshot ESC Grading Rubric (Studio, 2019)

3.7.2 Validation

A key part of survey development is testing for validity. Validity is defined as “the extent to which the instrument measures what it purports to measure” (Tuckman, 1999). Many different options are available to test validity, but the area which correlates to this study is content validity. “A test has content validity if the sample of the situations or performances it measures is representative of the set from which the sample was drawn” (Tuckman, 1999). Content validity is a match for this study because the questions that were used to create the survey were pulled from test question banks from the University of California-Berkeley, Vanderbilt University, and Harvard University. All banks of questions were created to assess motivation, interest, and application. The questions were then reworded without changing the structure of the question to fit the study for the energy credential program.

To further test validity of the quantitative assessment a Principal Component Analysis (PCA) was performed. The use of a PCA allows for the results to clearly fall into categories based off of what the question is assessing (Nie, 2018). The PCA Figure 3.7 show the extraction of two assessment components amongst the entire course specific Likert scale question. The results indicate with the exception of question Q7_8, all Likert based questions assess a single measure. This is where content validation must be relied upon. The reason for this is that from a data standpoint, two questions assessing opinion based responses such as how someone feels will not always be grouped within the same category because the metric is still opinion based.

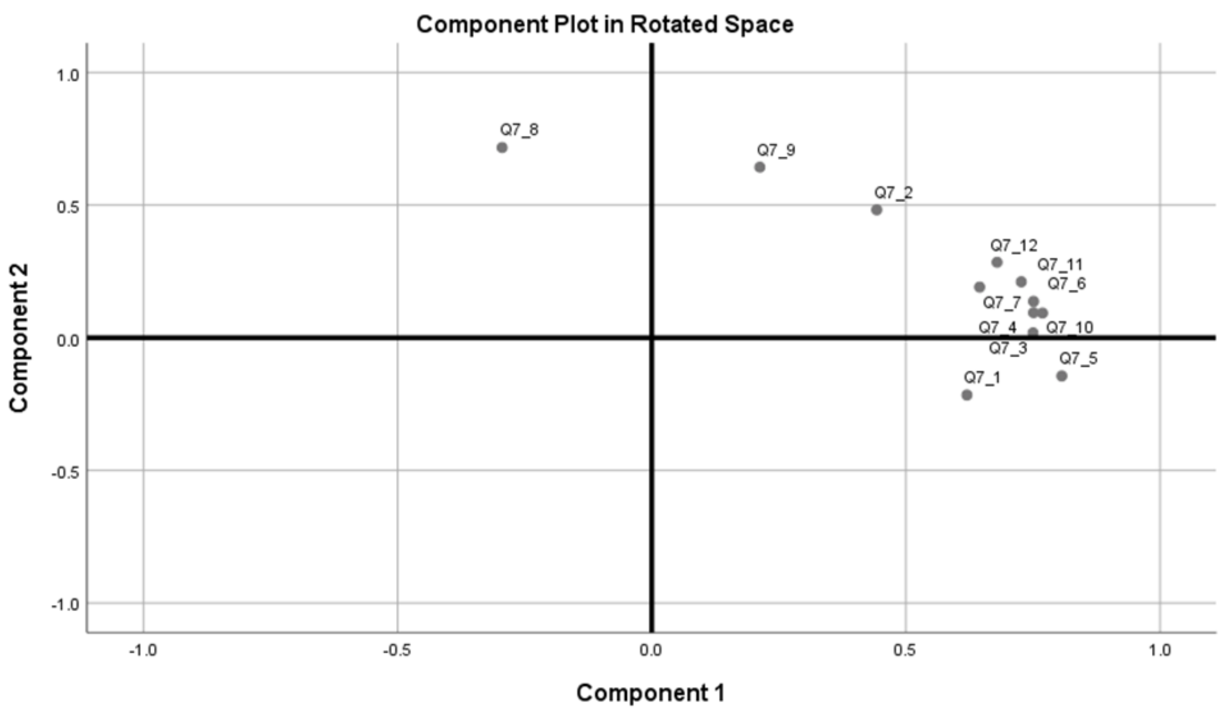


Figure 3.7 PCA Test on Course Specific Survey Likert Data

3.7.3 Utilization

Each student will respond to the validated surveys as well as the ESC interface to complete badges. As students are required to take the general survey twice during their freshman year and once per academic year thereafter, the general survey will be regularly utilized. Likewise, the course specific survey will be administered to students each time the course is run. Students will also need to measure their progress toward badges and their full credential regularly through the student interface to ensure they are on track.

3.7.4 Administration

Each survey will be administered through Qualtrics. The general survey will be given at the beginning of the students' freshman year while enrolled in ENGT 18000 and at the end of every academic year thereafter. The course specific survey will be administered upon the completion of the ESC activity within the courses involved. The students will be given a time frame to complete these surveys before the link to access them expires.

3.7.5 Reliability

Qualtrics is regularly used by Purdue University and other Universities as a reliable surveying tool. In the event of software failure, hardcopy surveys can be administered without concern of revealing any identifiable data. It is the students' responsibility to save the documents showing they fully completed the required steps at a level which fulfilled the requirements when being awarded each badge. The reliability of the surveys is crucial as the longitudinal analysis of students as they progress through their academic career is desired. Therefore, the surveys must be able to easily pull the key information that is being desired.

The most important part of survey creation for this project is the ability to test the instrument for reliability. A few different ways can be used to do this. Tuckman described test reliability as "test gives consistent measurement" (Tuckman, 1999). The first option to test for reliability is to use test-retest reliability in which a single group of people take the test twice and a correlation is made between the two scores. The second option is to use alternate form reliability. This is when the test is conducted in two different forms with the same content and a correlation is made between the two test scores for each person (Tuckman, 1999).

3.8 Data Collection

3.8.1 Respondents

The respondents represent two sets of general survey data and five sets of data from the course specific surveys. The course specific data is able to be merged with all other course specific data, as questions assessing the participants have the same focus. The responses for those participating in the ESC transformation contain a non-identifiable ID number for the researcher to match their data longitudinally. Not all data contains such an identification number, due to participation being voluntary.

The merged data from the general survey indicated that of the 184 students who began the survey, 171 (92.93%) completed it (Johnson, 2003). To remain in compliance with the IRB approval, the students involved in the study had to be at or over the age of 18. Of all the students who were asked 13 (7.14%) students indicated that they were not 18 years of age yet. The data collected on the course specific survey respondents showed that of the 306 students who began the survey, 242 (79.08%) of students finished. The incomplete survey numbers do not contain the 13 (4.25%) subjects that were unable to continue due to the 18 years of age requirement.

3.8.2 Non-respondents

Those who do not respond will not be able to earn their full ESC. Badges can be earned on a per-class basis; the full credential can only be obtained by those individuals who complete all surveys encompassed within the ESC transformation. Students are not required to complete the survey, and are aware that they will not receive the credential if they chose not to respond.

3.8.3 Follow-up Procedures

Reminder emails will be sent out through the platform used to track student progress on deadlines to complete surveys. Additionally, the instructors of the participating courses will give verbal reminders to all students to complete the course surveys. The instructors have the option of awarding extra credit to students to help solicit survey responses. Furthermore, students will be given the option to take the general survey if they missed it due to transferring from a different school/department or other reasons such as testing out of the ENGT 18000 course.

3.8.4 Anonymity/IRB

To ensure the safety of all students involved in the research, IRB approval has been obtained for this research within the given research field. The IRB approval falls under exemption category one. Category one includes standard academic practices, where all instructors of required courses must be on the research team. Additionally, each member of the research team is required to complete a basic course on responsible conduct of research through CITI training. The CITI training is required to be renewed every five years to remain compliant with the IRB. Proof of IRB approval can be found within Appendix B of this document.

Student surveys do not ask for any identifiable data to ensure anonymity. All freshman students are assigned a unique identifier in the form of a five digit code. If a student loses his or her ESC number they are able to look it up through their academic advisors. Student advisors, who are not part of the research team house this document. Housing the code there keeps the code and who it is assigned to it anonymous from any members of the research team. Upon graduation all identifier codes are destroyed to ensure confidentiality and satisfaction of required IRB protocols. The anonymity is crucial to ensure that all subjects involved within the study to eliminate any potential risks based off of their reported information (Mulder, 2014). Furthermore, as a result of ensuring anonymity, and that any sensitive data collected through surveys is handled with care, student participation on surveys can be increased (Mulder, 2014).

The approval from the Institutional Review Board (IRB) from Purdue University (IRB Approval 1806020752) was granted prior to the collection of any data.

3.9 Summary

The surveys that will be distributed will allow instructors to see where improvements can be made to the curriculum, both for now and the future. The surveys will be taken 5 times, 2 times freshman year, and the end of the year for the next 3 years. The surveys will come in two different forms as well as two different styles. There will be course specific surveys and general surveys. General surveys are for students wishing to receive the full ESC, whereas course specific surveys are for individual badges for those courses. The data from the surveys will be collected through means of quantitative and qualitative data. Quantitative data is collected in the form of survey questions, while qualitative data is in the form of short answers.

Data collected for this research only encompasses the initial launch, the first two semesters of the program, Fall 2018 and Spring 2019 semesters. It consists of only two general survey data sets and course specific survey data from all the courses taught within the program. Individuals who identified themselves as males are the ones who made up a large majority of the sample size. Not only MET students took the surveys, however, only MET students are involved in the study. Other students, in different majors, took the survey as they took the MET course as an elective or were a part of the initial ENGT 18000 course which includes all School of Engineering Technology majors.

The level of completion for the surveys came from what the MET Industrial Advisory Board said they would like to see of MET graduates. Through this research, the gap between employers and current graduates is hoping to improve. Class specific instruments are being put in place to analyze a predetermined classroom energy activity. These instruments not only increase the energy activity, but also the student understanding of each component and how the components work together. This helps drive student success in understanding energy and its application.

Upon the completion of courses, students take tests to determine if they will receive the badge for that course. Through the use of Passport, a Purdue University developed and supported system the students can track their progress as well as what they still must complete to earn their certificate. They are able to see the badges they have earned, submit content to earn more badges, and access supplemental learning content provided by instructors for badges yet to earn.

CHAPTER 4. DATA ANALYSIS

4.1 Data Recording

The recording of data contained within the research (outside of the pilot study) spans from the fall 2018 academic semester as well as from the spring 2019 academic semester. The spring data collected only contains data from courses within the study that have complete the ESC activity associated with the course. Furthermore, students taking the general survey within ENGT 18000 courses are grouped with the fall 2018 general survey as both groups of students, from a curriculum standpoint, are in the same graduating class. Within this time frame, the recorded data contained 229 valid data sets from the course specific surveys. The general survey data contained 158 valid data sets.

4.2 Data Conditioning

The information being recorded is currently housed within Qualtrics. Each of these data sets are downloaded in the form of CSV file. The conditioning of the data sets is done within excel where incomplete data can be reviewed to determine if the removal of said incomplete student survey response can be removed from the data sets. The analysis of the conditioned data sets can then be used within SPSS or SAS, both statistical software tools, as these programs can read these CSV files that were downloaded directly from Qualtrics. Further conditioning can also take place to assign the values recorded from Likert based questions to their corresponding response which the students indicate.

