Applied Learning within Thermodynamics: A Perspective on Energy Concepts

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***Abstract*— This Innovative Practice Category Full Paper presents synergy between energy-based courses, and the optimization of student involvement within a project-based learning environment; concepts that have only recently gained traction within today's educational system. A continuous curriculum along with teaching theoretical concepts using hands-on applications transforms the learning experience from dry lecture type courses to those that enhance student learning potential. Students provided feedback through survey responses, indicating their learning experiences and topic competency before and after implementing new course materials.**

Engineering technology students thrive within enhanced learning environments utilizing hands-on methods to teach theoretical concepts. Such environments significantly increase motivation and conceptual retention for students within technical fields. A large body of knowledge exists focusing on changes regarding course delivery to the engineering student population. However, little is known about similar effects on engineering technology students. In this work, research-based learning theory applied to project-based and team-based learning, allowed course developers to further understand how changes affect the learning environment for engineering technology students.

Early indications show a transformed class effectively motivates engineering technology students, enhancing both classroom culture and student learning potential. Experiential learning improved the students' understanding of concepts taught through project-based learning methods.

Keywords*— *engineering technology, continuous curriculum, energy, transformation, education, project-based learning

I. Introduction

Universities frequently look at new ways to enhance student-learning potential. Applied learning environments help influence student-driven learning [1]. As engineering technology inherently incorporates active learning [2, 3], course developers were tasked to look into new ways to engage and motivate students within the college.

Mechanical Engineering Technology (MET) is a four year ABET accredited program where this research took place, and has two separate required thermodynamics courses. The first thermodynamics course has a core focus on basic concepts including phase diagrams and heat transfer and provides an overview of thermodynamics topics. The second of the two courses reviews core concepts and applies these concepts to real world applications. Within the latter course students gain a greater understanding of the use of thermodynamics and its relationship to other in-depth topics. As the two courses support one another, the study is well suited to measure student responses to the new continuous learning environment.

Throughout the redesign of the two courses, the faculty responsible considered the possibility of how a hands-on pedagogical approach would impact student attention and provide increased learning opportunities. In preparation for a more hands-on approach, a variety of tools that could be used to encourage independent and group learning were investigated. These faculty reviewed textbooks and related software applications, having agreed earlier that use of the same textbook for both courses was preferred to increase continuity between the courses. The inclusion of a single text reduces complexity between courses and creates an intrinsic scaffolding environment [4]. Prior to the redesign of the courses, faculty teaching the courses used different textbooks, unrelated projects, and various evaluation methods resulting in asymmetry between courses. These methods included assigned readings followed by answering questions in order to gauge student understanding. After further evaluation, faculty pursued paths of teaching course material using a combination of readings and group work. The structure of the two courses were derived from the understanding that students have much higher contextual understanding and retention rates when compared to individual work and reading material prior to it

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being presented [5]. Such understanding was evident through course assessments and discussions.

The study focuses on student feedback from surveys conducted before, during, and after the course, as well as intermittently before and after specially designed projects. The specially designed projects were used in the second thermodynamics course and therefore only students in this course completed these project surveys. Surveys were designed to show the course instructors how well each of the students retained the information being taught. The results of the study look to further understand how the implementation of topic specific projects affect the learning environment created. This work also evaluated how students react to enhanced learning environments [3]. The value of the study is that a continuous learning environment was created and student progress was tracked throughout. Changing the way students perceived the two sequential classes helped students become more engaged throughout the courses [6].

II. Background

A. Literature Review

The ability to motivate a learner is key to effective learning [7]. Active learning environments are increasingly being used to motivate and engage students. A team based learning approach is an efficient method of producing a successful active learning environment [8]. The interaction between team members also allows students to build stronger communication skills, gain valuable experience on how to interact with different people, and establish strategies in team based problem solving. However, evidence suggests if not all members of a team become engaged, team based learning may lose its effectiveness [9]. Surveys were used as a means for students to review engagement by peers which provided a method for evaluating if a lack of engagement existed within teams [10].

