Student-Driven Career-Focused Development of Computer Aided Design & Automation Engineering Skills

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Introduction

Extracurricular activities can afford students the opportunity to develop knowledge, skill sets, and professional connections that enhance the value of their undergraduate preparation. These experiences often increase students' marketability and employment prospects. The CHEM E CAD & Industrial Automation course series at The University of California, Davis (UC Davis) is such an activity where students dedicate time to develop knowledge and skill sets in practical computer aided design (CAD) and automation that complement their core chemical engineering coursework. CHEM E CAD is a student-led peer-to-peer learning experience made possible by a succession of student leaders, who first learned with the group during one academic year, and then were selected upon expressing interest to lead the group learning experience during subsequent years.

Chemical engineering students take courses in process control and process design, subjects that necessitate the knowledge of controller design and the ability to produce technical drawings and models. Despite these being core chemical engineering subjects, students often receive little to no experience in practical process control as it is implemented in industry or in how to use computer aided design tools such as AutoCAD or SolidWorks to produce technical drawings such as process flow diagrams, piping and instrumentation diagrams, or 3D models of process equipment. These experiences have been noted to be important to include in chemical engineering programs so that graduates are prepared with the necessary skills to enter the chemical process industry [1,2]. There have been successful implementations in chemical engineering programs of instruction using AutoCAD for drawing of P&IDs and equipment plans [3], SolidWorks for generating 3D chemical and biochemical reactor models [4,5], and 3D printing of mesoreactors [6]. Additionally, instances of chemical engineering students building and programming programmable logic controllers (PLCs) have been noted in individual labs such as a liquid level control lab [7], and as the focus of an industrial controls course [8].

Peer-to-peer teaching is a model that has a potential to benefit the student teachers, as demonstrated previously in a medical setting [9], and to also benefit the student participants, particularly with respect to passing on generic skills [10]. In the engineering setting, in one study, 87% of student participants rated their peer-learning experience as positive and valuable [11]. Additionally, in this study, peer learners indicated that their peer-learning experience resulted in better communication, more engagement, and helped them overcome student-teacher anxiety [11]. On the negative side, it was noted that the peer-teachers were less organized and that there was a lack of structure during class time [11]. In another implementation, higher student engagement was reported in a peer learning environment, and peer teachers were reported to be reflective, consistent, and fair graders [12]. In a circuits lab, it was found that the peer teachers benefited from the experience in that they gained an increased understanding of the material and developed confidence and teamwork skills [13]. The CHEM E CAD & Industrial Automation courses employ peer-to-peer teaching to pass down skills from students who have developed them in the courses previously or elsewhere (e.g. at an internship) to new student participants. This is intended to be a benefit to both the peer learners (participants) who gain new skills, as well as the peer teachers who gain experience in leadership, course organization, communication, and assessment.

The CHEM E CAD & Industrial Automation course series and its early impacts were previously presented to the chemical engineering education community in 2021 [14]. Since that time, the course series has seen significant improvements, particularly with respect to the PLC design project, thanks in large part to donations from industrial partners and increased mentorship from local automation professionals. We have now iterated and improved on the courses after six full offerings of the course series, and in this work, we will detail the student experience in the CHEM E CAD & Industrial Automation courses. We will explain the role of the undergraduate student learning assistants, and present quantitative and qualitative evaluations of the impact of these experiences. We aim to demonstrate the effectiveness of this student-driven learning experience in teaching chemical engineering students valuable CAD & industrial automation skills.

Course Structure

CHEM E CAD & Industrial Automation (abbreviated as CHEM E CAD) courses are offered as a series of three 1-unit lower-division "directed group study" courses at UC Davis, which operates on the quarter system (Fall, Winter, and Spring terms). The courses are graded on a "Pass/No-Pass" basis. The courses do not have any pre-requisites, and students are allowed to take courses out of series. The courses are open to all engineering students in any year of study, however, in most years, it is primarily upper-division chemical engineering students that enroll in the courses. We believe this is due to the courses being offered through the chemical engineering department and the applicability of the courses to students' impending job searches. Recent improvements in advertising the course through the program's AIChE student chapter has begun to attract more interest from lower-division students. Enrollment in these courses has varied from about 15 students to as many as 35 students depending on student interest and room availability. Course activities are geared towards encouraging each student to create virtual and physical products that could be included in a professional portfolio.