Averaging the student data based off of questions which assess a specific research question allowed for students to have a singular score based off of the averages seen. The first research question used the course specific Likert scale questions Q7_5, Q7_6, and Q7_11 to assess the students' motivation. The second research questions used course specific Likert scale questions Q7_3, Q7_4, Q7_7, Q7_10, and Q7_12 to assess the students' perceived understanding as a result of the ESC activity.

For the independent variable, assessing whether or not the students would be participating in the ESC as a whole or not, or be pursuing the badge within the course, further conditioning was needed. The question was not a forced response question within the survey, and as a result 83 (36.24%) of all respondents did not indicate an answer from the options of "Yes, No, and Unsure". Due to this, students who do not respond to this question will be placed within the "Unsure" grouping.

4.2.1 Biases

A common problem with voluntary response sampling is the influence of biases as a result of the yielding strong opinions may be more likely to respond (Clover, 2017). As a result of this, it was warranted that the data sets which contain straight response values be removed from test samples. The straight answer responses (responding to all Likert based questions using same value) can indicate a possibility of a bias response, but do not mean the responses are guaranteed to be biased (Nie, 2019). The removal of such subject data is acceptable as long as the study determines the removal a procedure to be practiced for all sets in the data conditioning process (Nie, 2019).

4.3 Analytical Procedures

The data collected from the two surveys will be used to answer the two research questions. The quantitative data obtained from the course specific surveys will be used to answer these research questions and the hypotheses that are correlated with the two of them respectively. Furthermore, the quantitative data from the general survey is applied in a quasi-experimental design to analyze the students longitudinally. The research questions identified within the introduction are:

- Does active learning impact the motivation to learn of engineering technology students within energy related courses?
- Do energy focused activities improve perceived student understanding of energy concepts?

Through the guidance given by Statistical Consulting Services at Purdue, the use of SAS and SPSS were selected in order to run the data analysis. Furthermore, guides to graphically represent information from the study were given by graduate students within the statistics department (Nie, 2018; Pei, 2019). The SAS or Statistical Analysis System used to analyze T-test information about the respondents is version 9.4 of the software program. The results will be used in the longitudinal study of the students' progression through their academic career. The SPSS or Statistical Package for the Social Sciences software program used to run the multiple group regression or ANOVA tests is ran on version 25 of the software program. The results of the test ran within SPSS will show not only if the hypotheses are confirmed within a certain confidence level or not, but also show the relation between independent variables. Furthermore, the SPSS results will be able to graphically display the distribution of responses as a whole as well as within each of the groups as along with indicating if the distributions are normal or not (Nie, 2018).

The results of a two-way ANOVA compares the mean differences within groups (Moore, 2014). The comparison between groups is done within the independent variables of gender and participation in the ESC program. The statistical test allows for the degree of interaction each independent variable has with the dependent variable to be measured at a statistically significant level (Moore, 2014).

The use of a two-way ANOVA requires the satisfaction of several assumptions based upon the data. The assumptions that need to be tested to ensure the multiple regressions produce valid results are the dependent variable has no significant outliers, the dependent variable is approximately normally distributed, and there is homogeneity of variance (Clover, 2017). Each of the assumptions upon running an ANOVA test allow for the effects of the explanatory variables to be confidently interpreted to a certain degree. Using a Tukey test will allow for the comparison of means for categorical data such as gender (Nie, 2018).

The degree to which variation can be explained is done through the use of a Confidence Interval (CI). A confidence interval contains a range of values which are estimated based off of a known sample statistic, such as sample mean ($\overline{x}$) or standard deviation (σ), which is thought to contain an unknown population statistic with a certain level of confidence (Clover, 2017). The level of confidence dictates how wide the confidence interval will span, and likewise the span will decrease as the sample size increases (Clover, 2017). Therefore, choosing a CI using the "estimated marginal means" allows for the variation between groups to be explained confidently even in the case of imbalanced responses in data sets (Moore, 2014).

As indicated within the instrumentation section, the Likert based surveys use three to four questions from each of the respondents to test each of the research questions. The corresponding responses gathered for each of the research questions are tested, and the test results will indicate the correlation, if any, to the independent variables. The dependent or explanatory variables are the gender of the student as well as if the student is currently or will be participate in the ESC program in the future. The results of the test will indicate whether the null hypotheses outlined later within this chapter and chapter five should be rejected or not. The two questions analyzed within the study are broken down based upon the results of Likert scale questions that were used to evaluate them as well as initial results from the longitudinal study of the general survey. Table 4.1 shows the questions used for each of these research questions. The division of questions pertaining to each of the research questions can be seen within the data conditioning section of this chapter.

Table 4.1 Course Specific Survey and Corresponding Research Questions

Q7 Please answer each of the questions below based on your experience in _______________. Use the following scale for each of the questions: 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree						
		Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
Research Question 1	Working on this energy activity increased my interest in __________. (5)	○	○	○	○	○
	This energy activity increased my motivation to learn more about energy. (6)	○	○	○	○	○
	Working on this energy activity made me interested in learning more about _______. (11)	○	○	○	○	○
Research Question 2	Working on this energy activity made me think of alternative applications of this concept. (3)	○	○	○	○	○
	Completing this energy activity has given me a new insight into ____. (4)	○	○	○	○	○
	This energy activity helped me develop skills that I can use in the future. (7)	○	○	○	○	○
	I feel confident in applying the concepts I learned in this energy activity. (10)	○	○	○	○	○
	Working on this energy activity allowed me to understand the importance of how energy impacts my daily life. (12)	○	○	○	○	○

Testing of the mean responses for the first research question "Does active learning impact the motivation to learn of engineering technology students within energy related courses?" will consist of a two-way ANOVA. The mean score will be calculated on a per student basis and is the average score for all questions associated with this first research question. The value of the calculated mean is based off of the same five-point Likert scale used within the surveys. Three alternative hypotheses are a result of the independent variables and this research question. These three hypotheses are:

H_a: There is a correlation between active learning activities and the motivation of MET students.

H_a: The motivation of MET students within energy related courses differs between gender.

H_a: Participation in the ESC causes MET students to demonstrate different levels of motivation within energy related courses.

The second research question "Do energy focused activities improve perceived student understanding of energy concepts?" will be analyzed by running a two-way ANOVA test over the questions looking at perceived student knowledge. The test will utilize the mean score from all survey questions assessing the research question. The results of the calculated mean uses the same Likert scale from the survey itself.

H_a: Energy focused activities do improve the perceived understanding within energy concepts.

H_a: The perceived understanding of energy related concepts for MET students differs between gender.

H_a: Participation in the ESC causes MET students to perceive their understanding of energy concepts within energy related courses at different levels.

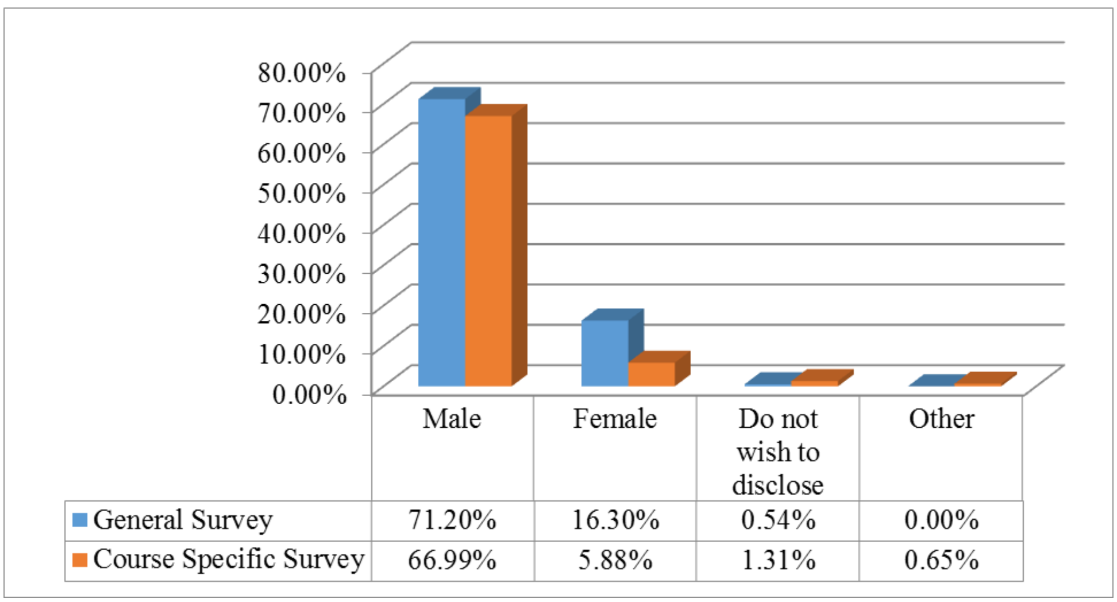
Furthermore, the analysis of the students' true level of knowledge regarding energy will be analyzed using the general survey data. A multiple regression analysis will enable the comparison between the independent variables seen before in addition to the independent variable of current academic standing. The analysis of the quantitative questions from the general survey lays the ground work for the future longitudinal studies. A one-way ANOVA will be used to compare the student reported knowledge level to that of their actual knowledge based upon the competency based questions seen within sections one through three of the general survey. The general survey can be seen within appendix A.

H_a: The true understanding of energy related concepts for MET students differs between gender.

H_a: The true understanding of energy related concepts for MET students is correlated to their perceived understanding.

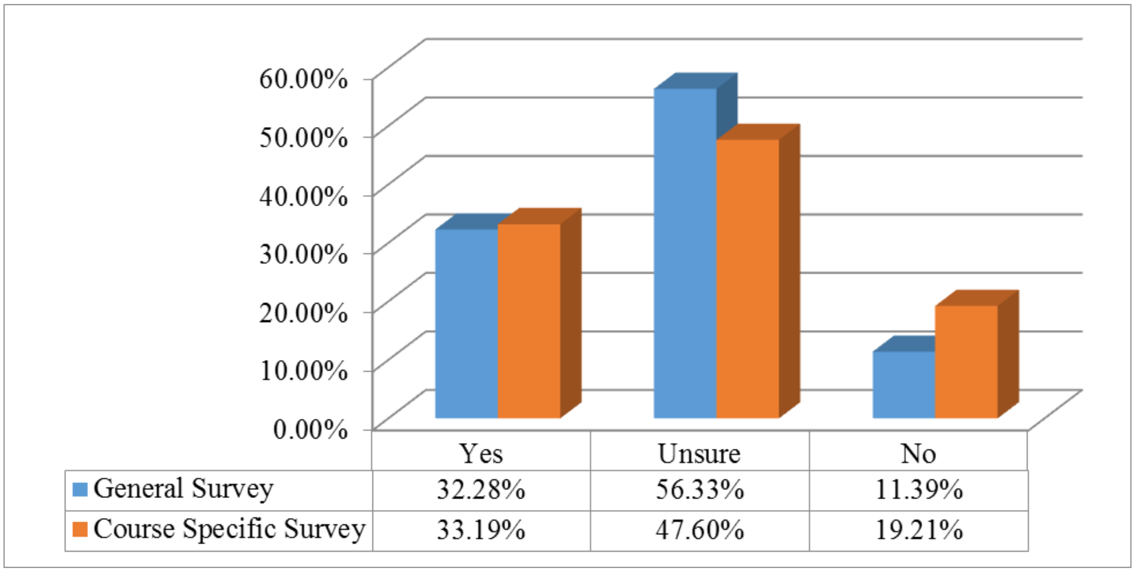
4.4 Findings

As discussed within chapter three, the parameters measured are the gender distribution, the participation within the ESC program, and the academic standing of the students (general survey only). Each of these questions, with the exception of general survey only questions, is taken with respect to the questions assessing the research questions. The gender of the students could be answered as female, male, other, and do not wish to disclose. The participation within the ESC program options are yes, no, and unsure. The academic standing of the students is freshman, sophomore, junior, and senior. Figure 4.1 shows the gender distribution of all respondents within the ESC, and Figure 4.2 shows the response for if students plan on participation within the ESC.



