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Board 136: Utilizing Active Learning to Replace Traditional Homework in Undergraduate Engineering Majors

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”Zahra Pournorouz received her Bachelor of Science degree in Aerospace Engineering from Amirkabir University of Technology (Tehran Polytechnic) in Tehran in the Fall of 2014. After finishing her bachelor’s studies, she got admitted directly to the Ph.D. program in Mechanical Engineering at the University of Texas at Arlington and graduated in August 2018. Her research interests mainly focus on oil-based nanofluids and enhancing the thermophysical properties of synthetic oils. This was the first demonstration of the work ever done in this field and resulted in broad environmental and cost benefits, especially in energy storage and heat transfer applications. She has more than three years of experience teaching thermofluidic, mechanical design, and solid and structure courses and supervising senior capstone projects collaborating with industries such as Saint-Gobain, Klein Tools, and Parker. She also has served in leadership roles at the Society of Women Engineers and STEM advisory task force to represent diversity and inclusion and improve student success and retention for underrepresented students.”

Utilizing Active Learning to Replace Traditional Homework in Undergraduate Engineering Majors

Abstract:
The internet and social media are growing significantly at a rapid pace, making it harder for instructors to provide effective learning and authentic assessment of courses using only the traditional textbook. The future of undergraduate engineering majors is in danger of extinction as the creativity of students' minds and the experience of hands-on projects are fading in the shadow of outdated textbooks and repetitive theoretical assignments. As hands-on laboratories improve academic performance and increase student success, they need to be updated to serve today's world applications. This paper presents a new method to replace traditional homework with advanced active learning and lecturing in class. "Thermodynamics" was chosen as the subject of the case study. The traditional homework was not wholly removed but was presented as "optional." Meanwhile, a set of experiments and mini-projects was designed throughout the semester to replace the weight percentage of the homework. Activities included designing experiments, major-specified projects (biomechanical, civil engineering, mechanical engineering, etc.), and solving real-world problems that were defined by involving cleantech and energy startup companies. These activities can extend the student's ability to think outside the box and grasp fundamental concepts more clearly, and for example, include designing thermal protocols for thermal equipment to perform tests for different nanofluids or designing hardware for harvesting wasted heat and converting it to electricity utilizing Carnot cycles. The students' learning process included the problematic concepts of thermodynamics. They were familiarized with the research and development industry in the energy field, and it broadened their perspective toward their future careers. In addition, compared to an equation and problem-solving-only class, this novel method would lead to higher grades, thus, better retention for students and more valuable learning.

Introduction:
The main objective of this paper is to provide engineering students with a more engaging and practical experience of Thermodynamics. One of the primary challenges engineering instructors face is creating more relevant and hands-on assignments that can authentically assess the student's understanding.

In today's digital age, students have shorter attention spans, which reduces them even further when learning online. The new generation of students has an attention span of eight to ten minutes which reduces to eight seconds in an online environment [1]. To keep students engaged in the classroom and improve their learning abilities, interactive lecturing has become crucial and essential to engage students in the classroom and enhance their learning abilities [2]. Hands-on assignments are a proven solution to create an interactive classroom environment. Previous studies have shown that hands-on laboratories can improve academic performance and increase student success by allowing them to experience the theoretical content in real-world examples.

However, hands-on assignments come with various challenges, including the availability of space and equipment, instructor creativity to design experiments, and student capacity for class enrollment. This paper will present new ideas for developing assignments that keep students interested in learning and can evolve with new technologies. By incorporating innovative and relevant topics and using modern technologies, we can create more engaging and interactive assignments that improve student learning outcomes.

Methodology:

Engineering Thermodynamics is a core course required for all non-ME engineering and science majors at Stevens Institute of Technology and was selected as a case study.

The homework portion of the grade was offered as “optional,” Instead, a series of mini-projects were introduced throughout the semester. The traditional homework questions were chosen from the textbook. The problems with these homework questions are that the solutions are available online, and with minimum monthly subscription payments, students can access all the answers. Instructors rely on homework for students to practice, and students making minimal to zero effort leads them to fail exams and quizzes.

The mini projects start with research about the relationship between thermodynamics and the student’s current study major. This is the first attempt and a core step to encourage and motivate students to understand why they need to learn what they are learning. The new generation is more adventurous and curious and can’t be forced into learning a concept or fundamental theory. Knowing the reason behind the specific education helps with their willingness and excitement toward learning new materials. These are mini-projects because students don’t need to write a full report or essay. Instead, they must present their findings to the class in 3 – 5 minutes. They practice being concise and efficient.