The CHEM E CAD courses are led by undergraduate learning assistants. The learning assistants are students who have completed the course series, displayed clear effort or interest in the CHEM E CAD course material, and demonstrated leadership skills during the completion of the group projects. These learning assistants can enroll in a different 1-unit upper-division group study course for which they receive credit that can be used towards their chemical engineering technical elective requirements. However, some learning assistants choose to serve on a volunteer basis. The typical size of the learning assistant team has been 5 students but fluctuates from year to year depending on the number of interested and qualified students, with the smallest team being 4 students and the largest team being 7 students.

These learning assistants are supported by a faculty adviser who serves at the instructor of record for the courses. The faculty adviser manages the team of learning assistants, provides guidance and oversight on the curriculum, and secures space and materials for the class. The faculty adviser also attends many of the class sessions to interact with both the student participants and learning assistants. Learning assistants are observed during class by the faculty adviser, who assigns them a “Pass” or “No Pass” grade for the upper division group study course based on their performance and participation in leadership activities (teaching, mentoring, assessing student work, and managing the course website). Each learning assistant assumes roles for the class that align with their schedule and skills, where some enjoy lecturing on new concepts and answering questions, while others prefer to perform administrative tasks like grading and providing feedback for submitted assignments. These roles are assigned within the leadership team under the purview and consent of the faculty adviser.

CHEM E CAD courses have drawn consistent student interest over the past six years. As students enter the upper-division portion of their undergraduate education, job searching becomes increasingly prevalent. Drawing on the growing emphasis on career preparation, CHEM E CAD presents itself as a low-pressure, professional skill-set development course, catered towards increasing an individual’s competitiveness in industries, especially in automation-focused roles. Being purely supplementary to core coursework, students who commit to the course are given space to explore new, industry-relevant skill sets.

Skill development in UC Davis’s CHEM E CAD courses is achieved through an emphasis on in-class demos and independent assignments, promoting active recall. Due to the nuances and procedural memorization associated with learning new software, CAD and automation learning heavily benefit from this structure.

In independent assignments, students often encounter roadblocks in their progress. The peer-to-peer teaching model utilized in the CHEM E CAD course reduces student-teacher anxiety, minimizing the friction associated with seeking assistance on independent assignments. The course’s low student-to-learning-assistant ratio maximizes this effect, allowing for many questions to be answered within the time frame of one class period.

The class is structured around weekly lessons and typically includes both in-class and homework assignments. Classes are scheduled for a required 50 minutes a week, with an additional 50 minutes of optional office hour time held immediately afterwards. Students are graded on attendance and assignment completion and must complete 70% of each to earn a “Pass” grade for the class. Assignments also have flexible deadlines. This provides busy students with greatly appreciated flexibility, allowing them to focus on core classes during particularly busy weeks without compromising their learning of core CHEM E CAD class content. The structure helps not only the students, but also the student learning assistants who are similarly busy with the many commitments of student life.

Industry mentors, including CHEM E CAD alumni and local automation professionals, serve as a critical resource to the learning assistants and faculty adviser. The mentors give advice on curriculum, occasionally attend class sessions to help teach skills, and network with students, giving them advice on applying for jobs and entering the automation industry.

