Adding Reflection and Oral Communication to a Design Project – Work in Progress

Reflection-in-action was encouraged in a junior-level design project by providing a competitor's design to teams. Students then compared their designs to the competitor's design in an oral presentation. The competitor's design had calculations errors and a different, less expensive process than most of the students chose to use. Interesting questions developed as students compared their designs to that of the competitor. Methods, transferability, pitfalls, and future studies are discussed in the paper.

Introduction

A colleague [placeholder for blind review] and I have taught similar junior-level courses at different universities for a few years, and we have done joint design projects. The projects have had varying success, and the students often complained about the difficulties in working with a remote team (which was part of the point of the joint project). Because my 2017 seniors complained that they had made very few, if any, oral presentations in coursework before making presentations during their summer internships, I wanted to add an oral presentation to my design project for the junior year. The plan to continue the joint remote project with an oral presentation was that each of my teams would be given a design from a remote competitor team and would make a presentation comparing its design to the competitor's design. Although the joint remote project did not come about this year, I created a single competitor design for my teams to compare to their work in an oral presentation. Studying the competitor's design nudged the students to ask if they could revise their own designs before the oral presentation. This reflection is something that I want to encourage and study in a future offering of this course.

Reflection-in-Action

According to Schön 1983, an expert practicing engineer engages in reflection-in-action, evaluating and learning from situations as they occur. The reflective process is often triggered by a surprise. Receiving the competitor's design provided a surprise to my students, which led them to reflect on the work they had just completed. This activity is similar to the reflection activity by Issen 2017 in which the students complete a peer review of another team's design. Peer reviews require less time of the instructor: no time necessary to create the competitor's design and possibly less time grading as the students review each other. The students have likely already been discussing their design projects extensively and may be submitting relatively similar designs, so peer review may not generate much of a surprise. A competitor design prepared by the instructor or a teaching assistant can incorporate differences from the students' design that are intended to surprise the students. The next sections describe the assignment, the competitor's design, and the common questions generated by the competitor's design.

Adding Oral Communication to a Design Project

The design project was started in the same way as in previous semesters. I collected information on schedules and writing ability on TeamMaker by Layton, Loughry, Ohland, and Ricco 2010 and had it form ten teams of four students with similar schedules and disparate writing abilities.

The teams were given a project based on work by Turton and Shaeiwitz 2017 to simulate a cryogenic air separations process, estimate the capital and operating expenses, and recommend a design for further study based on the lowest equivalent annual operating cost. Each team prepared a memo on its recommended design with a detailed appendix of supporting calculations. The difference this semester was that I prepared my own simulation, calculated costs, and wrote a memo to create the "competitor's design". After the students submitted their reports to me, I gave them my simulation, Excel calculations, and memo. Each team then had a week to prepare a 10-15 minute presentation comparing its design to mine and recommending one for further study.

The design project accounted for 15% of the course grade, and the teams had three weeks to prepare their memos after receiving the problem statement. Writing aspects (grammar, spelling, etc.) were 30% of the project grade. Technical aspects were 50%, and the oral presentation was 20%. The oral presentation was graded on length, equal participation, slide quality, design comparison, and recommendation, with comparison receiving 6 of out 20 points, recommendation only 2, and the remainder evenly distributed. Students were not graded on speaking skills or lack of nervous habits. Students did not receive any feedback on their memos or designs before making the oral presentations other than through informal office discussions. Teamwork was assessed using CATME by Loughry, Ohland, and Moore 2007, and some grades were lowered by 5 points because of low team evaluations.

Development of the Competitor's Design

Although I tried to do a good job with my competitor's design, it was not perfect when I gave it to the students. It did not quite meet the required product purity or flowrates (depending on the number of significant figures one assigned to the target values). I knew that most of the students had chosen a design with a very low temperature refrigeration process that would require substantial operating and capital costs, and my design avoided the refrigeration process. I added some "adjustors" to my simulation that I did not provide costs for, as I was using them only to make our simulation package match the (dubious) thermodynamics of the problem statement. My competitor design then wound up having some aspects that were better than most of the student designs and other aspects that were worse than their designs.

Because I was rushed for time, I inadvertently made cost estimation mistakes that the students found. I made a unit conversion error, used the wrong maximum size for equipment, and forgot to multiply a price per item by the number of items. The unit conversion error made my equipment sizes and corresponding costs much higher than they should have been, and forgetting to multiply by the number of items obviously made the equipment costs lower than they should have been. The net effect was that my equivalent annual operating cost, which was already lower than most of the students', was higher in my memo than the real cost of the design.

Reconsideration in Preparation for the Oral Presentation

The students then ran into interesting questions as they prepared the comparisons of their designs to mine. If they found a mistake in the competitor's design, should they correct it? If they and the competitor used a different "constant", such as overall heat transfer coefficient, should they

use the same one in both designs for better ground for comparison? If they found mistakes in their own designs, should they correct them before the oral presentation? These questions and my resolutions are discussed below.