	Male	Female	Do not wish to disclose	Other
General Survey	71.20%	16.30%	0.54%	0.00%
Course Specific Survey	66.99%	5.88%	1.31%	0.65%

Figure 4.1 All Respondents Gender Distribution



	Yes	Unsure	No
General Survey	32.28%	56.33%	11.39%
Course Specific Survey	33.19%	47.60%	19.21%

Figure 4.2 All Respondents ESC Program Participation

4.4.1 Does active learning impact the motivation to learn of engineering technology students within energy related courses?

Active learning environments and competency-based education might contribute to the learning motivation of engineering technology students within energy related courses, but the effect could also differ across gender, ESC participation, or both. The utilization of a two-way ANOVA tested the self-indicated motivation of MET students across the two indicated independent variables. The assessment of student motivation averaged three five-point Likert scale questions designed to assess the self-reported motivation of MET students. The results indicate that responses do differ at a significant level across two of the three hypothesis formed for the research question. The tested alternate hypotheses are:

H_a: There is a correlation between active learning activities and the motivation of MET students.

H_a: The motivation of MET students within energy related courses differs between gender.

H_a: Participation in the ESC causes MET students to demonstrate different levels of motivation within energy related courses.

The overall mean score of (μ = 3.862) was indicated with a standard deviation of (σ = .76) over the population of (N = 182) students. Due to the population size some of the independent variables only have ($n = 1$). This is where the estimated marginal means allows each of the variables to be weighted accordingly based off of the respondents. The distribution of responses, their sample size n, the standard deviation σ, and their sample means $\overline{x}$ can be seen within Table 4.2.

Table 4.2 Descriptive Statistics for Research Question 1 “Motivation” from Course Specific Survey Results

Descriptive Statistics				
Dependent Variable: RQ1				
Participation	Gender	Mean	Std. Deviation	N
No	Do not wish to disclose	2.666667	NA	1
	Female	2.333333	NA	1
	Male	3.777778	.7005289	33
	Total	3.704762	.7443532	35
Unsure	Do not w	4.666667	NA	1
	Female	3.380952	.7800421	7
	Male	3.626016	.8070170	82
	Total	3.618519	.8065913	90
Yes	Female	4.466667	.3800585	5
	Male	4.205128	.5162030	52
	Total	4.228070	.5084910	57
Total	Do not w	3.666667	1.4142136	2
	Female	3.717949	.9010915	13
	Male	3.836327	.7479273	167
	Total	3.826007	.7610097	182

Students from the MET department within energy related courses associated with the ESC demonstrate increased learning motivation at a significant level as a result of the ESC active learning activities (F (7,174) = 5.344, $p < .001$). Furthermore, the data indicates variance between the two independent variables at a significant level (F (3,174) = 3.134, $p = .027$). Looking at the two independent variables of gender and participation within the ESC program the data does not provide enough evidence that the motivation of MET students within energy related courses differs between genders (*F* (2,174) = 1.486, *p* = .229). The null hypothesis of "participation within the ESC program causes no difference in the motivation of MET students within energy related courses" can be rejected based upon data showing participation does affect their perceived motivation at a significant level (*F* (2,174) = 9.166, *p* < .001). To further analyze the significance of the alternative hypothesis pertaining to participation, a Post hoc test was used. All two-way analysis of variance tests were ran using a confidence level of (α = .05). Table 4.3 shows the results from the two-way analysis of variance. Table 4.4 is the results of the estimated marginal means. The confidence intervals and the levels of significance show the variation within groups for the independent variable of participation.

Table 4.3 Test of Between Subject Effects for Two-way Analysys of Variance for Research Question 1 "Motivation" from Course Specific Survey

Tests of Between-Subjects Effects						
Dependent Variable: RQ1						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	18.548[a]	7	2.650	5.344	.000	.177
Intercept	223.079	1	223.079	449.906	.000	.721
Participation	9.090	2	4.545	9.166	.000	.095
Gender	1.474	2	.737	1.486	.229	.017
Participation * Gender	4.662	3	1.554	3.134	.027	.051
Error	86.275	174	.496			
Total	2769.000	182				
Corrected Total	104.824	181				
a. R Squared = .177 (Adjusted R Squared = .144)						

Table 4.4 Estimated Marginal Means within Groups Multiple Comparison of Participation for Research Question 1 “Motivation” fromCourse Specific Survey

Multiple Comparisons						
Dependent Variable: RQ1						
Tukey HSD						
		Mean Difference			95% Confidence Interval	
(I) Participation	(J) Participation	(I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
No	Unsure	.086243	.1402712	.812	-.245350	.417837
	Yes	-.523308*	.1512138	.002	-.880769	-.165847
Unsure	No	-.086243	.1402712	.812	-.417837	.245350
	Yes	-.609552*	.1191980	.000	-.891329	-.327774
Yes	No	.523308*	.1512138	.002	.165847	.880769
	Unsure	.609552*	.1191980	.000	.327774	.891329
Based on observed means. The error term is Mean Square(Error) = .496.						
*. The mean difference is significant at the .05 level.						

Residuals plots from the data are used to evaluate the normality of errors. Residuals can be defined as the data prediction difference (Clover, 2017). The residuals plots are broken up into a three by three matrix where the patterns indicate how applicable the regression is. Figure 4.3 shows the residuals from the data collected pertaining to research question one. Utilizing the fit line tool within SPSS it can be easily noted that the distribution of all cells with the exception of observed/predicted have a random distribution. The patterns within the observed/predicted can be a result of low samples (*n*) within specific independent categories. This also supports the two-way analysis of variance for insignificance of variables.

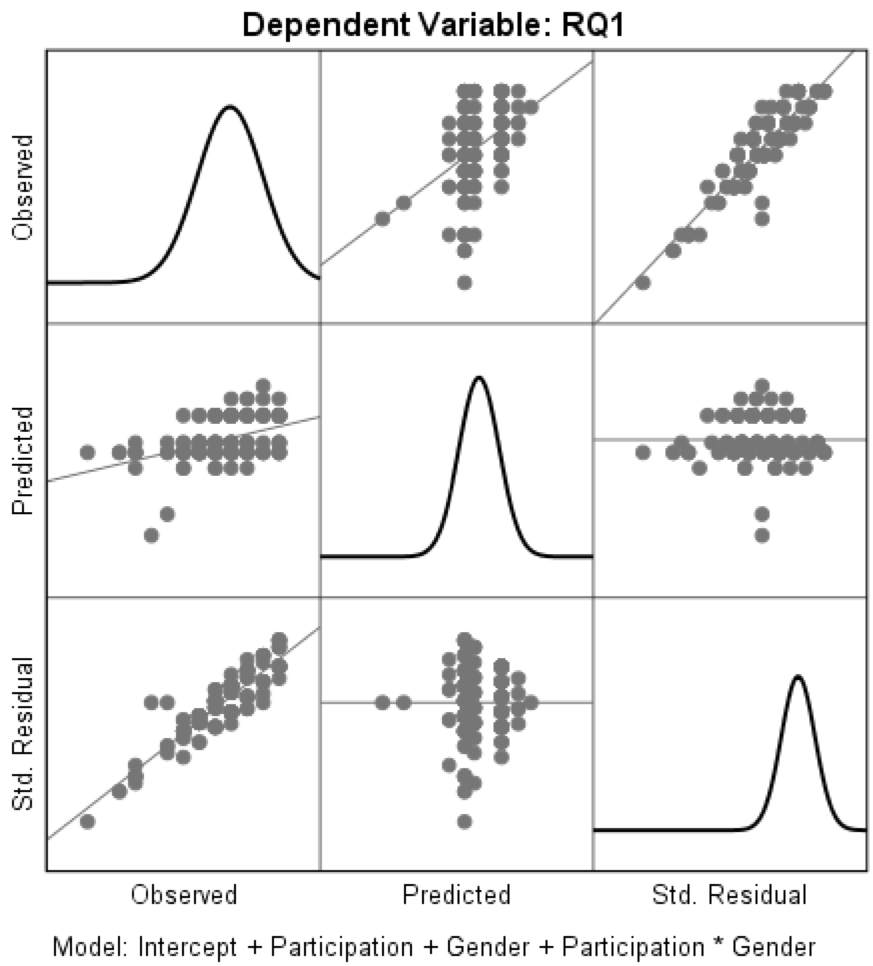


Figure 4.3 Residuals Plot for Research Question 1 “Motivation” from course specific survey

Figure 4.4 plots the estimated marginal means by each of the independent variables. Typically, within plots such as this, the crossing of the marginal means can indicate a correlation between the variables. The plot shows for each of the genders displayed, the mean response for research question one was higher if the participation within the ESC program was determined to be “yes”. The male population means decreased when they were “unsure” if they were going to be participating in the ESC program, this was the only degree observed. The lines crossing imply there is likely an interaction between gender and participation.

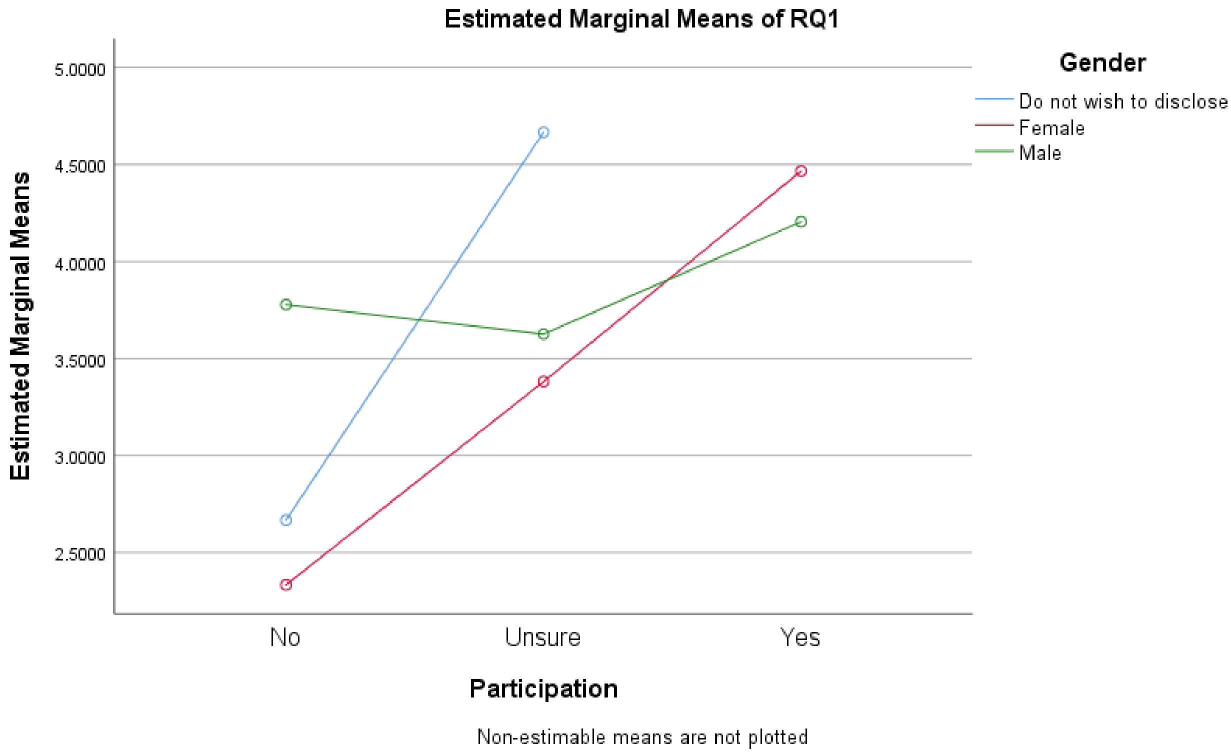


Figure 4.4 Estimated Marginal Means Plot for the Independent Variables in Research Question 1 "Motivation" from course specific survey

