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Enhancing participation, engagement, and retention in undergraduate and graduate curriculum through applied energy conversion course

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Abstract

To increase student interest in the graduate program, and to increase retention in the undergraduate program of mechanical engineering, energy conversion course was incorporated to provide an avenue to apply fundamental concepts to practical scenarios and provide design solutions for mini steam power plants. This strategy improved the fundamental grasp, confidence, ethics, and responsibility of engineering students. Towards the middle of this course, local engineers from the industry were invited to give a guest talk related to energy conversion applications incorporated in their respective industries. This course covered topics related to the application of regeneration, reheating in boilers to solve a complex project related to setting up a steam power plant, analysis of jet engines and gas turbines, and application of sunlight for chemical energy conversion and storage through Hydrogen production. This course also contained an ethics component to meet one of the ABET requirements. Through individual exams, group projects, presentations, group design/analysis, and attending presentations from industry personnel, the student's performance was evaluated. Additionally, an outgoing survey was taken from the students. The overall rating of this course was 4.53/5 and the students' survey indicated excellent application-based learning. 6 graduate and 7 undergraduate students took this course and 4 out of those 7 undergraduate students who took this course as an elective signed up for the accelerated masters' program track, thereby suggesting an increase in retention, participation, and improvement in the curriculum through such applied courses.

Keywords: Retention, enhancing participation, energy conversion, ethics.

Introduction

The energy conversion course in mechanical engineering plays a crucial role in attracting undergraduate students towards pursuing graduate studies in this field. This course provides students with an opportunity to gain an in-depth understanding of the fundamental concepts and practical applications of energy conversion systems, which are critical for advanced research and development in mechanical engineering. According to a recent study by the American Society for Engineering Education (ASEE), students who take energy conversion courses are more likely to be interested in pursuing graduate studies in mechanical engineering, as compared to those who do not take such courses (Liang et al., 2021).

To enhance student participation, engagement, and retention in the energy conversion course, novel teaching techniques have been proposed and implemented. These techniques focus on creating an interactive and collaborative learning environment that enables students to apply theoretical concepts to real-world problems. For instance, flipped classroom techniques have been used to encourage students to take ownership of their learning, by requiring them to prepare for lectures and engage in discussions and group activities during class time (Elnaga & Imran, 2013).

Additionally, active learning techniques such as problem-based learning, case studies, and simulations have been incorporated into the course curriculum, which have been shown to improve student engagement, motivation, and retention (Freeman et al., 2014).

At the University of Texas Permian Basin, a new graduate program in mechanical engineering was launched in Fall 2020. Since then, efforts have been made to increase student enrollment in the program. One such effort involved the introduction of a new course, MENG 6389 Energy Conversion, in the Summer 2022 semester. This course is an elective requirement for both undergraduate and graduate programs in mechanical engineering.

The objective of introducing this course was two-fold. Firstly, to increase enrollment in the graduate program by offering a course that appealed to both undergraduate and graduate students. Secondly, to use different teaching techniques to increase participation, create awareness related to the importance of energy conversion, improve collaboration among students, develop intellectual curiosity of energy applications, and create a chance to listen to industry speakers. Notably, both senior-level undergraduate students and graduate students took the course, and there was no difference in the curriculum between the two levels. This was because the course was not co-listed with the undergraduate course during its first offering. As the class size was less than 15 students and most of them being graduate students, whoever undergraduate students took this course, it was ensured that they completed thermodynamics-II course which covered energy cycles.

A strong grasp of fundamental concepts is crucial for success in engineering courses, as poor grades resulting from a lack of understanding can lead to frustration and academic failure for students (Chandrasekharan et al., 2020). This is particularly concerning in core (higher level) courses, where a drop in enrollment can occur due to students' difficulties with basic concepts. The energy conversion course at the University of Texas Permian Basin was designed to address this issue by providing a primer on fundamental concepts related to thermodynamics laws and cycles, as well as frequent reminders of their importance throughout the course. By presenting critical discussions on cycles and requiring students to repeat fundamental concepts, the course successfully improved students' grasp of these concepts.

Active participation and engagement are also essential for student success, as lack of involvement can negatively impact performance (Cavanagh et al., 2016). The energy conversion course addressed this issue through applied example problems, individual and group projects, presentations, and invited guest lectures from industry personnel. Additionally, strategies presented in the 2022 ASEE conference paper "Gaining Retention and Achievement for Students Program (GRASP) A Professional Development Program for Engineering Faculty To Increase Student Success" (McShannon, 2022) were implemented to further increase student engagement and retention.