Should a team correct a mistake in a competitor's design? Yes, when it is possible. My teams received much more information than they normally would from a competitor: a competitor is not going to include the cost estimation equation as I did, for example. Because of this, it was fairly easy for them to find my mistakes when they reviewed my calculations. If they were actually reviewing a bid on the job and noticed that the costs were not reasonable for the sizes the bidder was claiming, they would either question the bidder about the costs to get a correction or not go with that bid. I could have provided a revised set of files that corrected my mistakes, but it was more instructive for the students to find them and correct them. I did not penalize students for not finding all of my mistakes.

Should both designs use the same constants? I let the students decide on this one and discussed the benefits of each approach with them in my office. Using the same overall heat transfer coefficient for heat exchangers with similar functions makes comparisons between the two designs clearer. Two different companies can reasonably use different overall heat transfer coefficients within a range of values, though, and it may be that the two different companies simply have different in-house values to use for estimations. The students should be encouraged to do a sensitivity analysis of the constant in question on the final value of interest.

Should the students correct mistakes in their submitted, written reports before making the oral presentation? Absolutely! Data that are known to be incorrect and can be corrected are a very poor support for that design. Does the team then automatically recommend the competitor's design because it is correct and theirs is wrong? Of course not: the team will correct the design. Teams were allowed to correct their calculations before presenting. I did discourage them from making big changes, such as removing the refrigeration system to make the design more like the competitor's design. Small changes such as unit conversions and constants could be made. In real life, the team would need to resubmit the written report, but that was not required for the course.

One student complained that my calculations were hard to follow because they were not laid out the same way as her team's calculations! As engineers will spend many hours deciphering the calculations of their colleagues, I considered this to be a good exercise.

Course evaluations revealed that the concept of evaluating a competitor's design will need to be carefully explained. At least one of my students felt insulted that the competitor's design was not as high quality as the students' designs and that not much time was invested in it because of my mistakes. Good engineers should compare a competitor's design to their own estimates of the feasibility and costs of the design, which does mean repeating the calculations. Good engineers do not assume that the competitor's design is flawless. With a simulation package and a pre-existing spreadsheet, the time involved in checking calculations should be minimal, but the students should be prepared psychologically to do this.

Oral Presentations

Each team chose a 30-minute slot for the 10-15 minute presentation to me alone. The intent of the presentation was to give them at least one chance to present before being required to present at a summer internship. After questions were done, I went through the team's slides one-by-one, giving them positive and constructive feedback. I gave the class a template on the Assertion-Evidence format of slides by Alley 2017, but some had difficulty applying the format and others ignored it entirely. Feedback right after the presentations in a discussion worked well.

Most of the teams addressed the questions above in their oral presentations. They mentioned that they found and corrected errors in the design that was supplied to them. They highlighted the different values of the overall heat transfer coefficient, or they mentioned that they had changed to a consistent set. They addressed the effect of the extra refrigeration equipment in their designs on the overall cost. Some mentioned that the numbers for their design were different in the oral presentation than from the memo because they had corrected mistakes since the memo was submitted.

Transferability to Other Courses and Projects

Several aspects of this design project could be easily transferred to design projects in other courses. My competitor's design had flaws that could be incorporated in many situations: not meeting the specifications and calculation errors. The expensive refrigeration system and thermodynamic adjustors are not easily transferred to any other project. If many of the students are going down one path with the design and another path is feasible, using that other path for the competitor's design provides more discussion material for the students. For example, a thermodynamics design project with an open feedwater heater steam power plant could have a closed feedwater heater power plant for the competitor design. Careful explanation should be given if the competitor's design is outside the scope of the students' assignment, so they do not feel that it is an unfair comparison.

Oral presentations are not needed to gain the benefits of comparing the team's work to a competitor's design. The students could make the comparison in a written report instead. If oral presentations are desired but scheduling them is a problem, the students could make videos of their oral presentations.

Future Study

Reflection-on-action is a break in the activity that is used to reflect on the processes that have just been completed, evaluate them, and consider changes for the future, as described by Schön 1983. Reflection-on-action can be used to assess reflection-in-action, according to Davis et al. 2009. To assess the effect of surprise from the competitor's design, reflection-on-action assignments will be given to a control class and an intervention class. Both classes will have a design project, and both classes will report with a memo and an oral presentation. The control class will be a sophomore-level, Fall 2017 thermodynamics class, and they will not receive a competitor's design to compare to their own designs. The intervention class will be a junior-level, Spring 2018 separations class, and they will compare their design to a competitor's design

for the oral report. Both classes will complete a reflection-on-action exercise after submitting the memo and after giving the oral presentation. This exercise will be based on the Problem Solving Focused Questions from Siewiorek et al. 2010. These questions ask the students to describe "aha" moments in the problem solving process, and I hope to see that some of them are prompted by the competitor's design. The students will be asked to give examples from later in the process rather than earlier, if possible.

Conclusions

Although the oral presentation was added to the design project to simply provide the juniors an opportunity to present before summer internships, the assignment yielded much more. The reflection-in-action triggered by the competitor design led to a much richer experience than the students would have had if they had presented on only the team's design. The students had to understand someone else's work, evaluate that work, and then reconsider their own work after learning from another's design.

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