B. Design of Courses

The research, as previously stated, affects two thermodynamics MET courses. The two courses are offered in both the fall and the spring semesters. Each course regularly sees enrolment between 70 and 100 students per semester, with attendance growing as the departmental enrollment expands. The instructors agreed to provide continuity between the two courses, using the first course to introduce requisite topics and the second to probe more deeply into the required material. The incorporation of a single textbook was the initial starting point for transformation of the courses. The instructors noted anecdotally that in prior semesters the differences between textbooks and other course materials produced discontinuous learning, and student confusion. Present technologies permit the redistribution of course materials within an electronic textbook (eBook) format that incorporates customized versions of an existing text. Utilizing Bloom's Taxonomy [11] to better organize learning goals, the instructors created resources which encompassed all learning objectives for both courses and furnished uninterrupted learning succession promoting higher order thinking. The new way of thinking allows students to confront tasks that required higher problem solving skills with more confidence [12].

After resolving textbook issues and moving to a single text structure, instructors then looked to other areas for improvement. Similarly, Bloom's Taxonomy learning hierarchy model [11] was used to incorporate common learning objectives between the courses and including a renewable energy aspect to each course. The first course tours solar panels on the roof of a campus building. The tour provides students the opportunity to examine the system and learn about its functionality, and it's designed to increase student knowledge and exposure. The second course expands upon the tour by conducting a full analysis of the photovoltaic (PV) array through instructor-designed modules. The analysis incorporated into this course provides students with real world understanding about the application of renewable energy. Knowledge gained through the experiential learning activities within both courses produces an enhanced learning environment and is well suited to the students learning styles [13].

The final aspect of this course transformation is the implementation of a modified scaffolded learning environment [4, 14] throughout both courses. Similar techniques include the incorporation of team activities within a formal learning environment for undergraduate students providing experiences that build on teamwork, leadership, and other valuable qualities that employer's desire [15-16]. The previous versions of these two courses were not vertically integrated to connect the technical topics between them, the revised versions of the two courses on the other hand do integrate the technical concepts to give continuity and connection to the learning experience of the students.

Additionally, the projects provided an opportunity to connect non-technical skills such as team collaboration and project planning. One of those skills was assessed using the online team management tool called CATME [17], this is a tool created to help measure the engagement in and development of team work skills, an ability that is of high importance in professional life after college [18]. This tool was specifically used for ensuring collaborative learning by using the peer evaluation feature embedded in CATME. The students were encouraged to actively participate in the group activities. Students were penalized through score reduction for lack of involvement and participation. Lastly, student teams were also indirectly evaluated on their project management skills by providing a preliminary design submission prior to project execution.

The original courses evolved over time and as a result were limited in similarities between materials, pedagogy, and instruction. The first course was historically designed to include a laboratory section, whereas the second course does not. This becomes problematic as the second course still includes team-based projects. After further evaluation, the added projects did not appear to consume a significant amount of course time while achieving the goal of increasing team based learning and project based skillsets. [19-21].

Bloom's Taxonomy [11] sets an order to the many different activities that are desired to help the student focus on specific skills within the classroom. This allowed learning objectives to be better organized depending on the course level. The goal of this project was to produce a multi-level learning environment that fosters the retention and execution of knowledge gained through the transformation of these two courses. Following Bloom's Taxonomy [11], the text for the courses was selected to increase student knowledge, comprehension, application, and analysis of problems. This was accomplished by providing both examples and content in the form of readings as well as interactive retention based questions. Considering the Cognitive Process Dimension [11] of the taxonomy, it is anticipated that both courses will be able to achieve this goal through interactive reading assignments, real world projects, and team work.