Through these efforts, the energy conversion course not only improved students' understanding and performance but also helped to create a sense of responsibility and motivation towards pursuing higher education and becoming responsible engineers. By highlighting the importance of advancing knowledge and encouraging students through feedback and positive reinforcement, the course served as a successful model for enhancing student participation, engagement, and retention in engineering courses.

In conclusion, the energy conversion course is a vital component of mechanical engineering education, which plays a critical role in attracting undergraduate students towards pursuing graduate studies in this field. The use of innovative teaching techniques can significantly enhance student participation, engagement, and retention in this course, which can ultimately lead to increased interest in pursuing advanced studies in mechanical engineering.

The energy conversion course was novel in several ways, as outlined below.

1) Firstly, the course was taught in a unique manner that involved design and analysis problems, individual and group projects, and invited guest speakers from industry. This interactive approach to teaching helped increase student engagement and participation, resulting in better understanding and retention of the fundamental concepts related to thermodynamics.
2) Secondly, the course generated a high level of interest from both undergraduate and graduate students. By providing a real-world example of a thermal power plant design problem, students were able to apply the knowledge they had gained over their four years of undergraduate study to solve a complex problem. This not only increased their grasp of the subject matter but also instilled confidence in their ability to present their work.
3) Finally, the course was designed to encourage collaboration between undergraduate seniors and graduate students. By fostering this type of interaction, the course helped increase interest in the program and ultimately led to improved retention for both undergraduate and graduate students.

Overall, the energy conversion course was successful in attracting interest from students, improving their grasp of fundamental concepts, and promoting collaboration and retention in the mechanical engineering program.

Course curriculum

The energy conversion course was designed to cover a wide range of topics related to the application of different technologies, including regeneration and reheating in boilers, jet engines and gas turbines, Fuels and combustion, wind turbine analysis, the solar energy conversion in photovoltaic cells, Hydrogen production and storage, and nuclear energy. The course also incorporated an ethics component to meet ABET requirements.

Throughout the course, students were expected to achieve several learning outcomes, including understanding the workings of steam power plants and gas turbines, analyzing input and output parameters, implementing regeneration and reheat concepts, and calculating efficiency. They also learned about IC engines, turbocharging, propellers, wind turbines, and hydrogen production techniques and their use in fuel cell technologies. By working in groups, they were required to demonstrate the working principle and perform energy analysis of their energy conversion system of choice and identify the quantity (of systems) required to power Odessa, TX. Additionally, they were required to participate in group projects and present their findings to the class and attend guest lectures from industry personnel who use energy conversion techniques.

The course materials included several books, such as "Energy Conversion" by Kenneth C. Weston, "Principles of Energy Conversion" by Archie W. Culp, Jr., and "Energy Conversion: Systems, Flow Physics and Engineering" by Reiner Decher.

Applied project given in the first quarter of the semester

Figure 1 shows a model of a design of steam turbine power plant. This was assigned as an individual project at first quarter of the semester. Here, students were given a task of analyzing the power plant by calculating and presenting the flow of heat energy in the form of steam by finding the percentage of initial mass 1234 Kg/s distributed along the system by calculating the values of mass flow rates, y1 to y8. Additionally, the students were asked to find the Carnot efficiency, thermal efficiency, and representing all the states on P-v, T-v and T-s plots.

Course grading scale and assessment

HW's and presentations	40%
Attendance	10%
Midterms	20%
Final Project	15%
Final Exam	15%

Innovative techniques

Towards the middle of this course, local engineers from the industry were invited to give a guest talk related to energy conversion applications incorporated in their respective industries.