Learning Objectives and Activities

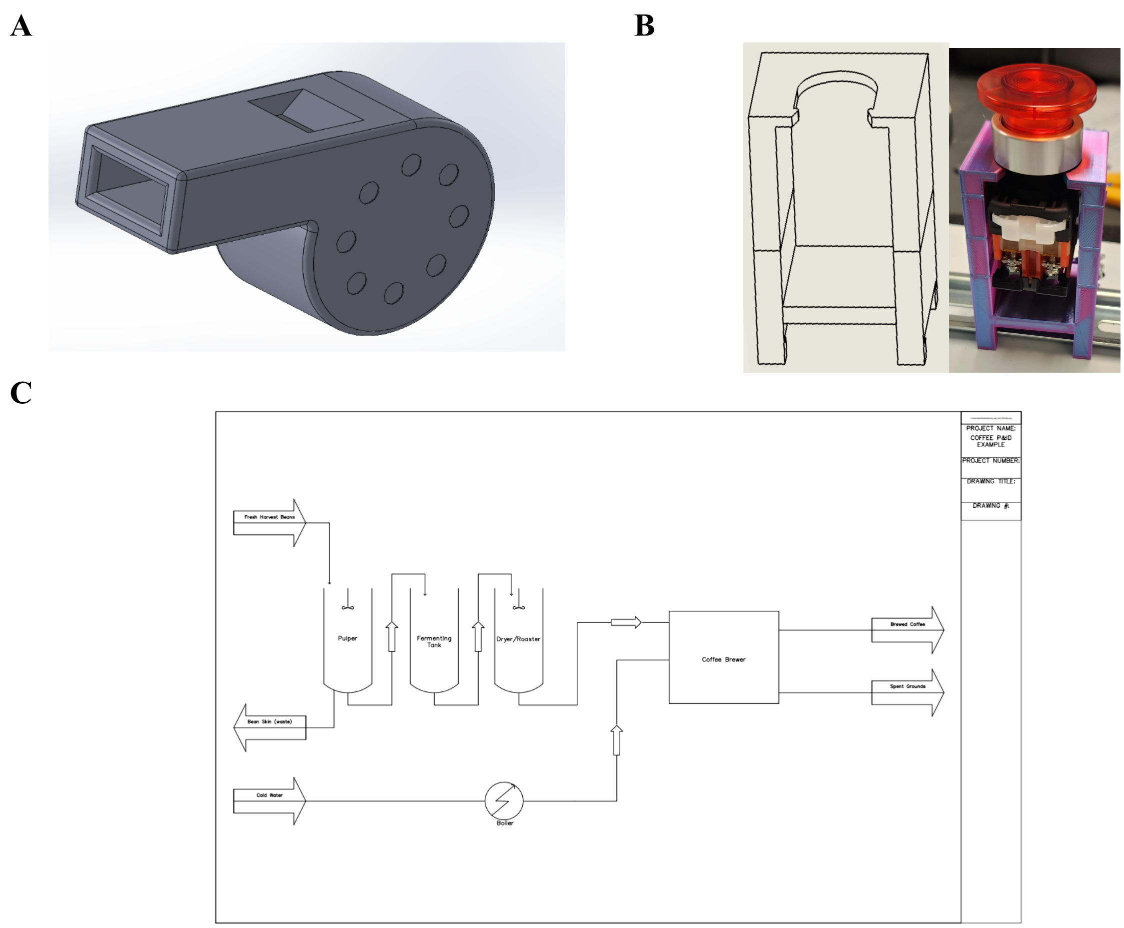


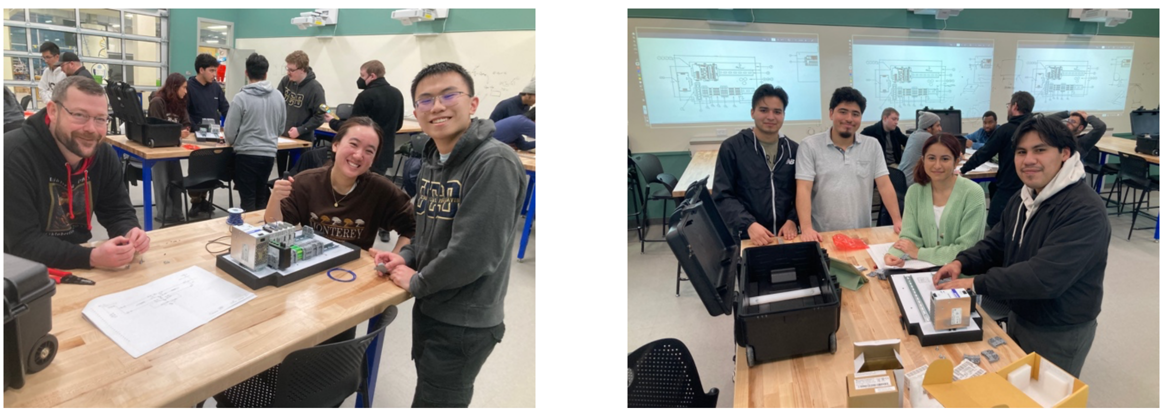
Figure 1. Student Activities in the Fall Term CHEM E CAD Course. A) Example 3D model of a whistle created in Solidworks. B) Example 3D print of light holder made during Fall for the Winter Quarter PLC build. C) Example process flow diagram created in AutoCAD.

In the first CHEM E CAD course, offered during the Fall term, students focus on learning the basics of CAD software (SolidWorks and AutoCAD), and get trained to use the 3D printers in the UC Davis College of Engineering's Engineering Student Design Center. Students produce a variety of 3D models and technical drawings as well as a 3D print of their choosing. Examples of student work in this Fall quarter course are shown in Figure 1.

The learning objectives for the Fall course are as follows. By the conclusion of the course students will improve upon their ability to:

- Create a 3D modeled part in SolidWorks
- Create a 3D assembly of at least 3 parts in SolidWorks
- Create a 3D print of reasonable quality
- Create a 2D electrical schematic in AutoCAD

A



