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Integrating Student Perspective, Feedback, and Real-World Examples to Get the Most Out of Students; Improving a Paper-Based Design Project

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Abstract

How engineering students are taught design is a critical function of their education. Students need to not only learn how to design, but also how to share their designs with others. This sharing of information requires both written and oral communication skills. However, mastery of these skills alone, does not make one good at design. Therefore, engineering instructors focus on ways to teach design, and practice communication. Very rarely are students asked to provide input on what methods work best for them. Pencil and paper design projects are convenient because they are cheap and easy to execute with little planning or coordination. However, this does not reflect what students will experience when they finish school. This paper offers a continuation of a previous paper which discussed an assignment where students enrolled in a second semester thermodynamics course were assigned the task of designing a small-scale powerplant, capable of powering a small- to mid-sized university. The students were asked to do this having never actually set foot inside a power plant. While students had been required to provide a general idea on the size and location of their plant, it was clear students struggled with this requirement. To give current students a better appreciation of necessary design considerations they were given the opportunity to tour a local powerplant prior to starting the assignment. This tour also included students who had previously completed the assignment without this hands-on experience. This dichotomy provides a unique opportunity to examine the structure of the assignment and how to best enhance student learning. Both groups were able to reflect on how seeing a power plant firsthand guided or would have guided their decisions as part of the project. Input from both groups of students was assessed to be incorporated into future iterations of the project in order to help students get the most out of this project as they work through the design process.

Introduction

The goal of engineering faculty is to train new engineers. In addition to teaching fundamental concepts, faculty must also teach students how to design solutions to different problems. As noted by Koen [1], the primary function of an engineer is to design. Thus, engineering faculty are looking for ways to incorporate design projects into their classrooms. Ideally, these projects will excite students and enhance their learning experience. One of the challenges with this is finding new and relatable real-world problems for the students to work on. These goals and the challenges associated with them were discussed in the dissertation of Svensson [2].

The use of projects in engineering courses is nothing new. The study of Dym et al. [3] highlighted the importance and the challenges of teaching design in engineering courses. This difficulty has been documented in several Thermodynamics classes, as noted by Carvell [4] who found that students struggled when they moved on to more advanced topics such as system analysis.

Typically, design projects are assigned between the third- and half-waypoint through a semester. Assignments lay out the general guidelines students are supposed to follow. Students are than expected to, using their gained knowledge, develop a feasible solution. When students submit their project, faculty assign a grade based on how well they feel students completed the task. What this does not directly assess is the student thought process as they approached the problem. Invariably different students will focus on different aspects of a complex engineering problem.

One of the ways to foster student engagement is to include them in more of the assignment development process. The study of Bovill et al. [5] examined student involvement in curriculum design with mixed results. The primary goal of this paper is to examine how small changes in the way a project is presented to students affect how they approach the problem. This includes direct student involvement in the assessment in how the project was presented.

This paper begins a discussion of the learning pedagogy. This is followed by an overview of student experience throughout the curriculum, prior to the current design project. This is followed by a brief synopsis of the assignment as presented to the students. The next section provides the instructor's evaluation of the student performance as a whole. This is followed by the equally valuable student perspective of how the assignment went. This includes aspects of the assignment they found useful and items they wish they had known prior to starting the assignment. Finally, conclusions, lessons learned, and suggestions for incorporation into other assignments are presented.

Learning Pedagogy

Projects are always changing and adjusting to meet student needs. The value of hands-on learning is well documented. Green [6] highlighted the value of thermodynamics students touring a powerplant to see how the topics discussed in class are applied in real-world situations. This view is not universally held as other studies have found students to become overwhelmed by the size of a powerplant, losing track of the basic cycle they are attempting to model as discussed in Kelly [7], [8]. Therefore, adding a powerplant tour to this project was not a goal in the first few iterations, but when a connection was made with the local powerplant, the opportunity was taken to give students this experience.

When teaching design, the goal is to get the students to move beyond a simple paper-based design and appreciate and apply real world limitations. The study of Kribs [9], examined undergraduate student confidence levels in comparison to actual performance in engineering labs. In general, students were always more confident than their abilities, however, there was a greater disconnect with students who performed poorly. Design projects are similar to labs in that they require students to apply the principles taught in the classroom. One of the ways suggested to limit this dichotomy was to expose students to the vast amount of knowledge in the field. While there is a danger of this amount of information overwhelming students, it could also give them a more accurate understanding of their skills and limitations.

While professors are constantly trying to invigorate students, developing a new grand project every year could be dangerous. As discussed in Boles et al. [10], it is important to maintain a stable curriculum, therefore minor changes are preferred. While projects must be constantly updated and evaluated for effectiveness, major changes could negatively impact student learning.