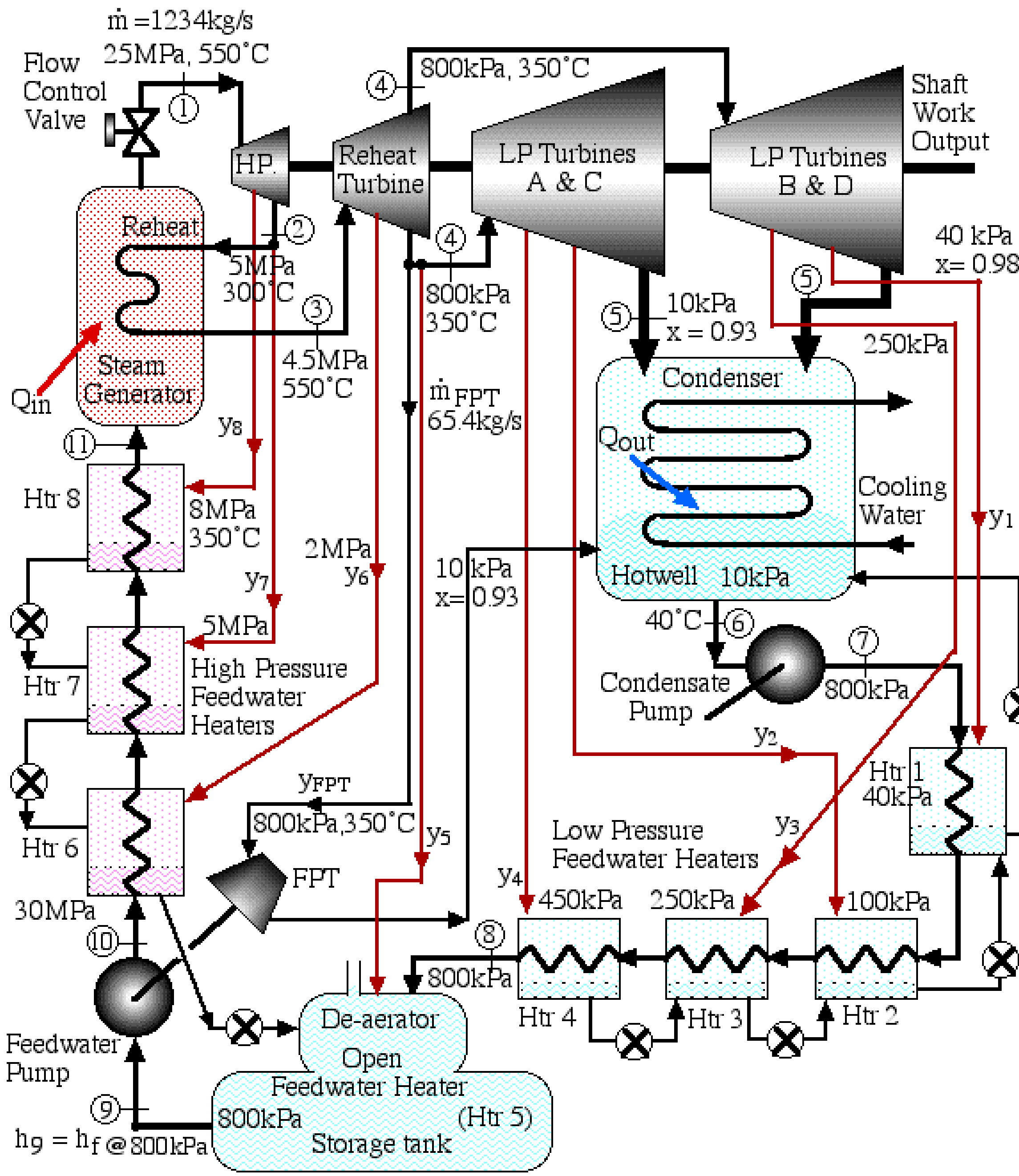

Figure 1: An example of a project assigned to students to solve for y_1 through y_8 (where y's represent the mass flow rate) and representing all the states in a P-v, T-v and T-s diagrams.

Final project

Instructors may come up with their own ideas for the final project. In the first time this course was offered in summer 2022, the following was the final project assigned.

Final Project Presentation Tasks/Guidelines
Instructor: Dr. Anveeksh Koneru

For the final project make sure you address all the below listed questions and design aspects that are required. You need to make a power point presentation and present it as a group. For some information in some of the points below, you may have to discuss that with other group members. This is allowed. But the design aspect must be independent group work. Each group will have their own design for the last point in this project.

I liked the following YouTube videos, as they have nice animations to improve our inquisitiveness and perspective.
50 MW gas turbine by Siemens:
https://www.youtube.com/watch?v=fr5eDxiYqEs
How Jet Engines work
https://www.youtube.com/watch?v=L24Wf0VlTE0