4.4.2 Do energy focused activities improve perceived student understanding of energy concepts?

The perceived understanding of energy concepts within MET students could be influenced through the use of energy focused activities, but changes to their perceived understanding could also be influenced across gender, ESC participation, or both. To assess the perceived understanding, a set of Likert based questions measuring student perception of their knowledge were created. A single mean response can be created through averaging the questions used to answer the second research question. A two-way analysis of variance will measure the mean perceived understanding score across student identified gender and response to participation within the ESC to look for evidence of correlation. The alternative hypothesis used to further understand the potential correlations are:

H_a: Energy focused activities do improve the perceived understanding within energy concepts.

H_a: The perceived understanding of energy related concepts for MET students differs between gender.

H_a: Participation in the ESC causes MET students to perceive their understanding of energy concepts within energy related courses at different levels.

The population as a whole reported a mean score of (μ = 3.8681) on a five-point Likert scale. Those participating in the ESC program reported a mean score of ($\overline{x}$ = 4.2807) having a standard deviation of (σ = .4549). Students who indicated they were unsure about the participation within the ESC program reported a mean score of ($\overline{x}$ = 3.6533) having a standard deviation of (σ = .6887). The students who indicated they will not be participating in the program indicated a mean score of ($\overline{x}$ = 3.7485) and a standard deviation of (σ = .6123). Due to the population size (N = 182) some of the independent variables contain only a single response. The distribution of responses, their sample size n, the standard deviation σ, and their sample means $\overline{x}$ can be seen within Table 4.5.

Table 4.5 Descriptive Statistics for Research Question 2 "Understanding" from Course Specific Survey Results

Descriptive Statistics				
Dependent Variable: RQ2				
Participation	Gender	Mean	Std. Deviation	N
No	Do not w	2.600000	NA	1
	Female	3.400000	NA	1
	Male	3.793939	.5926315	33
	Total	3.748571	.6123107	35
Unsure	Do not w	4.600000	NA	1
	Female	3.457143	.6399405	7
	Male	3.658537	.6903124	82
	Total	3.653333	.6887866	90
Yes	Female	4.400000	.2449490	5
	Male	4.269231	.4701016	52
	Total	4.280702	.4549092	57
Total	Do not w	3.600000	1.4142136	2
	Female	3.815385	.6755814	13
	Male	3.875449	.6642749	167
	Total	3.868132	.6686143	182

Testing the student responses using a two-way ANOVA shows relationships between variables and if the relationships are statistically significant at a confidence level of ($\alpha = .05$). The results indicated that students within the MET department have a significantly increased level of understanding for energy based concepts after the conceptualization of concepts through focused activities (F (7,174) = 6.665, $p < .001$). Looking at the interaction between variables "Participation*Gender" the p-value is not significant. Therefore, the effect of participation on the perceived knowledge does not change due to gender. Due to the interaction as well as gender being insignificant, the effect on the students' perceived understanding can be associated with participation alone. The data indicates that there is a significant correlation between the participation within the ESC program, and the students perceived knowledge level as a result of the energy based activities (F (2,174) = 6.262, p = .002).Additional analyses over the significant correlation between participation and student mean perceived knowledge level are broken down using a Post hoc test. Table 4.6 shows the results from the two-way analysis of variance. Table 4.7 is the results of the estimated marginal means.

Table 4.6 Test of Between Subject Effects for Two-way Analysys of Variance for Research Question 2 "Understanding" from Course Specific Survey

Tests of Between-Subjects Effects						
Dependent Variable: RQ2						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	17.109[a]	7	2.444	6.665	.000	.211
Intercept	235.107	1	235.107	641.143	.000	.787
Participation	4.592	2	2.296	6.262	.002	.067
Gender	.163	2	.081	.222	.801	.003
Participation * Gender	2.626	3	.875	2.387	.071	.040
Error	63.806	174	.367			
Total	2804.080	182				
Corrected Total	80.915	181				
a. R Squared = .211 (Adjusted R Squared = .180)						

Table 4.7 Estimated Marginal Means within Groups Multiple Comparison of Participation for Research Question 2 “Understanding” fromCourse Specific Survey

Multiple Comparisons						
Dependent Variable: RQ2						
Tukey HSD						
		Mean Difference			95% Confidence Interval	
(I) Participation	(J) Participation	(I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
No	Unsure	.095238	.1206299	.710	-.189924	.380400
	Yes	-.532130*	.1300402	.000	-.839538	-.224723
Unsure	No	-.095238	.1206299	.710	-.380400	.189924
	Yes	-.627368*	.1025074	.000	-.869690	-.385047
Yes	No	.532130*	.1300402	.000	.224723	.839538
	Unsure	.627368*	.1025074	.000	.385047	.869690
Based on observed means. The error term is Mean Square(Error) = .367.						
*. The mean difference is significant at the .05 level.						

The residuals plot for the second research question Figure 4.5 shows the residuals from the data collected. Utilizing the fit line tool within SPSS it can be seen that it appears they are not normally distributed, and slightly form patterns. However, after running tests for normality within SPSS the distributions were determined to be normally distributed at a confidence level of (α = .05). The patterns within the observed are a result of a missing variable. The cause for missing variables in this case is low count of samples (n), within the independent variable gender (other).

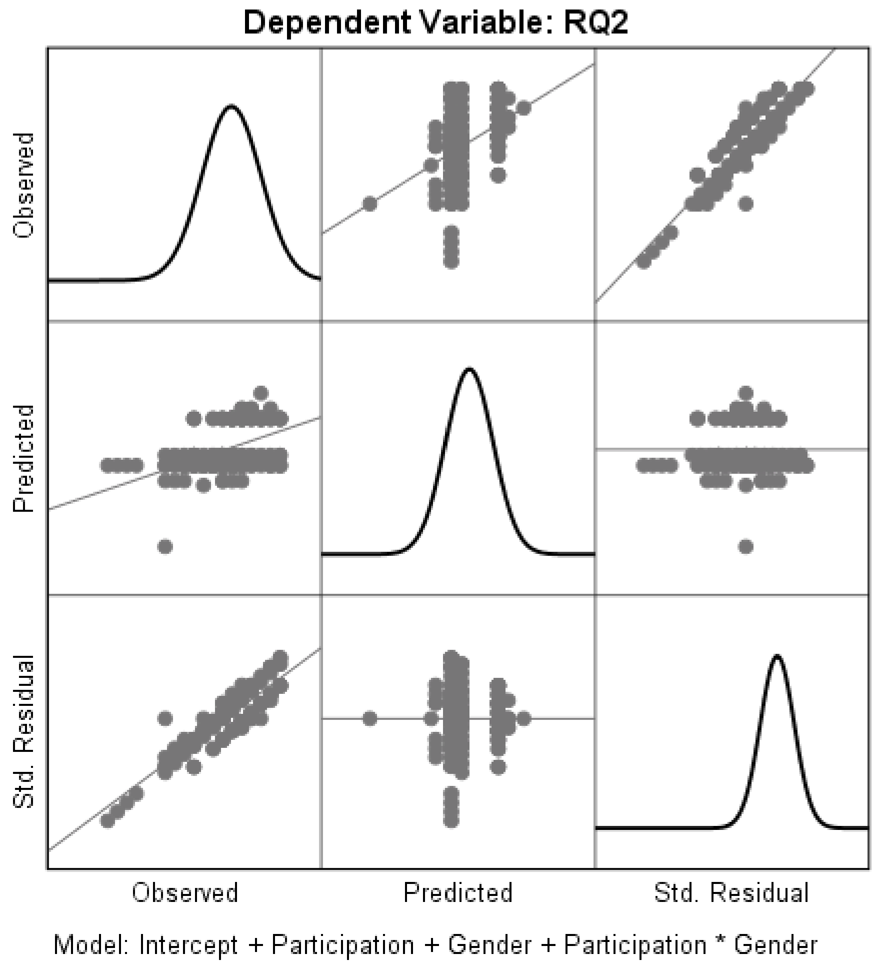


Figure 4.5 Residuals Plot for Research Question 2 “Understanding” from course specific survey

The estimated marginal means plot Figure 4.6 is based on the means for the independent variables. The plot shows similar results to that of the first research question with one exception. The estimated margin of means for the female sample who indicated they would not be participating within the ESC project is much closer to the male estimated margin of means for the same category. The interpretation of these similarities is that the gender (females and males alike) did not indicate an increase in the understanding of energy related concepts between the categories of “No” and “Unsure” for participation. The lines crossing imply there is likely an interaction between participation and the dependent variable.