Previous Experience

Mechanical engineering programs are designed to get students more comfortable with designing systems as they progress. While this starts with solving problems with single answers pulled from textbooks, as students progress, they are presented with problems where multiple answers become acceptable solutions.

Students at the University of Jamestown are introduced to design in their first semester of the engineering curriculum. The goal is to give students at least one design experience, with increasing complexity, every year in preparation for the capstone senior design course. These projects are presented as assignments contained within various courses. The goal is that these assignments will engage students more than a simple homework problem.

Paper based design projects are attractive because they have virtually no cost and students who put forth an effort are guaranteed at least some level of learning. Thermodynamics as taught to mechanical engineering students is typically a one- or two-semester series. While the first semester introduces the laws of thermodynamics, the use of steam tables, and analyzing key components; the second semester turns its focus to cycles, particularly gas-power cycles and vapor-compression cycles.

This background of knowledge is used to introduce the concept of designing their own cycle. This paper is a continuation of the project previously reported by Keesee [11]. The project this year was enhanced by giving the students an opportunity to tour a local powerplant prior to beginning to design their own cycle. What makes this updated version of the project unique is that both previous students and current students were invited on the tour, and able to provide feedback about how this additional experience affected the project. This included previous students highlighting the things they wished they had known.

Assignment

Students enrolled in Thermodynamics II were presented with the scenario of designing a new powerplant for the university. The parameters for this plant were that it must produce at least 12-MW of power, with a maximum temperature of 620 °C. This power usage was based on an estimate of what a typical small- to medium-sized college campus typically uses. The temperature limit was based on the Rankine Cycle metallurgical limit as specified by Çengel et al. [12]. However, if students could prove a higher temperature could be achieved, they were allowed to use the higher temperature. As shown in Figure 1, the assumed starting point for this project was a simple, ideal Rankine Cycle. At a minimum students were expected to find data relevant to isentropic efficiencies of real components and make adjustments accordingly.

Students divided into teams of two to complete this project. Deliverables included a written report that was to be roughly 4-5 pages in length. This report was expected to include any necessary figures, diagrams, and calculations. Students were also required to give an oral presentation in class. The target length for these presentations was fifteen minutes.

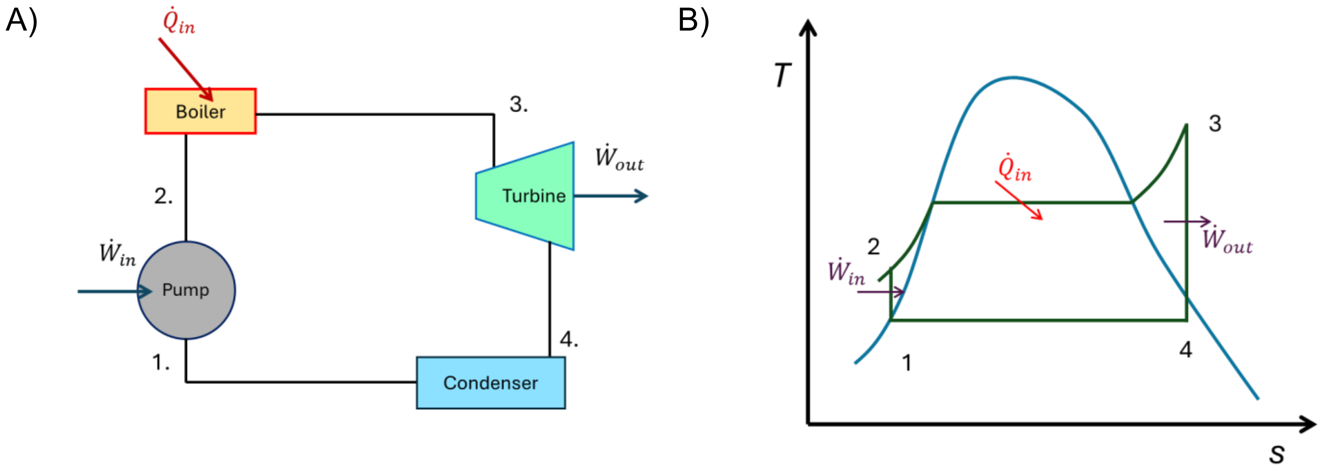

Figure 1. A) Component diagram for a generic, ideal Rankine Cycle. B) T-s diagram for the generic, ideal Rankine Cycle

This iteration of this project differed from previous years by two key factors. First students were given the opportunity to tour a local power plant prior to being presented with the assignment. This tour was also open to students who had previously completed Thermodynamics II. This allowed for a unique opportunity. Both groups of students were asked, on a strictly voluntary basis, to provide feedback as to how the tour directly impacted their completion of the project. The current students were able to focus on how details they learned during the tour directly impacted their design. Former students were able to provide a more retrospective analysis focusing instead on things they learned in the tour that they wish they had known. The results from the student feedback are contained herein.