The second project involved more Thermodynamics concepts incorporated into their major of study. Again, the student groups consist of different disciplines. For example, a computer engineering major was in a group with two civil engineers and one naval engineer. This helped the student to be exposed to different disciplines and broaden their visions and knowledge of engineering.

The topics presented in mini-project #2 are listed below in Table 1. These topics include the first and second laws of thermodynamics. The related major column is a suggestion by the instructor, but students are encouraged to choose whatever project they find interesting. The majors are Industrial and Systems Engineering (ISE), Engineering Management (EM), Software Engineering (SE), Pure and Applied Mathematics (Math), Civil Engineering, Computer Engineering (CE), Naval Engineering, Electrical Engineering (EE), and Biomedical Engineering.

Table 1. A list of mini-project #2 topics and a suggestion to related engineering majors.

Project title	**Related major**
Performance Analysis of Heat Engine using Conventional Fuel vs. Biofuel	ISE, EM, SE, Math
Alternative Energy Sources: Wind Energy Harvesting	Civil Eng., CE, SE
Fuel Cells vs. Heat Engine	Naval, and Civil Eng., CE, SE
Tidal Energy Technology	EE, Naval, and Civil Eng., SE, CE

Solar Thermal Power Generation	EE, ISE, EM, Math, SE
Subway cooling methods with a minimal power requirement	Civil Eng., EE, Math, ISE
natural vs. artificial pacemakers and thermodynamics	EE, Bio Eng., Math
hyperbaric chamber	Bio Eng., ISE, EM
centrifugal blood pump development	Bio Eng., ISE, EM, Math
prosthetic devices, pressure, and thermodynamics	Bio Eng., Math

The third mini project is going to be a design of an apparatus using the cylindrical cell method for thermal conductivity analysis. This project aims to learn thermal conductivity and how to measure it. The students will use my skills to understand the experiment procedure for a thermal process and gain experience in thermal data analysis. This project is a coloration of a Green technology startup named SeebeckCell Technologies, Inc., and is very helpful for students to see the real-world application of their effort. Each group was assigned a small part of the design. The CAD design and electrical wiring schematics were already provided to the students. Figure 1 shows the phase diagram to be used in the assignment [3].

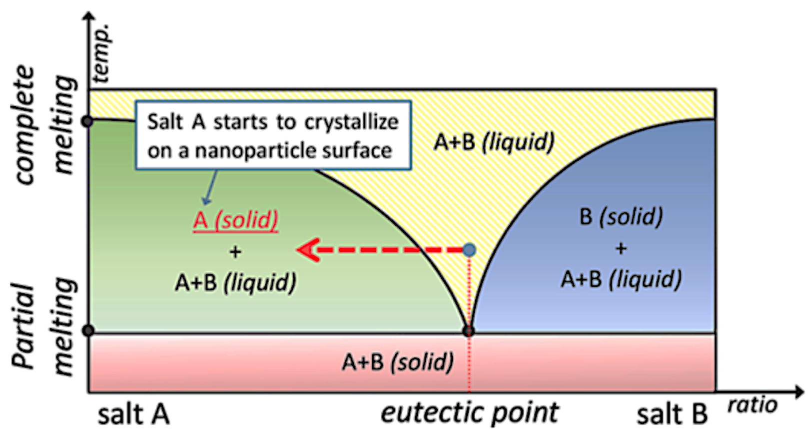

Figure 1. A phase diagram of a mixture of two salts [3]

In one session, students will be introduced to concepts and definitions of eutectic salts and molten salt nanofluids. They will learn the molten salt nanofluid application and the relation of nanofluid's thermal conductivity regarding Green Technology in the energy industry. The students will use the given information along with the phase diagram to develop a method to measure the thermal conductivity of nanofluid. This method must be applicable for nanofluids and pure materials like water without any modification or adjustments to the apparatus.

The students don't need to CAD design for the assignment. Instead, they are required to only develop the experiment process simply with hand sketches for both the material housing and experiment process flowcharts. The assignment is only a preliminary attempt to push students' minds beyond basic Thermodynamic equations and understand one of the many applications of thermodynamics.

The submissions will receive feedback from the founder of SeebeckCell Technologies company. They will be graded based on the students' understanding and grasp of the material only since this is an open-ended assignment with not one but many correct answers!

Results and discussion:
The Thermodynamics class or ENGR234 is required for all students at the Schaefer School of Engineering and Science at Stevens Institute of Technology except for mechanical engineering students, as they need to register for a mechanical engineering thermodynamics. Each section of the class consists of students from various majors. There is an average enrollment of 100 students per section, and for this case study, we had a total of 49 groups in four different sections (ENGR234-RA, RB, RC, and RD) with an average of 4 students per group.