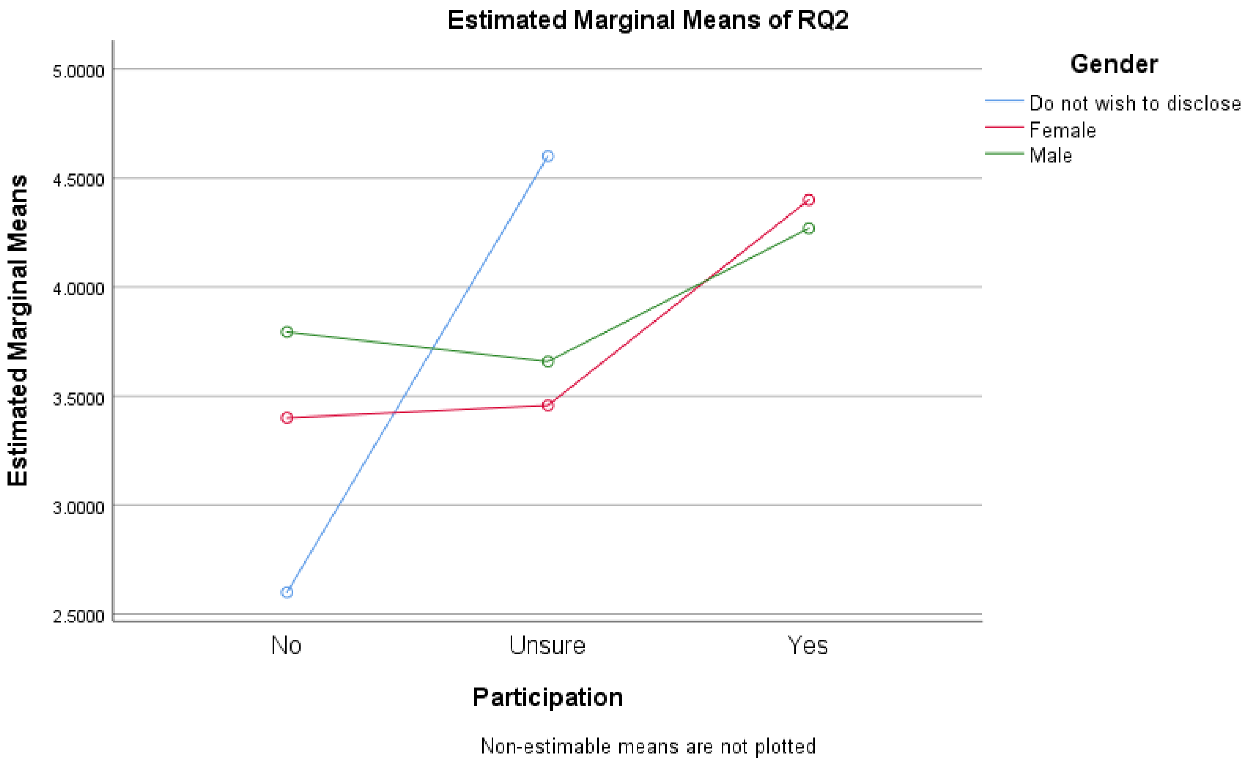


Figure 4.6 Estimated Marginal Means Plot for the Independent Variables in Research Question 2 "Understanding" from course specific survey

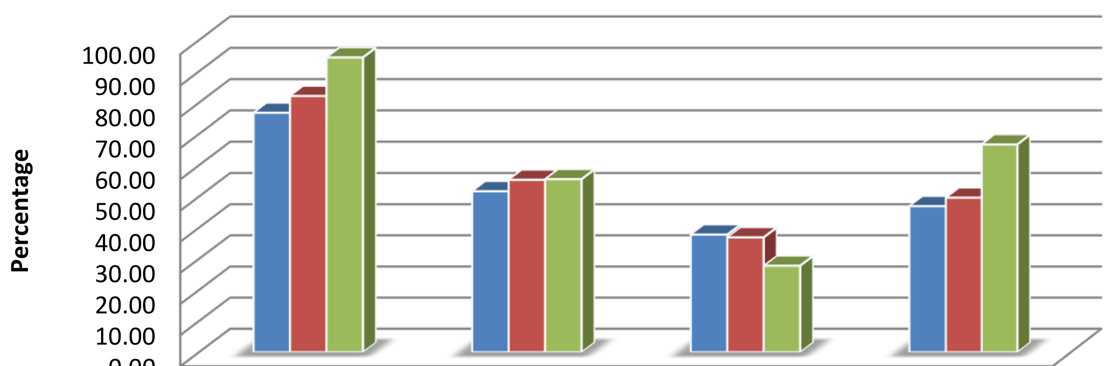
4.4.3 Energy Understanding General ESC Survey

The general knowledge regarding energy concepts within MET students could be correlated to their progression through the ESC and their degree, but understanding could also be influenced across gender, their perceived knowledge, or both. The assessment of their understanding is measured through a series of knowledge based questions within the general ESC survey. As each of the questions are weighted equally, an average score is produced for each respondent. The longitudinal tracking of the averages scores by student, class, gender, perceived knowledge, and participation allows researchers to understand the correlation between each of these variables and the students' intellectual growth. A one-way analysis of variance will measure the average score of each student across the student identified gender and perceived understanding level to look for evidence of correlation. The alternative hypotheses used to further understand the potential correlation as a result of these independent variables are:

H_a: The true understanding of energy related concepts for MET students differs between gender.

H_a: The true understanding of energy related concepts for MET students is correlated to their perceived understanding.

The population as a whole received mean score of 14.85 out of 28 (52.99%) for their true knowledge relating to energy. The median reported perceived level of knowledge for the population is on a five-point Likert scale where (1) correlates to novice, (2) correlates to beginner, (3) correlates to intermediate, (4) correlates to advanced, and (5) correlates to expert. The population consisted of (N = 158) where the sample size of students identifying as female is (n = 30), the sample of those identifying as male is (n =*127*), and one student did not wish to disclose their gender. Table 4.8, displays the descriptive statistics for the analysis of variance between gender and true score, and Table 4.9 displays the descriptive statistics for the analysis of variance between the Likert score for perceived knowledge and actual score.



	Energy Forms Avg Score (%)	Heat Power Avg Score (%)	Fluid Power Avg Score (%)	Electric Energy Avg Score (%)
Freshman	76.77	51.71	37.80	46.93
Sophomore	82.14	55.36	36.90	49.64
Junior	94.44	55.56	27.78	66.67

Figure 4.7 Energy Related Knowledge by Academic Standing from General Survey

Table 4.8 Descriptive Statistics of One-way ANOVA of Actual Score for Knowledge Relating to Energy and Gender from General Survey

Descriptives								
True Score								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Male	127	53.80	10.569	.938	51.94	55.66	21	86
Female	30	50.24	12.926	2.360	45.41	55.06	14	75
Do not wish to disclose	1	32.14	NA	NA	NA	NA	32	32
Total	158	52.99	11.192	.890	51.23	54.75	14	86

Table 4.9 Descriptive Statistics of One-way ANOVA of Actual Score for Knowledge Relating to Energy and Perceived Knowledge from General Survey

Descriptives								
True Score								
					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
(1) Novice	23	48.76	10.250	2.137	44.33	53.19	14	61
(2) Beginner	70	52.35	11.406	1.363	49.63	55.07	21	86
(3) Intermediate	58	55.85	10.925	1.435	52.98	58.72	25	75
(4) Advanced	7	49.55	9.796	3.703	40.49	58.61	32	61
Total	158	52.99	11.192	.890	51.23	54.75	14	86

The results of the two one-way ANOVA tests indicated that there is a relationship between both perceived knowledge and gender when compared to the true score received by students for their knowledge relating to energy. The two tests were performed while using a confidence level of ($\alpha = .05$). The results indicated that students within the MET department do differ in their true knowledge relating to energy based upon their perceived knowledge level at a significant level ($F(3,154) = 2.744$, $p = .045$). Furthermore, the true score of the MET students pertaining to their general knowledge of energy differs across the identified genders at a significant level (F (2,155) = 3.052, p = .050). The additional analyses over the significant correlation between the independent variables and student true knowledge score are broken down using a Post hoc test. Table 4.10 shows the results from the one-way analysis of variance for true score versus gender, and Table 4.11 is the one-way analysis of variance results for true score versus perceived knowledge level.

Table 4.10 One-way ANOVA results for Actual Score for Knowledge Relating to Energy compared to Gender from General Survey

ANOVA					
True Knowledge Based Score					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	745.069	2	372.535	3.052	.050
Within Groups	18920.432	155	122.067		
Total	19665.502	157			

Table 4.11 One-way ANOVA results for Actual Score for Knowledge Relating to Energy compared to Perceived Knowledge from General Survey

ANOVA					
True Knowledge Based Score					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	998.038	3	332.679	2.744	.045
Within Groups	18667.464	154	121.217		
Total	19665.502	157			

The means plot for average score across all reported genders can be seen within Figure 4.8. The plot shows the differences in the average true score recorded based upon the 28 knowledge based questions on the general survey between all of the reported genders from the sample. The plot shows that females and males have comparable scores, whereas students who did not wish to disclose have significantly lower true scores based upon the questions within the general survey. It should be noted however that the score within the category “Do not wish to disclose” is based upon the scores of a single student. Figure 4.9 displays the means plot for the average true scores recorded from the general survey broken up based upon the Likert value indicated by the respondents on their perceived knowledge of energy. As seen a trend appears where an increased perceived knowledge score correlates to an increase true score for knowledge through Likert response score (3) intermediate knowledge. Students who reported Likert scores corresponding to advanced knowledge received significantly lower true scores compared to students who did not perceive their knowledge to be so high.