C. *Course Projects*

The progression of technical projects throughout the courses follows the cognitive process dimension of Bloom's Taxonomy [11]. Within the two courses students regularly applied attributes of Bloom's Taxonomy [11] including the comprehension and application of course concepts. Throughout the second thermodynamics course students learned about various forms of renewable energy including solar, hydroelectric, biomass, and wind. The students learned these concepts through lectures, a class project, and by the completion of an Introduction to Renewable Energy Certificate from Solar Energy International [22], which allows students to evaluate and analyze renewable energy systems. Both learning methods provided environments that would enhance their learning and understanding of concepts. This was accomplished by implementing concepts learned. Students were given the opportunity to apply, analyze, evaluate, and create a solar energy system through two team projects with three to four students in each team. In Both Projects, students became familiarized with the topics through reading assignments and lecture materials that encouraged the comprehension and retention of information prior to execution of the project.

Project 1 Focus: Solar Energy

- 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 Take-away: 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 [23]

- Task: 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 Presentation & Description of their Energy Conversion Mechanism
- Student Learning Take-away: Further Improved Team Communication/Interaction, Energy Conversion Processes, Losses within Energy Conversion, and System Efficiencies.

III. RESEARCH QUESTIONS

In developing the courses and surveys, two questions were considered by the instructors regarding the implications of transforming the thermodynamics series.

- *Do project based experiences influence the learning of engineering technology students in thermodynamics? And,*
- *Do real-world, experiential projects improve student understanding of thermodynamic concepts?*

It is anticipated that answers to these questions will provide an early indication if more research is needed. The information gathered via class surveys will determine the impact of changes to classroom delivery on engineering technology students.

IV. METHODS

The ability to clearly identify reactions from the students about the newly structured course, and its projects was vital. Instructors developed Likert based surveys [24] to collect the student reported data. The questions asked throughout the surveys focused on three different areas of the solar energy project, the energy conversion project, and the course overall. The survey was developed using accepted survey design criteria [25]. The project surveys were given only to the students within the second class of this series, and reviewed in this work.

A. *Student Survey Creation*

Course survey questions were designed to address opinions on the textbook and course delivery from the students. The technical project surveys had focuses in student interests on topics, teamwork conditions, and their self-evaluated level of knowledge for technical project concepts. Student assessments were made using the same metrics pre and post course transformation in both the first and second course. These surveys were administered at the beginning and end of both courses.

B. *Data Comparison*

To assess the results of the surveys, the authors used descriptive statistics to define the student population and content analysis method [26, 27] to evaluate student survey response. This is a systematic research method and has produced evidence that valid inferences can be made when carefully applying these steps to qualitative data [28]. Conclusions can be drawn by grouping data, creating categories, and establishing coding. The defined variables represent both the categories, and the data content, intentions, and meanings of what the students wrote. In this case, investigators will be able to understand the impact of projects included within the course. Investigators will also be able to determine if there are any significant successes, or improvements that need to be made.

V. Results

In attempts to further the understanding of the student population within this research, instructors examined data provided by students. The results of examining student data yielded the following results:

- Students within this population range in age from 17 to 30 years old, and contained no outliers.
- Slightly over 90% of all students identified as male [29].
- All students involved within the study are majoring in mechanical engineering technology and taking courses required within its curriculum.
- The majority of the students in the class reported to be between their fifth and seventh semesters of the program.

The comparison from the pre and post survey data indicated that students possessed a stronger desire to gain in-depth knowledge of thermodynamics. Students also indicated that they had expectations that the course would be an extension of the pre-requisite course.

Survey comments showed the instructors that students found the eBook to simply be too wordy at times which led to confusion. The eBook was also indicated to be too expensive; this notion began to fade when students used the same text book for the following thermodynamic course. Students reported that the homework and exams were much more difficult, and thought the course should include a laboratory section. Overall, the feedback provided showed that the students understanding of renewable energy and heat and work conversions increased because of technical projects, lectures, and the energy certificate.

Two projects were included within the course the first being the "Solar Energy Project" and the second the "Energy Conversion Project." The pre and post project survey responses are compared using the content analysis method [26, 27].

