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Using Senior Peer Mentoring for Experiential Learning of Core Chemical Engineering Topics

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Work-In-Progress: Using senior peer mentoring for experiential learning of core chemical engineering topics

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Introduction/Motivation

Novel practices are being implemented that deviate from the typical in-class instruction with an emphasis on applying classroom learning to real-world situations. Internships are a great way to enable the implementation of this objective. They provide hands-on experience and help connect the subject matter to practical applications. In experiential learning, students learn by doing and reflect on their learning [1]. Creative projects can help accomplish this goal. In this work, we bring the benefits of the internship experience to the classroom. We combined this with peer mentoring [2],[3],[4],[5] for added benefits. Senior students have been informally known to guide lower-division peers, whether it is through study advice, resource sharing, or being a point of contact. Having shared similar experiences, they can benefit the mentee by helping them avoid common pitfalls to be successful.

In this work, we have created a novel interaction between the final-year students and the juniors. The two courses selected for this experience were Capstone Design and Process Control and Safety. These courses were selected since the authors are the instructor of record for the courses.

Methodology

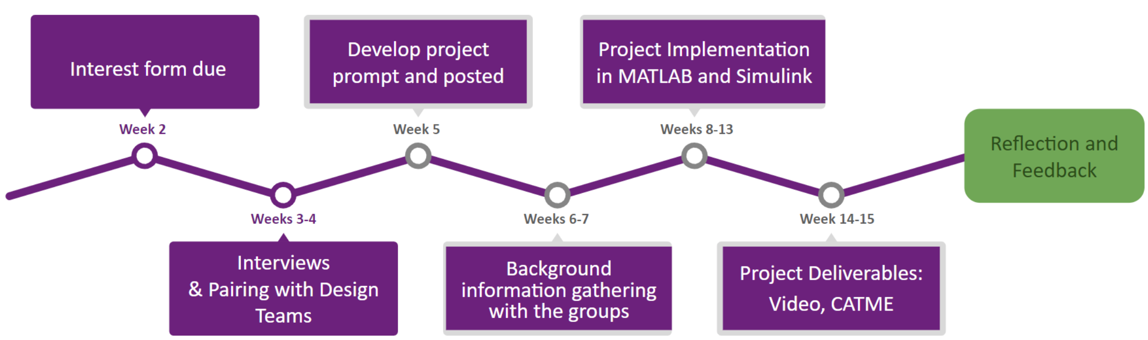

Figure 1: Workflow of the process with the timeline.

The workflow of the implementation process is presented in Figure 1. The process starts with recruiting the juniors to participate in this project. The juniors submit their resumes which are shared with the design teams. Both seniors and juniors prepare for a round of interviews in person. The interview process is designed to mimic a formal interview but is much shorter. The instructors provide the interview schedule based on the student's availability. If students cannot attend the interviews, they prepare a short video highlighting their skills. The design teams and the students interviewed are allowed a minimal number of vetos based on their impressions during the interview. Student feedback is collated and used in pairing the juniors with the design teams. Depending on the class sizes and the interest, 1-3 interns can be assigned to a team by the instructors.

The students who do not participate in this internship experience or those who don't get placed are assigned a separate project to fulfill the requirement. Once the pairing is complete, the actual implementation of the project starts. The design teams then develop the project prompt comparable to the regular controls project but adapted to their capstone project. The two instructors ensure that the scope of the work assigned is feasible. The interns start their work with background information collection based on the assigned prompt. Although, at this point, the juniors haven't learned all the concepts needed for project completion, they are advised to work on it as they keep learning the material. This also helps with relating the class concepts to the project at hand. Working with the senior design teams on data gathering also helps build relationships. The final phase of the project involves completing the implementation of the control scheme in MATLAB and Simulink. The final project deliverable is a short 4-5 min video per student. The video describes the overall chemical process of the design team, the details of the unit operation to be modeled, and the control strategy and implementation. All the necessary files are delivered to the respective design teams. The videos are graded by the design teams and the instructors, emphasizing grades from the two instructors. The juniors have to complete a CATME [6],[7] if they work with other juniors and provide them feedback. They can also leave feedback to the instructors about their experience with the project idea.