The first mini project: Students were to present the relation of Thermodynamics to their major. Here are some examples of their presentation:

- Group A11 consists of four Biomedical Engineering students. They showed a cellular metabolic map of animals and plants and presented that they need to learn thermos to understand better the biological processes of organisms and their thermoregulation along with cardiovascular system and cell potentials across a membrane.
- Group A4 consists of two Computer Engineering, one Software Engineering, and one Electrical Engineering. They presented that the laws of thermodynamics can be used to calculate the maximum temperature of a computer chip and to optimize the cooling systems used in electronic devices to keep them from overheating, and the fact that the higher heat in electrical components leads to higher runtime for programs and codes.
- Group B4 consists of one Math major, one Industrial and Systems Engineering, and one engineering management. They presented that math and thermodynamics are interrelated and gave an example of the Laplace equation of heat. They also talked about the communication of engineering analysis, data interpretation, and thermodynamics, as well as connecting efficiency and the second law to industrial systems.
- Group D1 consists of one Civil Engineering, one Engineering Management, one Software Engineering, and one Electrical Engineering. They presented the relation between pressure, flow rates, and designing a dam and solar panels for renewable energy.

The second mini project: Each group picked their topic from Table 1. They were required to prepare a short 5–10 minutes presentation that included a title slide with the group's info, a problem statement slide, research and solution for the chosen topic, and a final slide for Q&A. The topics were broad in different areas to cover all the majors in the class. The objective of this assignment was to familiarize students with the diverse real-world applications of Thermodynamics and to help them understand the significant challenges faced by our planet, climate, and emerging technologies. Through this assignment, students were encouraged to explore and investigate beyond the confines of the classroom, delving deep into real-world phenomena and the practical application of theoretical concepts.

The third mini project: Each group will have the opportunity to design an experiment and create an in-lab apparatus for measuring the thermal conductivity of various nanofluids or materials. The primary objective is to encourage brainstorming and collaboration among group members to design a methodology and conceptual designs for the thermal conductivity measurement device. Through this assignment, students will have the chance to apply their knowledge of thermodynamics and develop critical thinking skills by working in groups to create a feasible and effective experiment design. They will also gain valuable experience in developing and testing experimental setups, as well as interpreting and analyzing experimental data. Overall, this assignment will help students improve their understanding of thermodynamics and its practical applications while also building their collaboration, problem-solving, and experimental design skills. By engaging students in a type of hands-on activity, we broaden their perspectives and enhance their understanding of thermodynamics in real-world contexts. This assignment will enable students to develop critical thinking skills and improve their ability to apply theoretical concepts to practical scenarios.

Conclusion:

The mini projects are an innovative alternative to traditional homework, serving as the first step towards replacing it as the primary means of assessment. While homework remains an option for those interested in honing their fundamental skills, its submission is now optional. Students who do choose to submit their homework will receive feedback and comments, provided that their work is not found to be the result of cheating.

The field of education is constantly evolving, and this is a work *always* in progress, and improvements are needed to increase the efficiency of the assignments. As new technologies and discoveries emerge, we must adapt our teaching strategies to ensure that students are adequately equipped with the skills and knowledge they truly need for their future endeavors and reach their full potential.

Seeing that the students developed a more comprehensive understanding of Thermodynamics through our approach is rewarding. Previously, they may have viewed Thermodynamics as a set of complex equations without much practical application. However, with mini projects and real-world examples, they are now able to see how Thermodynamics is relevant to their daily lives.

By connecting the theory to the real world, students grasp the importance of Thermodynamics in fields such as renewable energy and its technologies.

This approach has effectively promoted a deeper appreciation and understanding of Thermodynamics among the students. As we, the instructors, continue to refine our teaching methods and incorporate new technologies and techniques, we can further enhance their learning experience and prepare them for success in their future endeavors.

Additionally, topics relating to renewable energy and nanomaterials should be incorporated to broaden students' perspectives and keep up with new advancements in science and technology. By incorporating more relevant and up-to-date topics, students can better understand the latest trends and technologies in the field. Furthermore, a greater emphasis on renewable energy can help raise awareness of the importance of sustainable energy sources and encourage students to consider more eco-friendly approaches in their future careers.

Overall, by refining the assignments and expanding their scope, students can benefit from a more enriching and comprehensive learning experience. This approach encourages students to think beyond the confines of traditional learning and develop their research-oriented skills. By the end of the semester, they will have gained exposure to the research and development industry and broadened their career horizons. Students will have the opportunity to enhance their experience, skills, and knowledge for future employment while also learning how to design and conduct experiments. Ultimately, the goal is to replace conventional exams with hands-on and experimental projects, which are highly valued in the thermal and energy field.

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