A. *Solar Energy Project*

Initial surveys showed that students were interested in various energy forms including wind, solar, nuclear, and petroleum sources. Post project surveys indicated that students possessed an increased interest on solar energy, and placed a higher level of importance on it as a renewable energy. Regarding the importance of solar energy, students reported that the increased level of importance was a result of understanding its benefits on the environment. Nearly all of the students acknowledged the importance of solar energy to the future. The data as a whole showed the students' opinion on solar energy became more positive and their understanding of its importance increased pre to post solar energy project demonstrating the project influenced student learning. Figure 1 compares the pre and post survey results regarding the student's opinion on the importance of solar energy.

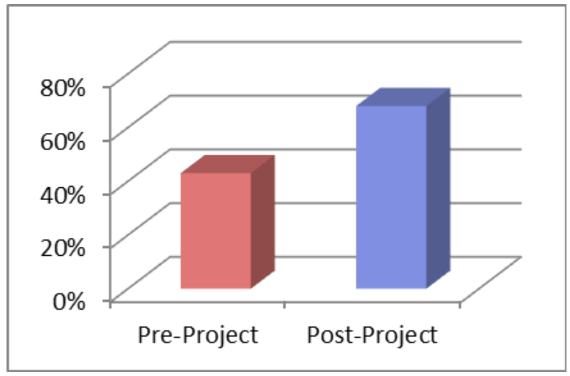


Fig. 1. Comparison of Pre/Post Survey Results – Importance of Solar Energy

The level of understanding for renewable energy concepts throughout the first technical project increased demonstrating the project's influence on student learning and increased student knowledge level. Prior to the start of technical projects, students rated their knowledge for renewable energy on a five point Likert scale. Zero on the scale represents no pre-existing knowledge about renewable energy, and four 4 indicates a very extensive knowledge of renewable energy. During this pre-project survey, students reported a mean knowledge score of $\mu = 1.92$, indicating that students had some knowledge of renewable energy. The standard deviation for the reporting was at $\sigma = 0.83$, with $N = 75$ students completing the survey. Upon the conclusion of the first technical project, instructors observed a significantly increased reported knowledge level. Utilizing the same Likert scale [22], students indicated an increased mean ranking $\mu = 3.35$, with a reduced standard deviation of $\sigma = 0.78$. Showing students upon the completion of the solar energy project had a much higher body of knowledge regarding renewable energy. During the post project survey $N = 104$ students reported, slightly higher than indicated in the pre assessment survey. Upon running a two-sample z-test the data proved that with greater than 99.999% confidence, there was a mean score increase in student responses after the implementation of technical project number one at a significance level of $\alpha = 0.05$. Figure 2 compares the pre and post survey results regarding the students' perceived knowledge for renewable energy.

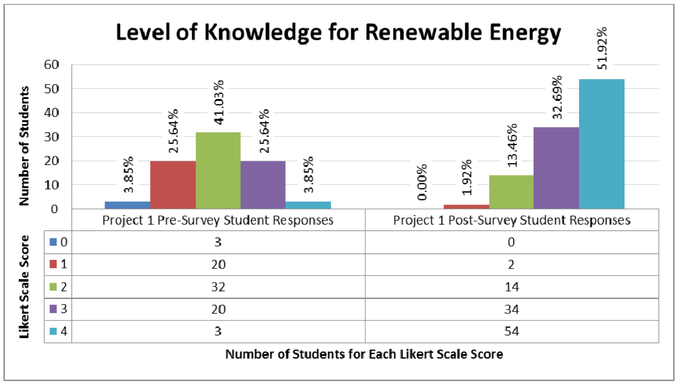


Fig. 2. Comparison of Pre/Post Survey Results – Level of Knowledge for Renewable Energy

Comments provided post solar energy project addressed how having guidelines provided an interesting way to learn course concepts. 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 about solar energy. Other students commented on the lack of time to complete and conduct experimentation with the project.