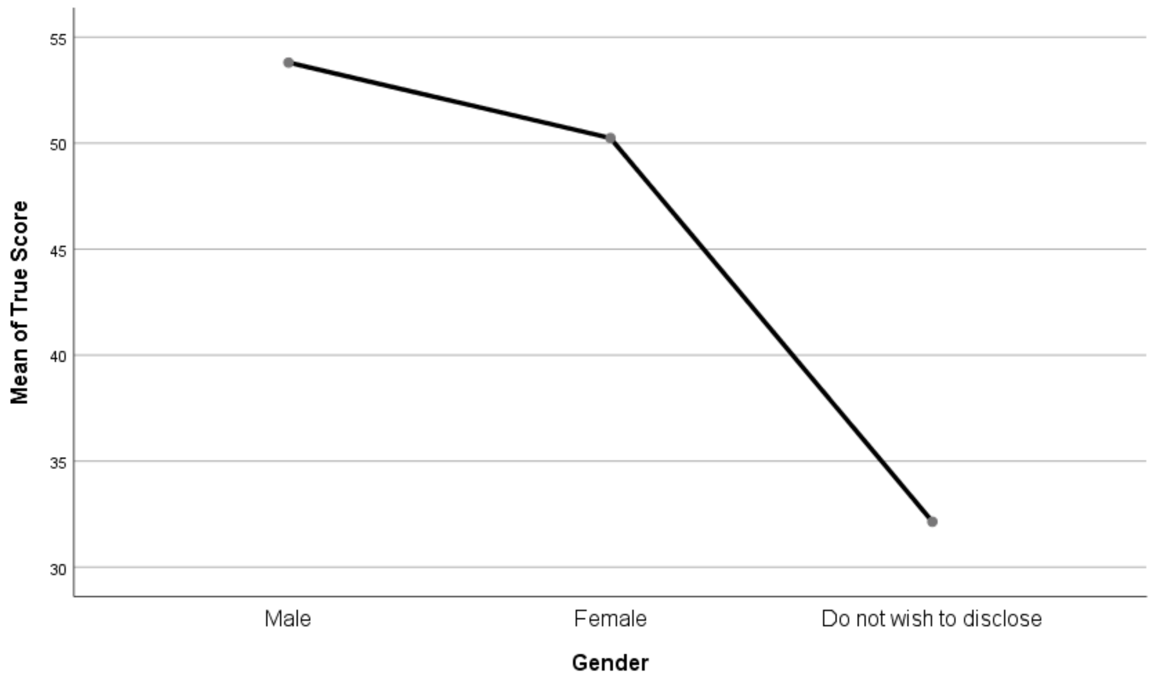


Figure 4.8 Means Plot for the True Score versus Gender from General Survey

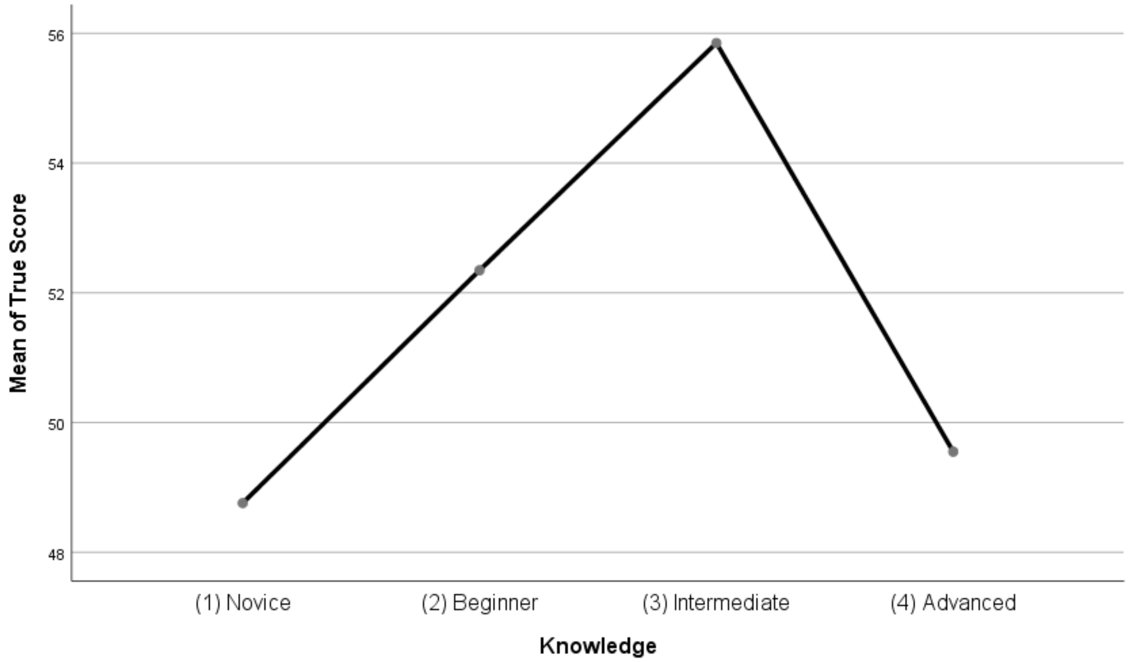


Figure 4.9 Means Plot for the True Score versus Perceived Knowledge from General Survey

4.5 Summary

The findings of this chapter produce the needed information to be able and answer each of the research questions. The results additionally indicated that there is significant correlation between the independent variables of gender and participation in the program. Additionally, correlation at a significant level was found between the independent variable of participation and the dependent variable. Further discussion is found within the next chapter.

CHAPTER 5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

Chapter five will not only expound upon the data which was collected within the previous chapter, but will also look to answer two questions about the research. The first question is what does all of this mean? This first question will be answered within the discussion section of this chapter. The second question which will be answered through the chapter is why are the findings important? Chapter five will tie in the findings throughout the entire thesis, to a single summary.

5.2 Conclusions

The transformation of the mechanical engineering technology department as a whole looked at how the learning environment for students within energy focused courses that can be very conceptual at times is modified in a way that promotes academic growth. The study looks at the ways, in which students can be placed in a learning environment that fosters their participation, inter-disciplinary problem solving skills, understanding and retention of concepts, their confidence when approaching problems, and their interest. The study focuses on an active learning approach centered on a common theme of energy to vertically and horizontally integrate courses. Furthermore, the study is laying the framework for a competency-based education to be practiced regularly within the MET curriculum, where students are able to display their mastery of multi-disciplinary skills.

The pursuit of answering two research questions guided the study to address the problems observed within the students learning environments. The research questions are:

- Does active learning impact the motivation to learn of engineering technology students within energy related courses?
- Do energy focused activities improve perceived student understanding of energy concepts?

These two research questions helped narrow the focus when identifying literature to help steer the direction of the transformation as a whole. The literature review revealed the need of learning environments much like the one this research implements to equip students with the tools to succeed within and outside of academia.

The method chosen to achieve the learning environment is through a competency based education model, where students can link the common theme of energy throughout courses and demonstrate their mastery of skills within those courses to earn a professionally recognized credential. The Energy Systems Credential incorporates an active learning activity specific to each of the courses involved within the study to allow students to demonstrate their competency of multi-disciplinary skills. The credential program utilizes feedback through quantitative surveys to track student progress longitudinally within a series of courses where students earn badges (each represented by a class in the MET curriculum) based off of their mastery of concepts for each class.

The use of statistical testing allows for student response surveys to be analyzed, ensuring that the questions identified to solve the existing problem within the students learning environments to be addressed. To help further explain the population and their academic growth independent variables involving the student gender and participation within the ESC are used to explain the ways student perceive their understanding and motivation.

5.3 Discussion

Throughout the creation of the survey tool, its validation, and distribution the focus remained on answering the two previously indicated research questions as well as gathering and analyzing baseline data for the longitudinal study. The quantitative course specific and general surveys which can be seen within appendix A collects non-identifiable information from the students who wish to respond. While a voluntary response sampling is not preferred, the requirement of completing the survey conflicts with model for the credential program which was determined as well as with IRB which was granted for this study. The quantitative responses analyzed are reported on a five-point Likert based scale by the students as well as through knowledge based questions. From the course specific survey questions Q7_5, Q7_6, and Q7_11 are used to assess the first research question, while the second research question is assessed through questions Q7_3, Q7_4, Q7_7, Q7_10, and Q7_12. Within this section the two research questions are analyzed at a confidence level of ($\alpha = .05$) using this data. The general survey measures the true understanding of energy concepts by scoring questions Q17 – Q49. The scores are then used to compare across various independent variables longitudinally.

5.3.1 Does active learning impact the motivation to learn of engineering technology students within energy related courses?

As discussed within chapter four, MET students indicated increased learning motivation at a significant level as a result of the ESC active learning activities within the related course (F (7,174) = 5.344, $p < .001$). Furthermore, students indicated a difference between the mean responses within the independent variables of gender and participation at a significant level (F (3,174) = 3.134, $p = .027$). The result of the difference between independent variables revealed that the null hypothesis of "participation within the ESC program causes no difference in the motivation of MET students within energy related courses" can be rejected based upon data showing participation does affect their perceived motivation at a significant level (F (2,174) = 9.166, $p < .001$). The alternative hypothesis used for the first research questions which were selected in favor of the null hypothesis based upon the two-way analysis of variance are:

H_a: There is a correlation between active learning activities and the motivation of MET students.

H_a: Participation in the ESC causes MET students to demonstrate different levels of motivation within energy related courses.

5.3.2 Do energy focused activities improve perceived student understanding of energy concepts?

The second research question measuring the students perceived understanding as a result of the ESC activity yielded further significant results. As discussed within chapter four, MET students indicated a significantly increased level of understanding for energy based concepts after the conceptualization of concepts through the ESC activity (F (7,174) = 6.665, $p < .001$). However, it was also found that there was no significant level of interaction between the independent variable "Participation*Gender" based off of the student responses. This means that the effect of participation on the perceived knowledge does not change based off of gender. As a result of the gender having an insignificant p-value whereas participation does, the effect on the students' perceived understanding can be associated with participation alone. Thus producing a significant correlation between the participation within the ESC program, and the students perceived knowledge level as a result of the energy based activities (F (2,174) = 6.262, p = .002). The alternative hypothesis for the second research question which were selected as a result of rejecting the null hypotheses are:

> H_a: Energy focused activities do improve the perceived understanding within energy concepts.
>
> H_a: Participation in the ESC causes MET students to perceive their understanding of energy concepts within energy related courses at different levels.

5.3.3 Energy Understanding General ESC Survey

The general survey is being used as a longitudinal study, following students as they progress through the credential as well as their degree. The analyzation of knowledge based questions across the students perceived level of understanding regarding energy as well as the students gender yielded significant preliminary results. The initial results for the longitudinal study indicates that MET students have a true understanding of energy that significantly differs across the identified gender of the student (F (2,155) = 3.052, p = .050). The results do however include the response of a single student from the category "Do not wish to disclose" that influenced the results to a significant level. The single student cannot be ruled an outlier from within the sample population as only one data point is contained, however after retesting for significant variation between gender and true score between sample populations with 30 or greater subjects no significance was found (F (1,155) = 2.522, p = .114). The data, as a result, fails to provide enough evidence to reject the null hypothesis at a confidence level of (α = .05).

> H_0: The true understanding of energy related concepts for MET students is the same amongst all genders.

The second one-way analysis of variance test compared the true knowledge relating to energy for MET students as compared to the students perceived level of knowledge. The results indicated that the true score of MET students regarding knowledge energy concepts varies significantly based off of how students perceive their level of knowledge (F (3,154) = 2.744, p = .045). As a result of the one-way analysis of variance the null hypothesis is rejected in favor of the alternative hypothesis:

> H_a: The true understanding of energy related concepts for MET students is correlated to their perceived understanding.

5.4 Recommendations

The study has contained several beneficial aspects emerge as well as some which call for potential changes/revisions. The recommendations do not change the focus of the study; rather can help support the focus more so. The aim of all changes will advance the educational takeaways of the research.

The first recommendation is concerned with the survey distribution. The surveys have shown to have mixed levels of participation for the course specific and general survey. The administration of the course specific survey at the time of the ESC activity will help yield higher response numbers. This will help with the overall distribution of data so that un-recognized biases will affect the model to a lesser extent. The addition of current academic standing is needed on this survey as well. This will allow for two-way analysis of variance utilizing this parameter.

The second recommended change is to the structure of both the course specific and the general surveys. The surveys request the ESC number of the student to be entered in. The question is not forced response. The data collected thus far from the general survey has consisted of students entirely from the ENGT 18000 course. The ESC numbers are distributed in the course the same week that the students are added into Passport where they can access the survey. The major advantage of using the general survey is to track the students' perception of energy usage as well as track their perceived versus actual knowledge within various energy types. Data trends from the general survey indicate that only 53% (113) students have indicated a valid ESC number on the survey. Forcing the response for this question may yield better statistics in the future.

The third recommendation is based around the attempt of eliminating biases within the course specific survey. The use of a check question in the middle of all questions can indicate if students are introducing biases based off of the input of straight answer responses. A response check in the middle could simply state a normal question, with an added not at the end such as “Answer Neutral for this Question only”. This will allow for a normal distribution of scores, increasing the significance level to further explain correlations within variables being measured and reported with higher levels of certainty.

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APPENDIX A. SURVEYS

General Survey

Purdue University SoET

Energy Systems Credential

Survey

Figure 5.1 ESC Logo

This survey is designed to demonstrate knowledge and attitude towards energy-related systems. Energy-related systems are systems that have the ability to do work by means of fluid power, thermal power, or electrical power. This is only an assessment tool, and no formal grade will be given. No personal information obtained in the survey will be published. Please be honest, and answer all questions to the best of your ability. Thank You!

Entry Question.

A. As of today are you 18 years of age or older?
    A. Yes (Allow Student to Continue to Survey)
    B. No (Automatically End/Exit Survey)

B. As of today are you actively pursuing a specific Energy Systems Credential Badge and/or the Energy Systems Credential in its entirety?
   A. Yes
   B. No
   C. Unsure
C. If you have a unique five-digit Energy Credential identifier please enter it in the block below. (If you do not have or remember this number, please enter 00000 in the space below).

   ____

D. Please enter your unique five-digit Energy Credential identifier in the block below if you are part of the Energy Credential program.