1) Present your understanding of regeneration using a figure, flow chart and T-s diagram. Derive the efficiency of a gas turbine regeneration. The final efficiency in terms of temperature and pressure ratio is given in page 505 of Cengel textbook. Make sure you list your assumptions used in your derivation properly.
2) Using a BTU value of approximately 1000 BTU/ft3 of natural gas. Use approximately 83% is CH_4 and 14% is Ethane and the rest of the mixture has 0.5%CO_2, 0.5%H_2O and 2%H_2S. How much air-fuel ratio is required?
3) What is the temperature of air after combustion? Using a BTU values written above, in point 2, calculate T_{hot}, using $mCp(T_{hot}-T_{cold})$. Show these formula and steps in the presentation. Remember, after combustion, heat energy is transferred to the products. Discuss among the group and calculate the exhaust temperature assuming that the ambient is at 300 K and the pressure ratio is 9. Caution: Pressure ratio must be used to calculate the exit temperature of the air after compression and that temperature must be used as T_{cold} in the calculation above. Which one should you use Cp or Cv and why?
4) As discussed in class, why did author in Cengel text book have the temperature of heated air higher than the exhaust air temperature after heat exchange? Isn't it against the 2nd law of thermodynamics, which can be stated as "Heat cannot flow from a colder body to a hotter body without any external work being done"? Explain if the author was correct and if so, why?
5) Using effectiveness, presented to the end of Tuesday's class, if you didn't pay attention, see the Cengel Texbook in page 504, as 75%, what is the efficiency of regeneration cycle? Assume that the pressure ratio is 9 and air enters the compressor at 300 K. After combustion it must enter the turbine at T_{hot}. You should've calculated T_{hot} in point 3) above.
6) Using the industry personnel contact given in class, I requested his guidance for this part of the project due to his experience, as engineers email and ask him what might a typical mass flow rate of the flare gas be? An assumption is OK. But consult your fellow engineers or engineers from the field to attain the mass flow rate of the flare gas. Typically, industry personnel may state volume flow rate, and you can convert this to mass flow rate. Use the Natural gas composition as stated in point 2. If you have a much more accurate data, feel

free to use that composition. But remember, your group must use the same composition that you start with (starting from point 2 till the end) for this entire project.

7) What is the typical energy usage of a pump jack in an oil field? Again, for this, consult your fellow engineers in class, I was able to find some data through the web and it seemed reasonable. Similarly, you may find it on the world wide web or ask your fellow engineers for this data. You need this information to design a gas turbine to power this pump jack in the later steps.
8) Which gas turbine will you employ? Search for existing models and show a picture with their specifications. If your chosen gas turbine produces more energy than a pump, you can sell the excess energy to the power companies at a price of $0.13/KWhr.
9) For the selected gas turbine model in point 8) how much power can be generated using the mass flow rate from point 6)? Distinguish the part of the power used by the compressor and the rest coming out of the system to power the pump jack.
10) In point 5) you calculated the efficiency for a pressure ratio of 9, what will be the efficiency of the pressure ratio was 15?
11) Design a 500 MW system to be established in Odessa-Midland region. a) Using regenerative natural gas powered gas turbine and b) combined gas turbine and steam turbine. Which one will have higher efficiency? What are the mass flow rates of fuel in each of the two designs? Make appropriate assumptions like temperature inputs and what will your exhaust temperature will be and things like that. This is an open ended problem and I expect you to go over as much detail as possible using flow diagrams, T-s plots, efficiencies, costs, and turbine models etc.

Overall, the semester went great. I will be very excited to see your presentations on Wednesday. This was a great learning/teaching experience for me. We did this. I'm proud of you. You can do this project. I know each one of you and your capability. I designed this project keeping that in mind.
All the above being said, I do not have a nano particle size doubt about your engineering abilities. You will be excellent engineers and contribute to the society through your work in industries/start-ups. The questions you raised in class and outside class have motivated me to prepare well and bring the practical perspective as much as possible.
Good luck with the project.!!!

Future plans

In order to further expand the reach of the energy conversion course, several plans can be put into action. Firstly, a pre-course survey will be given to students with a set of questions. These questions aim to gather information on the prior knowledge of students related to energy conversion, the specific topics they would like to cover in depth, the format of the course they prefer, and their interest in working in the energy sector.

Secondly, efforts will be made to expand student participation through research. This can include providing opportunities for students to conduct independent research projects related to energy conversion.

Thirdly, the course will feature more projects with collaboration from local industry and fellow faculty members. These projects will be designed to offer a wide variety of learning opportunities and to enable students to engage with the practical applications of energy conversion.

Fourthly, the course will feature more hands-on learning opportunities. This can include the use of computer simulations, laboratory experiments, and other tactile learning methods. These methods will be designed to allow students to gain practical experience in energy conversion.

Finally, the course will be included in the future Masters in Engineering curriculum. As part of this program, economics in energy conversion will be included as a topic. By including this course in the Masters in Engineering curriculum, it will allow students to build upon the knowledge they gained in their undergraduate studies and to specialize in the field of energy conversion.

Through the implementation of these plans, it is hoped that the energy conversion course will continue to expand its reach and offer students a more engaging and practical learning experience.