Figure 3 shows the solar kits used by students in this project, as well as the solar arrays used on the top of the building. Students have access to the kits, arrays, and the software recording data from the arrays.

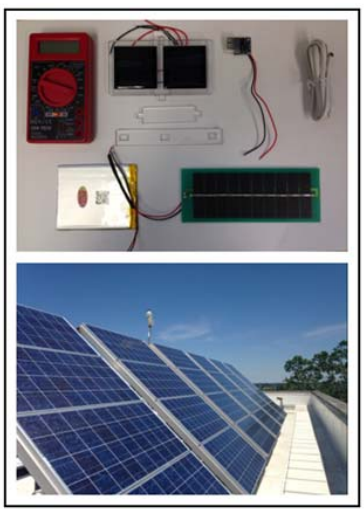


Fig. 3. Comparison of Pre/Post Survey Results – Level of Knowledge for Renewable Energy

As a whole, students found the project interesting and felt it was easy to conceptually visualize the course concepts. However, they felt that the project started too late, not allowing them to work with concepts learned as much as they would have liked.

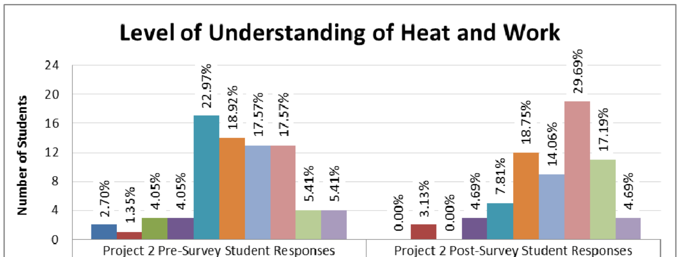
B. Energy Conversion Project – Student Built Heat Engines

The construction of energy conversion machines allowed instructors to measure students understanding, comfort levels, and knowledge about conversion processes. Through the use of Likert scales, students self-reported on a ten point scale. The construction of Stirling engines allowed students to build on their understanding, comfort level, and knowledge about energy conversion. Figure 4 shows student designed and built Stirling engines.

Fig. 4. Student Built Heat Engines

The reported knowledge level of students during the energy conversion process notably increased. The data collected indicated that 85% of the students rated their knowledge level higher than prior to beginning the energy conversion project. Further, when students were asked to rank their comfort in building the energy conversion machine, over 85% of them expressed comfort levels greater than five on the ten point Likert scale

Measuring and enhancing the understanding of heat and work was the primary goal within this second technical project. The pre-assessment survey revealed that collectively students on the same ten point scale rated their understanding at $\mu = 6.28$. Their standard deviation was at $\sigma = 1.95$ indicating a wide spread range of scores from the $N = 74$ reporting students. Upon the completion of the second project, instructors saw an increased mean of $\mu = 7.14$, score averaging nearly one point higher than previously showing an increase in student understanding of the topic. The post project standard deviation was $\sigma = 1.75$, making the spread of scores from the $N = 67$ students who reported much narrower. Running a two-sample z-test showed that with 99.3% confidence, the mean score reported by students increased after technical project number two at a significance level of $\alpha = 0.05$. Figure 5 compares the pre and post survey results regarding the students' ranking of their understanding for heat and work.



	Project 2 Pre-Survey Student Responses	Project 2 Post-Survey Student Responses
1	2	0
2	1	2
3	3	0
4	3	3
5	17	5
6	14	12
7	13	9
8	13	19
9	4	11
10	4	3

Fig. 5. Comparison of Pre/Post Survey Results – Level of Understanding of Heat and Work

C. Overall Course Impressions

The courses were surveyed at the start and end of the semester. Indicated in the post semester survey some students felt this course was similar to others offered, but the projects offered made it more interesting. Many students expressed their satisfaction with course materials.