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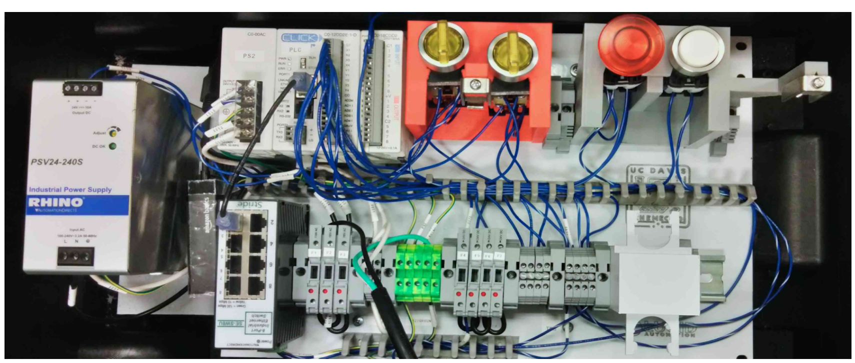

Figure 2. Student Activities in the Winter Term CHEM E CAD Course. A) Students working with industrial mentors from Lucid Automation on PLC design project. B) Picture of completed briefcase PLC.

In the second CHEM E CAD course, offered during the Winter term, students work in teams under the mentorship of practicing automation engineers to construct a programmable logic controller (PLC) system in a briefcase with a human-machine interface (HMI), buttons, and lights. Examples of student work in this Winter quarter course are shown in Figure 2.

The learning objectives for the Winter quarter course are as follows. By the conclusion of the course students will improve upon their ability to:

- Assemble a suitcase PLC (programmable logic controller)
- Read electrical drawings to wire components in the suitcase PLC
- Design and 3D print additional parts for the suitcase PLC as needed

In the third CHEM E CAD course, offered during the Spring term, students learn how to program their PLCs and HMIs using Ladder Logic and C-MORE software. Examples of student work in this Spring quarter course are shown in Figure 3.