The learning objectives that the project targets are as follows:

- Develop and solve fundamental or empirical models for dynamical systems
- Understand the fundamentals of control strategies and their implementation
- Use computer-based tools for dynamic model simulation and implementation and comparison of control schemes

In addition, this novel idea also satisfies the following ABET-related student outcomes:

- An ability to identify, formulate and solve complex problems, including the use of modern tools to solve them
- Oral communication
- Ability to work in teams

Preliminary Results

The authors have opened this opportunity within their respective classes for three past years: Springs 2019, 2020, and 2022 and currently 2023. As Spring 2021 was a completely online semester for the University (except for laboratory classes), it was skipped. The number of design teams and juniors that participated in this venture is summarized in Table 1.

Table 1: Number of Design Teams and Interns participating

	2019	**2020**	**2022**	**2023**
Design Teams	14	8	9	11
Interns	19	16	24	15

In Figure 2, we compare the scores received by juniors that participated in the intern project and the ones that remained with the regular project. The scores for the Intern project are consistently higher than the regular project and have a lower standard deviation (except in 2019). In 2019, two juniors did not fully complete their project and received lower scores. As seen in the figure, the differences for 2020 and 2022 are statistically significant. The 2019 comparison did not yield a significant difference due to the presence of the outlier. However, the means do indicate the same trend as the other two years.

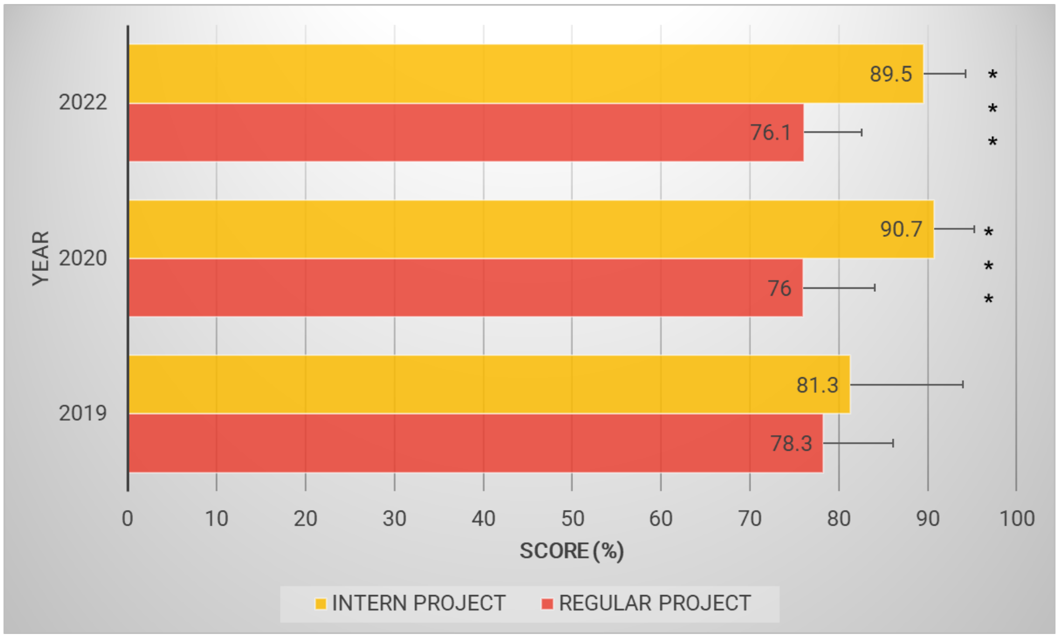

Figure 2: This figure shows the scores for the regular project compared with the intern project across three years of implementation. The three asterisks indicate statistically significant differences with p-values less than 0.001. The 2019 difference was not statistically significant due to the presence of the outlier.

There are no special requirements to participate in the intern project. Both instructors, when presenting the project, reinforce the idea about the experience versus being the ‘best’ candidate for it. In Figure 3, we compare the average GPA for the course for juniors that participated in the intern project. The differences between the course GPA are statistically significant for all years of implementation with a p-value of at least < 0.05.