Students self-reported that their understanding of solar energy and renewables increased after implementation of the solar energy technical project, lectures, and energy certificate. Student knowledge of energy conversion, confidence in building energy conversion machines, and understanding of heat and work increased after implementation of technical project two. Based upon student responses, improvements could be made to the timing of technical projects and duration of both the projects and reports. Students also reported enhanced learning from real world examples, an interactive textbook, and from the reading assignments. Students expressed their satisfaction with the course materials, while others suggested it as the same as in other classes. Inclusively, students were impressed with the level of hands on activities in a course that was noted as "lecture only." In general, the course transformation produced positive student responses and increased student learning in self-evaluations.

VI. Discussion

The general findings from the surveys showed that students were open to the content within the second thermodynamics course. This was found through a pre and post data comparison on questions about student anticipation of the second thermodynamics course and how they viewed the course upon completion. Students assumed it would expand upon their knowledge base from the first course, but without a laboratory environment. This mindset allowed the students to approach more complex tasks that required higher problem solving skills within the second thermodynamics course with more confidence [12].

Qualitative data provided insight that many students initially found the text book to be too costly as well as overly wordy at times. Additional data collection may provide insight to support this evidence. The rationale behind choosing the selected text simply was to provide continuity between the two courses and reduce the financial burdens on the students. The thought of students needing to purchase only one textbook between the two courses was an additional driving force for the change. Students within the second thermodynamics course were able to recognize the continuity or the division of the text book price across two courses. The notion of students within the first thermodynamics course did not include such ideas of continuity. On surveys administered within the first course students were displeased with the cost of the ebook. Survey responses for the second course indicated students realized the continuity of the textbook being used for two semesters and the cost per semester was thus reduced.

An ebook was available for purchase by the students, however, these students preferred to have the printed version. These engineering technology students, preferring a more hands on approach [13], thus explaining this preference. Various sources provide evidence that these students typically express displeasure when books and other materials are not available [30], supporting their desire to have physical means to study supporting hands on aspects of learning [31]. Anecdotally, instructors noted that students within these courses openly stated that they prefer hardcopies to electronic after being presented an eBook. Students shared that they believed hard copy book are easier to use and supported reference marking.

Overall, through the review of survey data and the anecdotal observations of faculty involved with the redevelopment and teaching of these courses the majority of students agreed that the two technical projects increased their interest in the course. Thus supporting that an applied active learning environment such as those created in these courses does increase such interest [1, 8] and student engagement [32-33, 6]. As indicated by the pre and post assessments, the students' interest, understanding, and level of comfort with the material was increased. This was evidenced after the course transformation, and the technical project intervention was complete, both being intricate to achieving the transformative learning goal of enhanced student learning. The transformation of the two courses allowed for an enhanced learning environment to be created [4].

VII. Conclusion

Overall, the addition of technical projects and a singular electronic textbook established and strengthened continuity between courses and coursework. In order for this continuity to flourish, improvements to the textbook and delivery should be made using student feedback. Technical projects provided a team-based experiential learning environment for students within courses. This enhanced environment increased student interest when dealing with renewable energy and energy conversion mechanisms. When dealing with these concepts observations provide anecdotal data supporting the understanding that these courses tend to be difficult. Through the use of team projects the learning environment is enhanced, thus improving student engagement and motivation.

Through research questions intended to be evaluated through survey data, it became evident that the course transformation influenced the learning of participating engineering technology students. Students reported that their knowledge on solar power and energy conversion was increased through the transformed courses. Comments and open ended questions resulted in answers that support this assertion. Students enjoyed team interaction, and in some cases shared desires of increased time to further explore project materials and other applications for them.

Finally, the authors found that the changed learning environment described in this paper resulted in enhanced learning and increased motivation for the students. Findings suggest that further enhancement to the learning environment both within and outside the classroom will increase learning outcomes for engineering technology students. Future work will want to focus on other projects, other subjects, and potentially increasing the scope of the classroom enhancement to other majors, colleges, and programs.

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