The learning objectives for the Spring quarter course are as follows. By the conclusion of the course students will improve upon their ability to:

- Use Ladder Logic to program PLCs (programmable logic controllers)
- Create HMI (human-machine interface) buttons and graphics using C-MORE programs
- Use HMIs to interface with PLCs

A **B**

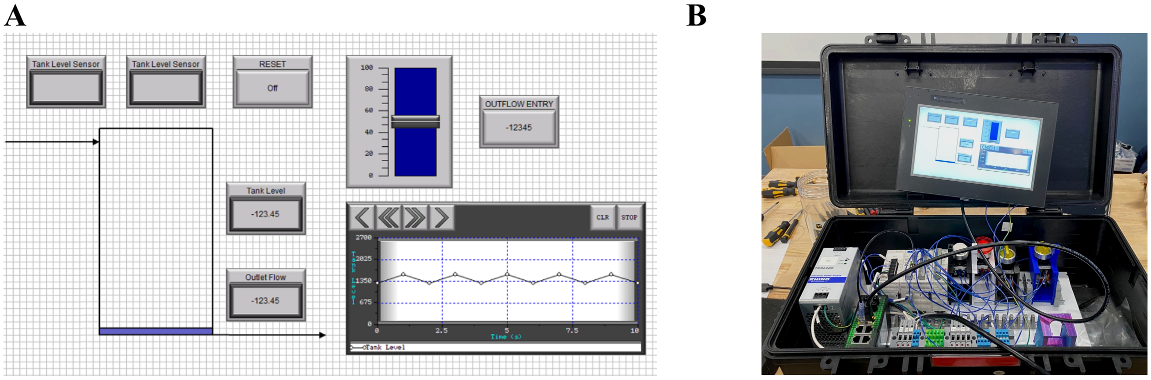

Figure 3. Student Activities in the Spring Term CHEM E CAD Course. A) Student work on C-MORE software to set up HMI. B) HMI in use on a student-constructed PLC.

The typical course schedule for each of the CHEM E CAD courses is provided in Table 1.

Table 1. Typical Schedule for CHEM E CAD Courses

Week	*Fall Term*	*Winter Term*	*Spring Term*
1	Intro & software set up	PLC project overview and demo of previous models	Intro & software set up
2	SolidWorks basic geometry	Mechanical hardware (1)	Ethernet/IP networking basics
3	SolidWorks more complex geometry	Mechanical hardware (2)	Introduction to Ladder Logic and Boolean
4	3D printer training at the Design Center	Wiring and labeling (1)	Ladder Logic programming practice
5	SolidWorks assemblies	Wiring and labeling (2)	Ladder Logic numerical methods (counters, timers, math)
6	AutoCAD basic functions	Wiring and labeling (3)	Introduction to HMIs and SCADA
7	AutoCAD blocks and layers	PLC power on and debugging	HMI display objects and tags (indicator light, button, etc)
8	AutoCAD electrical diagrams	Buttons, switches, and HMIs (1)	More HMI objects (numeric entry, line graph, etc)
9	AutoCAD paper space templates	Buttons, switches, and HMIs (2)	Process Controls Preview
10	Wrap up & feedback	Test PLCs & complete project	Wrap up & feedback

Undergraduate Learning Assistants

The CHEM E CAD courses are made possible by a succession of student learning assistants. The original student learning assistant came into the chemical engineering program with industry experience in CAD & industrial automation that he wanted to share with his peers. From that point forward, students who have completed the completed the course series and displayed clear effort or interest in the CHEM E CAD course material are identified and invited to join the team of learning assistants. This has created a passing down of skills from students to students that has now persisted over the past six academic years. In addition to the CAD & automation skills training the student leaders receive when they take the CHEM E CAD course series, student leaders continue to develop their technical knowledge base in consultation with industry advisers. This experience is also an opportunity to develop teaching and leadership skills in consultation with the faculty adviser and via on-the-job training. Future student learning assistants typically transition into the role by first helping the current student learning assistants during the final (Spring) term and receiving training under their direction. They are then prepared to take on a full leadership role during the subsequent academic year.

CHEM E CAD student learning assistants hold several duties. These responsibilities include grading assignments, providing guidance to students taking the class, leading and preparing for lectures, and performing hands-on work to prepare PLCs (programmable logic controllers) for student use. The role student learning assistants assume each quarter depends on the amount of time they can commit to the class. While some learning assistants may be busy during the in-person lecture, they can still assist by grading and creating assignments remotely.