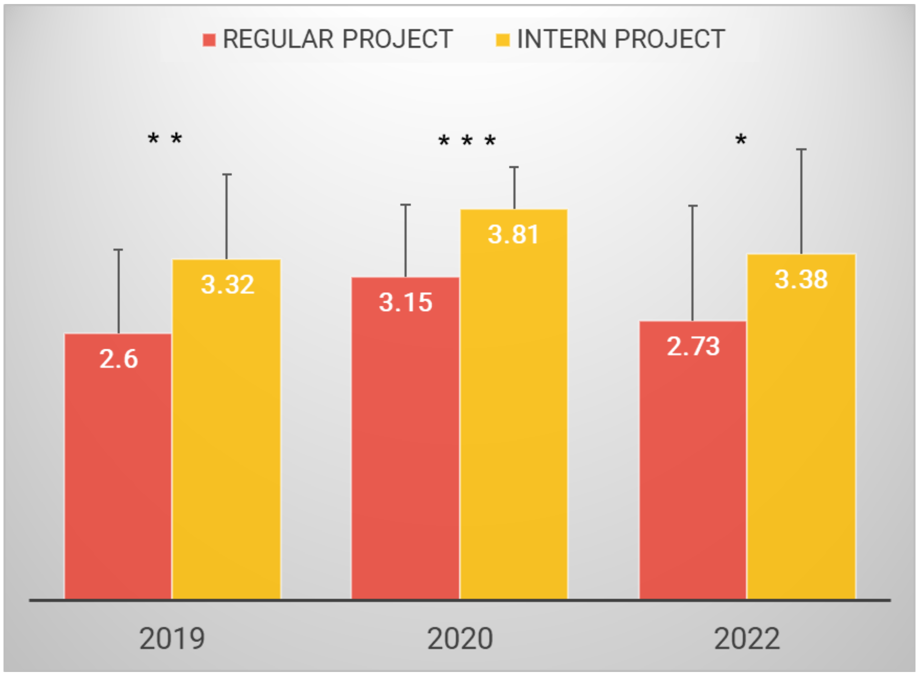

Figure 3: This figure shows the average course GPA for the regular project compared with the intern project across three years of implementation. The average course GPA for the Intern project is consistently higher than the regular project. The standard deviation, however, is similar for both project styles except in 2020. The asterisk denotes the significance of the result at varying p-values. (One, two and three asterisks correspond to p-value <0.05, <0.01, and <0.001, respectively).

Preliminary Feedback

Overall, this initiative has been well received by the students. A selection of juniors' quotes from the interview process and end of the semester are listed below. In summary, most of them were fairly positive, with a few recommendations for improvement.

- "Getting a glimpse of how the skills we're learning now will be applied to our design class was fun. I also enjoyed getting to meet the senior class of ChemEs, many I had never seen before."
- "One of the design groups had my resume open during the interview and asked me a few questions based on the information in it, which I really appreciated."
- "I really enjoyed working with this group. We didn't have much of any conflict at all. And I feel like we got what we could have done in the time permitted to us."
- "I think the intern project is tough but a great learning experience and well worth it."

Other comments that provided room for improvement have been listed below, with our strategy to incorporate the unfavorable feedback into the current implementation.
Theme: The assigned project is difficult, and tasks are not clearly communicated.
Change: As the instructors, we will vet the project prompt assigned by the Seniors. We will also require regular communication and meetings between the interns and the design teams.

Theme: Not enough time to learn the content related to the project and deliver the project

Change: The course schedule has been modified to front-load the controls content and ensure sufficient time for the project. We will also set intermediate deadlines for project deliverables for better project management.