   ____

E. I identify as.
   A. Male
   B. Female
   C. Other
   D. Do not wish to disclose

Pre-Assessment Questions. The following questions are about your thoughts on sustainable energy issues and personal choices. Sustainable energy is defined throughout this survey as environmental impact, alternative sources, and conservation. Please be truthful, there are no right or wrong answers.For questions asking you to rate your response, please use the following scale of 1 to 5 with 1 being the low end and 5 being the high end of understanding:
1-novice, 2-beginner, 3-intermediate, 4-advanced, 5 expert

1. What is your current academic standing?
   A. Freshman
   B. Sophomore
   C. Junior
   D. Senior
2. Using the above scale from 1-5 how would you rate your knowledge related to energy?

   A. 1 (Novice)
   B. 2 (Beginner)
   C. 3 (Intermediate)
   D. 4 (Advance)
   E. 5 (Expert)
3. Is energy sustainability something you are concerned with?
   A. Yes
   B. No
4. Of the following what three energy source do you see as best potential for the future?
   A. Solar Power
   B. Wind Power
   C. Geothermal Power
   D. Nuclear Power
   E. Coal Power
   F. Hydro-electric
   G. Natural Gas
   H. Petroleum
   I. Biofuels
5. How important is cost for you when choosing an energy source?
   A. 1 - Not Important At All
   B. 2 - Somewhat Not Important
   C. 3 - No Opinion
   D. 4 - Somewhat Important
   E. 5 - Very Important
6. How important is environmental impact for you when choosing an energy source?
   A. 1 - Not Important At All
   B. 2 - Somewhat Not Important
   C. 3 - No Opinion
   D. 4 - Somewhat Important
   E. 5 - Very Important

7. Do you Practice energy saving techniques such as turning lights off when leaving a room or unplugging appliances?
    A. Yes
    B. No
8. How would you rate your energy consumption? Energy consumption is defined as use of all previously defined energy sources.
    A. 1 - High energy usage
    B. 2 - Medium-high energy usage
    C. 3 - Medium energy usage
    D. 4 - Medium-low energy usage
    E. 5 - Low energy usage
9. Indicate all of the following energy types you use on a daily basis.
    A. Fluid Power Energy
    B. Thermal Energy
    C. Electric Energy

Section I. This section will assess your understanding of how **forms of Energy** can be portrayed as, and what they means to you. Questions will be both knowledge and opinion based.

1. At least two types of energy are used within each of your courses
    A. True
    B. False
2. What are the two most basic forms of energy?
    A. Elastic Energy
    B. Kinetic Energy
    C. Chemical Energy
    D. Atomic Energy
    E. Potential Energy
3. In an internal combustion engine, the force that creates mechanical energy is a direct result of which of the following?
    A. Heat Power
    B. Fluid Power

C. Electric Energy

D. All of the Above

4. Hydraulics are able to operate due to which of the following?

   A. Heat Power

   B. Fluid Power

   C. Electric Energy

   D. All of the Above

5. The flow of electrons is the base of what energy source?

   A. Heat Power

   B. Fluid Power

   C. Electric Energy

   D. All of the Above

6. While driving your car what all types of energy are you using?

   A. Heat Power

   B. Fluid Power

   C. Electric Energy

   D. All of the Above

7. Energy Transfer is something that I see daily. Rate your response on a scale of 1 (strongly disagree) to 5 (strongly agree).

   A. 1-Strongly Disagree

   B. 2-Disagree

   C. 3-Neutral

   D. 4-Agree

   E. 5-Strongly Agree

Section II. This section will ask about your knowledge and understanding of **Heat Power**. Please answer each question carefully and to the best of your ability.

1. How does Wade Utility Plant here at Purdue utilize heat power that makes it unique?

   A. Use heat-sinks to turn flywheels for kinetic energy

   B. Transfer unused energy to water to heat or cool buildings

   C. Take heated exhaust to turn secondary turbines

   D. Nothing, Wade Utility Plant is very dated

2. What is a BTU?
   A. Measurement of Electricity
   B. Unit of Heat
   C. Measurement of Heat Required to raise one pound of water by one degree Celsius
   D. Both A and C
   E. Both B and C
3. A heat pump can be considered a renewable energy
   A. True
   B. False
4. What is the difference between a Joule and a Watt?
   A. A joule is a measurement of energy and a Watt is the time rate of energy.
   B. A joule is a measurement of energy and a Watt is a measurement of pressure
   C. There is no difference.
   D. A joule is the time rate of energy and a Watt is a measurement of energy.
5. Is there a difference between a heat engine and a heat pump?
   A. True
   B. False
6. Which law must be satisfied in order for a refrigeration system to be built?
   A. Zeroth Law of Thermodynamics
   B. First Law of Thermodynamics
   C. Second Law of Thermodynamics
   D. Third Law of Thermodynamics

Section III. This section covers your knowledge and understanding of **<u>Fluid Power</u>**. Please answer each question carefully and to the best of your ability.

1. A device which can store fluid energy
   A. Receiver
   B. Pump
   C. Accumulator
   D. Reservoir

2. A turbine differs from a pump because the mechanical energy is extracted from the turbine, but not from a pump.
   A. True
   B. False
3. A turbine is similar to a pump because they both have Torque and Flow as physical inputs to drive them.
   A. True
   B. False
4. Which system uses kinetic energy to transmit power?
   A. Hydrostatic System
   B. Hydrodynamic System
   C. Pneumatic System
   D. None of the above
5. Both hydraulic and pneumatic systems demonstrate fluid power, however which is more precise?
   A. Pneumatic System
   B. Hydraulic System
   C. They are equally precise
6. Surface energy per unit area is numerically equal to what?
   A. Atmospheric Pressure
   B. Surface Tension
   C. Force Cohesion
   D. Viscosity

Section IV. This section will assess your knowledge and understanding of **Electric Energy**. Please answer each question carefully and to the best of your ability.

1. Electric energy is a form of kinetic energy from moving electrons. Where does a generator get these electrons to move?
   A. The Air (static)
   B. The Magnet
   C. The Wire

D. Creates New

2. An electric motor is different than a generator due to generators use electromagnetism to operate.
    A. True
    B. False
3. A transformer with a 1:20 turns ratio can take a 240 VAC input and produce a 4,800 VAC output of electric energy without violating conservation of energy laws.
    A. True
    B. False
4. In a water analogy if the voltage is most similar water pressure, what would the current be represented with?
    A. Pump
    B. Pipe Size
    C. Water Reservoir
    D. Flow Rate
5. What voltage law states “the sum of all voltages in any closed loop circuit is equal to zero”?
    A. Kirchhoff’s Laws
    B. Ohm’s Law
    C. Voltage Divider Rule
    D. Coulomb’s Law
6. What is the device allows the increasing or decreasing of voltage for an Alternating Current (AC)?
    A. Rectifier
    A. Voltage Regulator
    B. Transformer
    C. Inverter
7. How is voltage for an Alternating Current (AC) increased or decreased?
    A. Adding Sources
    D. Windings Ratio
    E. Rotational speed of Magnet

F. Add / Reduce Resistance

8. Electric Energy efficiency is defined as.
   A. Escaped power in an unusable form
   B. Electron bonds broken minus electron bonds formed
   C. The available power in a fuel source
   D. Power output divided by consumed power
9. Within the core of a Nuclear reactor, what process occurs?
   A. Uranium atoms combine and give off heat
   B. Uranium atoms are split apart and give off heat
   C. Uranium atoms are burned and give off heat
   D. Uranium isotopes are burned and give off heat.
10. Which of the following is NOT the power distribution system normally used in America?
   A. 3 Phase-4 wire
   B. 3 Phase-3 wire
   C. Single Phase-3 wire
   D. Single Phase-4 wire

Course Specific Survey

Energy Credential Survey

Classroom Specific

This survey is designed to measure your motivation, interest, and application of the concepts that you learn in this energy activity. Please use the following scale for each of the questions.

Scale: 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree

1. Please answer each of the questions below based on your experience in _______________.

I can see the relationship between what I did on this energy activity and what I want to do in the future. (1)	
It was important to me to complete this activity to the best of my ability. (2)	1 2 3 4 5
Working on this energy activity made me think of alternative applications of this concept. (3)	1 2 3 4 5
Completing this energy activity has given me a new insight into __________. (4)	1 2 3 4 5
Working on this energy activity increased my interest in ___________. (5)	1 2 3 4 5
This energy activity increased my motivation to learn more about energy. (6)	1 2 3 4 5
This energy activity helped me develop skills that I can use in the future. (7)	1 2 3 4 5
I can see the relationship between what I did on this energy activity and what I want to do in the future. (1)	1 2 3 4 5
It was important to me to complete this activity to the best of my ability. (2)	1 2 3 4 5

I was primarily interested in earning a good grade on the energy activity. (8)	1 2 3 4 5
Working with others (alone if solo), increased my motivation to do well on this energy activity. (9)	1 2 3 4 5
I feel confident in applying the concepts I learned in this energy activity. (10)	1 2 3 4 5
Working on this energy activity made me interested in learning more about ________. (specific skills i.e. project management, teamwork, problem solving, data acquisition, communication skills, energy measurement). (11)	1 2 3 4 5
Working on this energy activity allowed me to understand the importance of how energy impacts my daily life. (12)	1 2 3 4 5

2. List 5 key concepts from this energy activity that are important to you.
    1.
    2.
    3.
    4.
    5.

3. Working on this energy activity most piqued my interest in ____________________.

4. What is one way that this energy activity could improve for the future? _______________.

APPENDIX B. FORMS

Cover Page for IRB Form

Revised 4 Dec 2017

COVER PAGE FOR IRB SUBMISSION

Purdue University, Institutional Review Board

Type of Submission: ☒ Human subjects determination worksheet [*complete both sides of this form*]
☐ New exemption determination [*complete both sides of this form*]
☐ New application narrative [*complete both sides of this form*]
Check here if you believe your protocol will require full board review: ☐

Complete only #1 & 2 below ***AND*** *PI signature at bottom of page 2*

☐ - Amendments to approved protocol / **IRB Protocol #:**
☐ - Renewal of approved protocol / **IRB Protocol #:**
☐ Revisions requested by IRB / **IRB Protocol #:**
☐ Study - Closure / **IRB Protocol #:**

1. Project Title: Purdue Polytechnic Energy Transformation

2. Principal Investigator: Brittany Newell, Assistant Professor, Polytechnic SoET, bnewell1@purdue.edu, 765-494-7724
(Name, Title, Department, E-mail, Phone; ***Must sign at the bottom of page 2)***

3. Co-Investigators, Key Personnel and/or Consultants (Name, Title, Department, E-mail, Phone, for each):
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Raji Sundararajan, Professor, Polytechnic SoET, raji@purdue.edu, 765-494-6912
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Ragu Athinarayanan, Professor, Polytechnic SoET, rathinar@purdue.edu, 765-494-0940
Cole Maynard, Masters Student, Polytechnic SoET, maynardc@purdue.edu, 765-669-0283
Erika Bonnett, PhD Student, Polytechnic SoET, ebonnett@purdue.edu, 757-742-1222

4. Has the PI and all Co-Investigators, Key Personnel and Consultants completed CITI training?
☒ Yes (Proceed to 5)
☐ No (STOP here: CITI training must be completed by all prior to submission of this application)

5. This project will be conducted at the following location(s):
☒ Purdue, West Lafayette Campus ☒ Purdue, Regional Campus (Specify): SOET Statewide
☐ Other (Specify, including city and state):