A major motivating factor for student learning assistants to stay in the role is the satisfaction of helping other students learn valuable skills that are not taught in the standard chemical engineering curriculum. Student leaders gain a deeper understanding of the topics being taught in class as they have more exposure to the material, and they must be knowledgeable enough to answer questions raised during class. Being able to speak about the experience of teaching others is an extremely valuable point to have on a resume, beyond the underlying skills being taught. Several student learning assistants have leveraged the experience gained by teaching the CHEM E CAD class in their job search. Student learning assistants and, by extension, students who complete the course, enrich their knowledge in these technical fields and, in return, are better able to apply relevant topics. This is increasingly valuable in Industry 4.0, and AI tends to require a basic understanding of industrial control and efficiency, which spans across all engineering. This is especially useful due to the diverse range of industries that chemical engineers can work in.

In addition to the depth of knowledge on the topics taught in the course, student learning assistants also develop valuable teaching and leadership skills through active mentorship and course preparation. With the course material distributed to various student learning assistants, each person is responsible for leading the preparation and lecture of a given topic. Lectures are developed and taught in various approaches, dependent on what the learning assistant views as the best approach for students to learn. Furthermore, as every person learns differently, the style and amount of guidance required vary from student to student. Understanding where students are struggling and how they learn best builds adaptability in the student learning assistants, who interact with 20+ students each quarter. By developing such an adaptable skill set, this experience serves as a foundation for the learning assistants' professional growth and versatility in future careers.

The student learning assistants implement improvements to the course content based on evaluation surveys, completed by student participants, that convey the wide range of student comprehension. This is inevitable as CHEM E CAD is open to students of all grade levels and experience. For example, in past terms, some students found it difficult to follow the pace of the SolidWorks lectures. To address this, Fall 2025 lectures were recorded on Zoom as the classroom itself lacked lecture capture capabilities. At the same time, other students wanted to learn more advanced techniques, so optional advanced supplemental materials were compiled from online resources. Additionally, to improve the holistic comprehension of lecture course content, each of the weekly Winter 2026 assignments with ladder logic and HMI programming are being planned as part of a cohesive project. Instead of assignments with separate scenarios, having one cohesive project scenario gives students a better idea of how the software programs taught work together and can be used in industry, which students have found unclear in the past.

Improvements to document control especially in the transfer of information between graduating student learning assistants and those continuing their undergraduate education is also an ongoing area for improvement. Routine documentation of class sessions and feedback allows learning assistants to reference these notes when planning course schedules and developing lesson plans for additional guidance. The faculty advisor supports this by being available to answer questions and offer suggestions based on their own experience and knowledge of the former class teaching methods. Learning assistants teach each other, all improving their own skills and better equipping themselves with the knowledge to mentor students on similar topics or in future quarters. Support also comes from developing a closer relationship with industry partners, who are a direct and valuable connection to enhancing technical knowledge that can be translated into innovative and challenging projects for students. Continued improvement of the course as the quarterly schedule cycles back around ensures that the course material and methods are reflected on and adjusted for relevance, difficulty, and engagement.

Course Impact & Evaluation

Since its inception, more than 250 students have participated in at least one of the three CHEM E CAD and Industrial Automation courses, building skills in practical computer aided design and industrial automation. The most recent course evaluation data was collected in the Fall 2025 course offering to gauge student perceptions of their achievement of course learning objectives, the effectiveness of course learning activities, and their feelings toward other aspects of the course.