Seniors Feedback from Spring 2020

For the Spring of 2020, we asked the Senior Design team to answer four questions at the end of the semester: 1. What worked well with the Control Interns? (include selection, interview, interactions, deliverable, timeline, etc. 2. What did not work well with the Control Interns? (include selection, interview, interactions, deliverable, timeline, etc. 3. Provide two pieces of advice for your Juniors to become better engineers. And 4. What would you change if we were to do this next year? For the first two questions, we created two-word clouds:

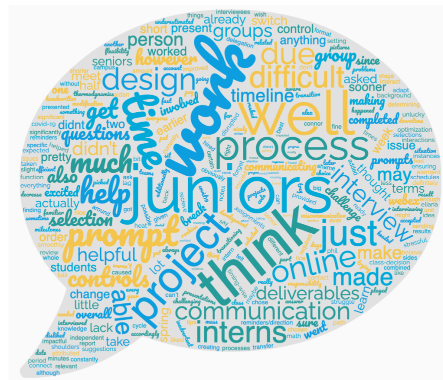

Figure 4: The word cloud on the right represents the text from what worked well questions. The word cloud on the left represents what did not work well.

Overall, the Seniors thought the interview process worked as it should, and many requested more time for an interview. Still, at the same time, it was followed with comments that they foresaw how this would not be practical or even possible regarding the number of students and interviews. They acknowledged that preparing the questions for the interview and the feedback received for their interview process was well organized. In terms of what did not work well. The program is small, students know each other, and many Seniors are teaching fellows for sophomore and junior classes. They know the students well, and we believe the past interactions influence the evaluation of the junior applicants. Another item highlighted was communication from all levels, instructors from both classes to their respective classes, to the other class, and communication between interns and the Senior Design team. Interestingly only one group out of the eight mentioned the pandemic and online instruction being a hindrance. The rest of the groups shared that Webex and GroupMe allowed them appropriate communication channels. The last item repeated in many teams was the timeline; interns start their work too late to feel it is a useful contribution to their project.

Table 2: Summary of the advice to the Juniors and changes to future implementations

Advice to the Juniors
Slide design is important

Learn to make assumptions to solve the project or don’t be afraid to make them
Ask questions!
Cooperation is key!
Do not fear making mistakes

Table 3: Summary of the recommended changes to future implementations by the students

Changes to implement in the future
Moving the project earlier
More interaction with juniors - Seniors are encouraged to meet with their intern team, but it was not measured or reported back
Consider interns participating in other aspects of Process Control and Safety class, not just controls, but safety or optimization.
Include juniors in Senior Design presentations
Increase the presentation time for the juniors' deliverables

Future Work

The authors acknowledge the timing between the work done in the Process Control and Safety class and the timing for the Seniors' deliverables is less than ideal. Adjustments in both classes are possible and would be looked into. Some other improvements would be to have more time for the interviews, have the design group project information provided to the potential interns beforehand, and incorporate a 5-7 min Q&A with all the groups at once, where the interviewees can ask all the groups at once certain questions.

We need to find a solution to the perception that only students with higher GPAs will be successful interns. Our average student population works more than 20 hours per week [8]. Many students cannot participate in an internship for a variety of circumstances. This effort is brought to the classrooms; students would have to complete a Controls project regardless, so our ability to provide them with a small glimpse of what an ‘out-of-the-classroom’ experience could be valuable. To this end, we will implement a short survey with specific questions for the students who did not participate. This could give the instructors an idea of how to change this outcome.

The authors believe this effort should continue; it strengthens the community between senior and junior level classes and benefits overall experience. We also provide a distinct channel that connects a junior class with the Capstone course.