Challenges

1) Students need to revise fundamental concepts: A primer on the fundamental concepts must be given in the beginning of the semester and a HW dedicated to the fundamental concepts assigned to students as HW 1 shall improve the students' performance in energy conversion course.
2) Students originally formed groups with their convenient team partners which separated undergraduate and graduate students into separate groups. To overcome this, the instructor must make groups comprising a mix of undergraduate and graduate students.
3) Limited availability of resources: The course covered a wide range of topics related to energy conversion, but due to limited resources, some topics could not be covered in depth. In the future, efforts will be made to ensure that students have access to all necessary resources for comprehensive learning.
4) Lack of industry exposure: Although the course had industry guest speakers, students did not have enough exposure to the industry. Efforts will be made to increase industry exposure through internships, site visits, and other relevant activities.
5) Keeping the course up to date: Energy conversion is a rapidly evolving field, and it is essential to keep the course content up-to-date. Instructors must keep themselves informed of the latest developments in the field and update the course content accordingly.

Performance

6 graduate and 7 undergraduate students took this course. Compared to the 1st midterm exam with an average score of 65%, the 2nd midterm and the final exam had an average of 70% and 80% respectively. This suggests that fundamental grasp of the concepts increased. 4 out of the 7

undergraduate students who took this course as an elective signed up for the accelerated masters' program track, thereby suggesting an increase in retention, participation, and improvement in the curriculum through such applied courses. Overall, the students attained a grade average of 77.8% including HWs, presentations, exams and projects.

Students were asked to present on topics such as

1) "History related to major engineering inventions that changed the course of our globe".
2) Presentation of the individual work after project 1 submission
3) Presentation of the individual work after final project submission

The instructor assigned scores and gave feedback on the categories that can be improved. Additionally, peer reviews with ratings were taken from the students.

Conclusions

Energy Conversion course is a crucial component of the undergraduate and graduate programs. It is designed to bridge the gap between these programs and help students increase their fundamental grasp, participation, engagement, retention, confidence, and responsibility. The course structure is centered around various measurable activities that are observed throughout the semester. The primary aim of this course is to increase the student's interest in fundamental concepts and provide them with the necessary skills and knowledge to apply these concepts in real-world scenarios.

The success of the Energy Conversion course can be attributed to its unique teaching approach. The course is taught through problems that involve design and analysis, individual and group projects, and industry guest speakers. The application of these concepts to real-world scenarios provides students with a better understanding of the subject matter. The course also includes an ethics component to meet one of the ABET requirements.

Throughout the course, students are exposed to a variety of topics related to energy conversion. These topics include the application of regeneration, reheating in boilers to solve complex problems related to setting up a steam power plant, analysis of jet engines and gas turbines, and application of sunlight for chemical energy conversion and storage through hydrogen production. Additionally, students learn about IC engine and calculate performance characteristics, analyze turbocharge, and understand and analyze the performance of propellers and wind turbines. The course also focuses on understanding and analyzing hydrogen production techniques and the use of fuel cell technologies. Students are encouraged to participate in group projects and present their assigned projects. The course is supported by teaching materials such as Energy Conversion by Kenneth C. Weston, Principles of Energy Conversion by Archie W. Culp Jr., and Energy Conversion: Systems, Flow Physics, and Engineering by Reiner Decher.

The effectiveness of the Energy Conversion course is measured by several outcomes. Firstly, the course aims to help students understand the working of a steam power plant and analyze input and output parameters. Secondly, students are expected to understand the working of a gas turbine and analyze input and output parameters. Thirdly, the course implements regeneration and reheat concepts and calculates efficiency. Fourthly, students are expected to understand the IC Engine and calculate performance characteristics. Fifthly, students should understand and analyze turbocharge. Sixthly, the course helps students understand and analyze the performance of propellers and wind turbines. Seventhly, the course aims to help students understand and analyze hydrogen production techniques and use fuel cell technologies. Finally, students are encouraged to participate in group projects and present their assigned projects.

Throughout the semester, students are assessed on their understanding of the course material through various projects, assignments, and presentations. The course structure is such that undergraduate seniors and graduate students collaborate to complete group projects. This collaboration between students enhances their interest in the program, ultimately helping in their retention. The success of the Energy Conversion course can be seen through the course evaluations provided by the students. Students wrote in the evaluations that the overall learning experience has been exceptional, and more courses like Energy Conversion are welcome in the future. The overall rating for the course was 4.53/5, indicating that the course was highly successful.

In conclusion, the Energy Conversion course serves as a bridge between the undergraduate and graduate programs and provides students with a better understanding of fundamental concepts related to energy conversion. The course is taught through real-world scenarios and includes an ethics component to meet ABET requirements. The course is supported by teaching materials and is assessed through various projects, assignments, and presentations. The success of the Energy Conversion course can be seen through the high course evaluations and overall rating. The course's effectiveness in increasing student interest and retention makes it a possible avenue for many positive attributes in the future.

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