Student Execution

The current cohort of students consisted of six students. This is comparable to the eight students who completed Thermodynamics II the previous semester. The largest cohort consisted of 9 students. This project has been assigned over the course of six semesters. The first three cohorts were required to complete the project independently, while the last three worked in teams of two to three students.

Every academic year is unique with its own challenges. As shown in Figure 2, the students this semester were presented with a slightly compressed timeline. This was due to where Thanksgiving break fell in the semester, and the limited class sessions for student presentations, and material review to prepare students for the final at the end of the semester.

In terms of cycle design there was very little difference between the current cohort of students and previous years. Estimated efficiencies ranged from 42.5% to 60.24%, which is similar to those of previous students. Interestingly, none of the teams completely modeled their design after the plant toured, a Combined Heat and Power (CHP) plant. Two of the three teams chose to design a combined cycle plant, while the third team chose instead to implement a reheat Rankine cycle. One of the Combined cycle plants also included a CHP system to get use out of the waste heat.

This brought their effective efficiency up to over 86.3%. One team took their analysis in an unexpected direction by including a full economic analysis of the university's actual power consumption.

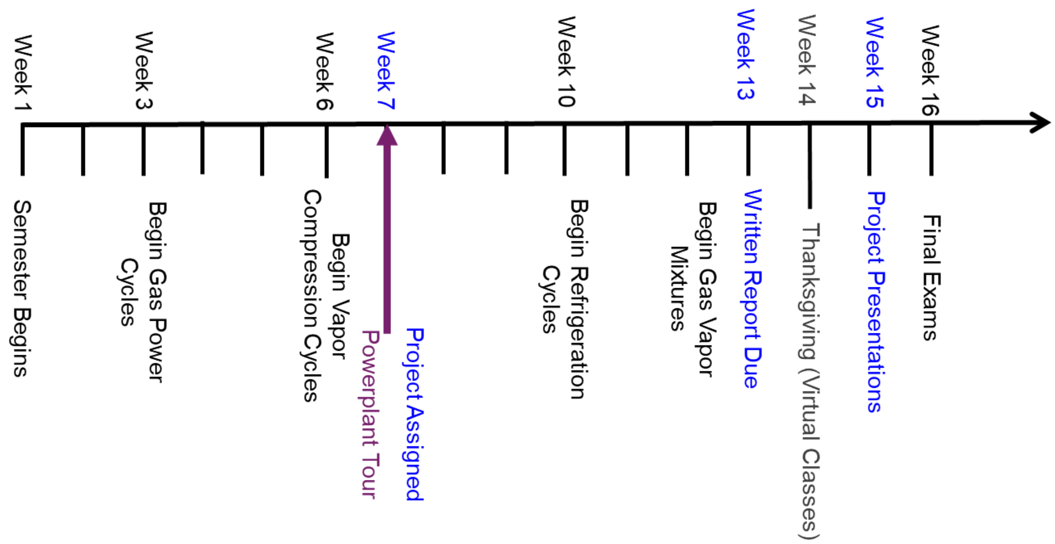

Figure 2. Project timeline, highlighting key points throughout the semester, including lecture topics, project deadlines, and student vacations.

In general, students do not come to the professor with lots of questions or seek counsel as the assignment progresses. When they do bring questions forward, they are generally short answer questions, such as, "I can't find a published isentropic efficiency for this component, what should I do?" On rare occasions, maybe twice in six years, students will come forward looking for a conversation about the pros and cons of different design decisions. If students seek this advice too early in their design process, the design is at risk of becoming the instructors instead of their own. The downside to this lack of intervention is that some students have no external input on their design until they submit their final project.

The hope was that changing this to a team-based project would alleviate this concern somewhat. Students would be forced to discuss various parameters with a classmate, determining which ones were most important to focus on to create an efficient design. However, the results of teams versus individual students are similar. This might be due to most students having the same baseline education and experiences. Therefore, the reduced grading time is the primary benefit of allowing teams.

One of the things this modified project highlighted was a lack of appreciation for what the students did not previously know. Since students "don't know what they don't know" it is not always easy to ask the right questions. A key example of this would be the astoundment at the sheer magnitude of the powerplant. The layout design and space requirement are significantly different when you understand your fuel consumption to be train cars of coal as opposed to one or two bags of charcoal.