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Supplemental Materials

A. Sample Project prompt for students participating in the regular project

ENCH 442 Spring 2023 Controls Project

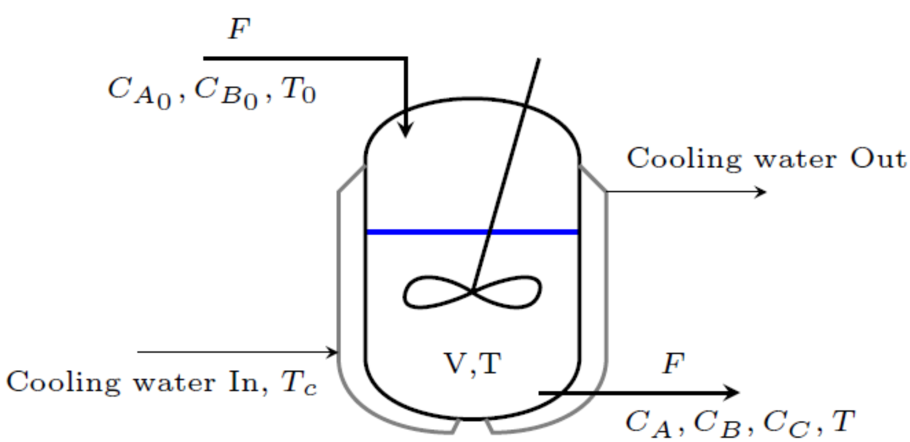
Goal: Control Scheme Implementation for Optimal Temperature Control with Safety considerations

Description

Consider the following exothermic irreversible elementary reactions (liquid phase) occurring in a continuous stirred tank reactor with a heat exchanger:

$$2A \rightarrow B$$

$$2B \rightarrow C$$



The CSTR system is optimized to find optimal operating conditions with the goal of maximizing the profit per year. The goal of the controls project is to design a feedback control scheme to control the temperature of the reactor. The temperature control is important since the conversion and selectivity depends on it. The reactor is also designed to operate in the permissible temperature range.

Control Goal: Addition of appropriate P, PI or PID controller allows precise control of the reactor temperature. You must provide recommendation on the best feedback control strategy to use for this case.

Safety Goal: Conduct a safety review of the reactor system with the control system in place.

B. Sample Project prompt for students participating in the intern project

Goal: Implement a Control Scheme for Optimal Temperature Control of the Inoculum Preparation Seed Bioreactor. **Description:** Cells produce heat as they grow and reproduce. To ensure that the cells remain at their optimal temperature, a cooling jacket will be needed. Using the information below, use your engineering background to design an optimal control scheme that will keep our cells healthy and alive.

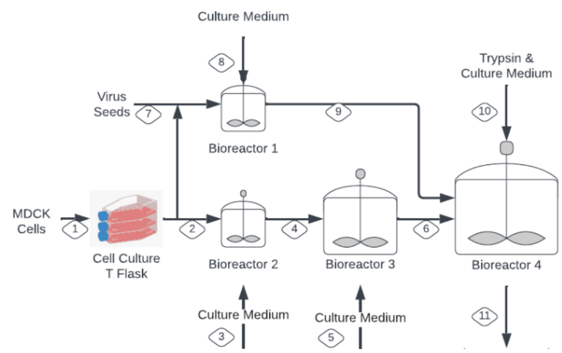


Figure 1. Schematic of the first four steps of the process.

The bioreactor three is our last unit before our bigger reactor, where viral production will occur; therefore, it is crucial that the cell batch in the former does not go bad and is ready to be used for the next step. Heat is often generated during fermentation reactions. The heat of combustion of cellular material can be defined by the following equation (Shuler, 2010):

$$Y_H = \frac{Y_{X/S}}{\Delta H_S - Y_{X/S}\Delta H_C}$$

where Y_H is the cell mass produced per unit of heat evolve, and ΔH_S and ΔH_C are the heat of combustions for substrate and cell respectively. Typically the Y_H for glucose is 0.42 g/kcal. The total rate of heat evolution in batch fermentation can then be described by the following equation (Shuler, 2010):

$$Q_{GR} = V_L \mu_{net} X \frac{1}{Y_H}$$

where V_L is the liquid volume (L) and X is the cell concentration (g/L).

For this project, please determine the effect that a cooling jacket would have on the temperature of the reactor. It is desired to maintain reactor temperature at 37 C, so it is important to calculate the amount of heat generated and ensure that the cooling jacket input temperature is low enough such that it accounts for this temperature change. Thus, the output variable is the reactor temperature and the manipulated variable is the cooling jacket temperature.

Objectives

- **Control objective:** Implement a controller using MATLAB/Simulink
- **Safety objective *(Optional)*:** Conduct a safety review of the reactor system with the control system in place.