6. Check the box(es) below if your project involves any of the following (check all that apply):
☐ Vulnerable populations (Children, pregnant women, or prisoners/incarcerated individuals)
☐ Elderly persons
☐ Economically/educationally disadvantaged persons
☐ Mentally/emotionally/developmentally disabled persons
☐ Minority groups and/or non-English speakers
☒ University students (Purdue PSY Department subject pool? Yes ☐ No ☒)

1

7. Indicate the anticipated maximum number of subjects to be enrolled or number of records or specimens to be included under this protocol as justified by the hypothesis and study procedures: 560
(Suggestion: if unsure, err on the side of a higher sample size)

8. Will this project involve the use of an investigational new drug (IND), investigational medical device or an FDA-approved drug/device for an unapproved use: ☐ YES ☒ NO

9. Check the box(es) below if your project involves any of the following (check all that apply):

☐ Intervention(s) that include medical or psychological treatment
☐ Use of voice, video, digital, or image recordings
☐ Subject compensation: Please indicate the maximum payment amount to a subject: US $ ____
☐ VO2 max exercise test
☐ Magnetic Resonance Imaging (MRI) (Location: Purdue Campus ☐ Other ☐)
☐ Radioactivity/ Radioisotopes (Radiation Safety Committee approved? Yes ☐ No ☐)
☐ Request for Waiver of informed consent
☐ Request for Waiver of documentation (signed) of informed consent
☐ Use of blood: Total amount of blood: ________ (volume) over ________ days.
☐ Use of human tissue, cell lines, or other human bodily fluids
☐ Use of Protected Health Information (PHI) obtained from healthcare practitioners or institutions
☐ Use of academic records obtained from an educational institution

10. Suggest the appropriate IRB to review your research given your study (final decision determined by IRB):

☐ Biomedical (*research involving human diseases, epidemiology, drugs, devices*)
☒ Social/Behavioral (*research involving education, social and behavioral science*)

11. How will this study be funded?

☐ Unfunded ☒ Purdue University ☐ External sponsor (provide name): ________

12. The Principal Investigator on this application is responsible for ensuring that all persons responsible for the design, conduct, or reporting on this research protocol have disclosed any research-related Significant Financial Interests (SFIs), see here. All Investigators with SFIs, are required to fill out a Research Related Significant Financial Interest Disclosure at: https://webapps.ecn.purdue.edu/VPR/PDD
Do you or any investigator on this study have a Significant Financial Interest related to this study?

☐ YES ☐ UNSURE (Contact fcoi@purdue.edu) ☒ NO

By signing below, I give my assurance that information supplied to IRB relevant to this project is complete and accurate. All materials submitted for review within this submission, unless otherwise indicated, are the original work of myself or those working in collaboration with me. I agree to accept responsibility for the scientific conduct of this project and agree to uphold the policies and procedures of the Purdue IRB and approved protocol(s). I understand my obligations as Principal Investigator. I agree to oversee the project to comply with all federal, state, and local laws regarding the protection of human participants in research.

Brittany Mercer ________ 06/25/15 ________
Signature of Principal Investigator — Date Signed

IRB Exemption Determination Form

Revised Oct 12, 2017

EXEMPTION DETERMINATION FORM

Purdue University, Institutional Review Board

Currently, federal regulations recognize six categories of research that are exempt from IRB review. However, in an ironic twist, the IRB must determine if your research fits one of these "exempt from IRB review" categories. Having fun yet? We are, too! Below you will find questions that will help us determine if your research project is exempt from *further* IRB review. Note that **research activities may not be implemented until the investigator receives written notification from IRB that an exemption from IRB review has been granted for a particular research project.**

Does your research involve prisoners? If so, you can stop completing this form now, as such research is almost never exempt and requires **IRB review.**

Does your research involve the collection of "identifiable information," defined as information by which a subject can be identified directly (e.g., name, PU ID number, SS number, email address, etc.), indirectly by triangulating multiple variables, (i.e., age, sex, race, profession, etc.), or through codes with links to the identity of a subject? If so, you can stop completing this form now, as such research is almost never exempt and requires **IRB review.**

Check the category (or categories) below that you believe correspond(s) to your research project:

X	*Category 1*: Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special educational instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
☐	*Categories 2/3*: Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless all of the following are true: (i) information obtained is recorded in such a manner that the human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, insurability, or reputation. **NOTE: This exemption DOES NOT APPLY to research involving survey or interview procedures or observation of public behavior when individuals under the age of 18 are subjects of the activity except for research involving observations of public behavior when the investigator(s) do not participate in the activities being observed.**
☐	*Category 4*: Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. **NOTE: To qualify for this exemption, data, documents, records, or specimens must exist at the time the research is proposed and not prospectively collected.**
☐	*Category 5*: Research and demonstration projects which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (a) public benefit or service programs; (b) procedures for obtaining benefits or services under those programs; (c) possible changes in or alternatives to those programs or procedures; or (d) possible changes in methods or levels of payment for benefits or services under those programs. **NOTE: To qualify for this exemption, project must be conducted pursuant to a federal statute.**
☐	*Category 6*: Taste and food quality evaluation and consumer acceptance studies, (a) if wholesome foods without additives are consumed; or (b) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural, chemical, or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

Revised Oct 12, 2017

1. Project Title: Purdue Polytechnic Energy Systems Credential

2. Principal Investigator: Brittany Newell, Assistant Professor, Polytechnic SoET, bnewell1@purdue.edu, 765-494-7724

(Name, Title, Department, E-mail, Phone)

3. Briefly state your research question(s) using non-technical *lay language* that can be readily understood by someone outside your discipline: All activities and surveys administured to students are normal educational practices within the classroom. Please Reference survey starting on page 3 through page 6.

Research Questions:
- Does an integrated energy curriculum influence the learning of engineering technology students within energy related courses?
- Does energy focused activities improve perceived student understanding of energy concepts?

4. If data are to be collected, identify where the research data will occur (check all the apply):
   ☒ Purdue University (identify campus: West Lafayette)
   ☐ Other setting (identify where:)

Complete below only if you checked Category 1, 2, and/or 6 on page 1:

5. What study procedures will subject participate in? Participants will participate in this study starting freshman year. Participants will take a pre test beginning freshman year, and a post test at the end of year subsequent year through Senior year. Normal educational practices within the classroom.

6 Will the activity occur regardless of whether you are conducting research or not?
   ☒ YES ☐ NO

7. Answer the following question only if you checked Category 1: When will the activities occur? (Check all that apply)
   ☒ During class time
   ☐ Outside of class time (state which activities will occur outside of class time here:)

8. Answer the following question only if you checked Category 6: Will the activity be a food tasting study? ☐ YES ☐ NO

9. Will subjects will be identified for recruitment. For example, how will schools, teachers and or students be identified for recruitment? ☐ YES ☒ NO

10. Briefly describe how potential subjects will be contacted and who will contact them: All subjects will be given written communication through their course medium to define and inform them of this study. Other communication will be provided through instructors in each of the individual courses.

11. Indicate below how the investigator will receive/record the research data.
- ☐ No identifiable data received/recorded
- ☒ Coded data received; investigators have NO access to code key
- ☐ Coded data will be received; investigators have access to code key
- ☐ Identifiable data received/recorded by investigators

12. Identify who will code and/or link the study data: Students will be assigned randmoly generated numbers they need to keep track of. Data will be linked each time the survey is taken by the students number. Upon completion the code is deleted from the system.

13. Describe what provisions, if any, will be taken to maintain confidentiality of identifiable data (e.g., surveys, audio, video, etc.). Please state where the data will be stored, how long it will be kept and who will access it: Student codes are randomly generated and non-identifiable. The surveys do not contain any personal information other than current academic standing. Upon the exit of the program or after 5 years the non-identifiable student codes are deleted.

14. Will identifiable data and/or coded (linked) data be made available to anyone other than the research team? ☐ YES ☒ NO

    If YES, please identify to whom data will be made available, the reason for the disclosure and attach a copy of any data transfer agreements:

15. Indicate below what will happen to the identifiable data at the end of the study:
- ☒ Identifiers will be permanently removed from the data and destroyed
- ☐ Recordings will be transcribed in a timely manner without identifiers and destroyed.
- ☐ Identifiable or coded data with existing code key will be retained for future use

Complete below only if you checked Category 4 on page 1:

16. What publically available data/specimens will be accessed for this study?

17. What non-publically available data/specimens will be accessed for this study?

18. When were the data/specimens collected and under what circumstances? (i.e., tissue bank, data repository, institutional documents, prior research data)?

19. Which institution is responsible for the data/specimens?

20. Who is in charge of data/sample distribution?

21. What data/specimens will be obtained?

22. Are subjects identifiable from the data, directly or indirectly? ☐ YES ☐ NO

23. Will the data be coded (with a data link maintained by the provider)? ☐ YES ☐ NO

24. Will the data be coded, with no link that would allow re-identification of subjects?
☐ YES ☐ NO

For data/specimens from a non-Purdue provider, the investigator should first contact the provider of the data/specimens to ask if a signed agreement is required by their institution. Agreements and requests for contractual document signature must be sent to Purdue University Sponsored Programs Services Contracting (spscontr@purdue.edu).

25. Has a written agreement been entered into between Purdue and provider? ☐ YES ☐ NO

If YES, please upload a copy of the agreement along with this form.

Note: If you will be accessing Purdue student records or involving the Purdue Registrar to distribute recruitment information, a Data Agreement between the Investigator and the Purdue Registrar must be uploaded along with this form.

ESC Observational Form

Observation Protocol
Energy Credential Program

Class:____

Energy Credential Year:

____

Observation Number: ____

Observer(s): ____

Category	**Includes**	**Field Notes**
Verbal Behavior and Interactions	Who speaks to whom; for how long. Who initiates interaction, language use, what is said, reactions?, etc. For individual projects, what questions are asked, how do they interact with other classmates, do they ask questions? Do they display any non-verbal cues?	
What stands out	People/Concepts/ Conversations, who gets a lot of attention, why does it get more attention?	
Physical behavior & interactions	What people do, who does what, who interacts with whom, who is not interacting. What activities are people doing. For single projects, how does the individual interact with project, what behavior do they display, what is their body language, facial expressions.	
Interaction with the project	Attitude toward the project, role, body language, interaction with other group members about the project, spoken and nonverbal communication in the group about the project and learning objectives	

Tips for observers:

1. No detail is too small
2. Look for themes when observing, make sure that you are observing in those themes and not just everything that is around.
3. For field notes, group themes together or put a code, so that it is easier to analyze after
4. Keep facts seperate from interpretation of what is happening

Observation questions to groups:

- The body language and the facial expressions are just as important during these informal questions. These questions are not meant to gain knowledge based answers, but instead to scale group interactions and discussions in the group
- Use research notes to write down more than just the answer, but the observations from the

1. How is it going?
2. What are you doing right now?
3. What is working? What is not working?
4. Are you frustrated?

PUBLICATION

Maynard, C., Newell, B., Lucietto, A., Hutzel, W., and Garcia-Bravo, J. "Applied Learning within Thermodynamics: A Perspective on Energy Concepts," *2018 IEEE Frontiers in Education Conference (FIE)*, San Jose, CA, USA, 2018, pp. 1-8. doi: 10.1109/FIE.2018.8658922.