Soliciting student input on project design is both a dangerous and eye-opening experience. Students without a real-world comparison were lost on how to even start the project. They found the requirement to find "components that exist" overwhelming when the textbook had presented shape-based diagrams and figures. This blind search for real components led to the internet, which provided the entire world of powerplant technology, making it difficult to narrow down what the students were looking for. Therefore, students might need more direct involvement and support as they work thorough this stage, as they are unlikely to seek help or advice unprompted.

Student Perspective

Student involvement for this project was very open-ended. Part of the goal was to generate completely honest feedback. The concern was that Likert Scale questions typically lead to quick answers and it is unclear how much thought or effort the student put into completing them. Aznar-Mas et al. [13] found that open ended questionnaires offered a broad amount of qualitative information for engineering faculty. While low response rates are somewhat discouraging the results can still be assumed to be valuable in designing and adjusting projects in the future.

Students were asked to provide one to two paragraphs about their approach to the project. Particularly, "How did the powerplant tour affect your overall approach to the project?" Or "What did you learn on the powerplant tour, that you wish you had known when you were working on the project?" A follow-up question asked about any changes that would be beneficial to future classes. Overall, the students found the powerplant tour beneficial. The below comments are taken directly from the student assessments:

- It was important to see the limitations of real-world products and understand how far from ideal a real powerplant is, especially compared to the idealized problems solved in class.
- The size and complexity of the powerplant was truly incredible. This provided a knowledgeable perspective when designing a powerplant on a much smaller scale, as this plant could produce ten times what the assignment required.
- An idea of what real life energy consumption and output looks like
- A firsthand appreciation of the amount of coal and natural gas consumed – rail cars full of coal constantly feeding the furnaces – this led to a realistic understanding of fuel flow rates
- How losses in ducting could affect possible locations
- Appreciation for the true scale of the equipment involved.
- Cannot visualize how large components such as turbines and boilers are from textbook problems

When comparing this project to other assignments, one student highlighted the fact that many courses focus on the steps that need to be followed without providing a full understanding of why those steps work. In hindsight, another student wished he was better prepared for the powerplant tour, with solid questions for the plant engineer. This student was also fascinated by the operational cost of running a powerplant. With this in mind the student's team investigated what the university spends on power and proposed ways that their design could become profitable if it was actually implemented. The recommendation was made to add a profitability component to the project in future years to broaden students' understanding of the overall impact of their design.

When asked if any additional steps should be added, to aid in the design process, one student thought either team (or individual) meetings with the professor to discuss their ideas could be beneficial. These meetings could be most helpful if they occur within two weeks of the project being assigned. This would allow the teams to get an initial understanding of the project scope and conduct preliminary research into specific designs. The student also pointed out that the effectiveness of these meetings would very much depend on the effort the students put into it. Ideally students would come to the meeting with a short proposal, and possibly a presentation, to guide the discussion.

Overall, the student response was lower than desired. Only one former student (out of ten available), and two current students agreed to provide feedback. The two students from the current year group represented different teams.

Conclusions

Over the past six years, students enrolled in Thermodynamics II have completed a paper-based project where they designed a powerplant for the university. These students are in their junior year of a four-year engineering program. The last iteration of the project was modified to give students the opportunity to tour a real powerplant, prior to being asked to design their own plant on paper. The hope was that this would greatly improve the student understanding of the requirements.

The tour of a powerplant definitely impacted students' understanding of the scope of the project. All the students who provided feedback commented on their surprise at the size of the components involved. This highlights a teaching challenge, where faculty are frequently required to convey such information to students without necessarily being able to show them a physical example.

With a small response rate, 18.75% of available students, to a survey there is always the danger of assuming the wrong thing. With such a small data set it is unclear if the tour had a significant impact on the student designs, as there was no significant difference in chosen designs or efficiency achieved. While a benefit is unclear, there is no evidence that it hindered their designs. Also, a deeper understanding of how students approach problems was gained. Without sufficient guidance and support students can become overwhelmed by an abundance of information as they seek to design a system without any appreciation for size and scope. The only way to understand the student thought process as they approach a design project, is to ask them, in a non-judgmental fashion.

With that in mind, future studies should focus more on the mindset of students as they approach a problem. In this case the students were awestruck by the sheer magnitude of a powerplant and designed with that in mind. Students could have just as easily focused on fuel consumption and searched for a design addressing that requirement. To address this open-ended vagueness an additional step will be added to future iterations of the project where students discuss their initial thoughts with the instructor. An additional future study will also look at how student design methodology morphs from their first exposure as freshmen through their senior design project.

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