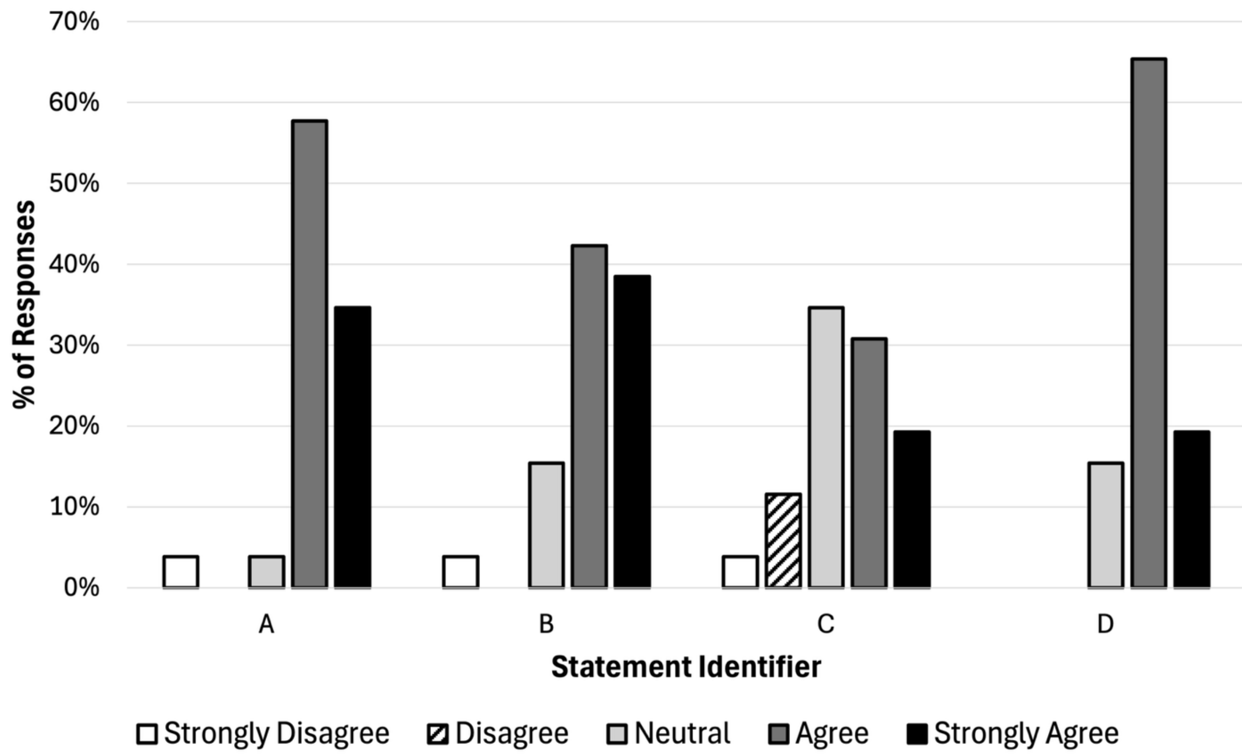

Figure 4. Student Evaluation of Course Learning Objectives, Fall 2025. Students responded to survey questions related to the learning objectives of the course. They were prompted to rate their level of agreement, from Strongly Disagree to Strongly Agree, with the following statements A-D. The statements were A) "I know how to create a 3D modeled part in SolidWorks", B) "I can create a 3D assembly of at least 3 parts", C) "I can make a 3D print of reasonable quality", and D) "I can create a 2D electrical schematic in AutoCAD." Twenty-six of the thirty-two students enrolled in the course responded to the survey (81.25% response rate).

Figure 4 shows student evaluation data with respect to course learning objectives in Fall 2025. Twenty-six of the thirty-two students enrolled in the course responded to the survey (81.25% response rate). Most of the students either agreed or strongly agreed that they "know how to create a 3D modeled part in SolidWorks" (92.31%), "can create a 3D assembly of at least 3 parts" (80.77%), and "can create a 2D electrical schematic in AutoCAD" (84.62%). Only 50% of the students either agreed or strongly agreed that they "can make a 3D print of reasonable quality." Due to time constraints during this offering of the course, the 3D printing exercise was made optional, and the students were allowed to decide if they wanted to take advantage of the opportunity to produce a physical 3D print.

Figure 5 shows student evaluation data with respect to course learning activities in Fall 2025. A majority of students either agreed or strongly agreed that the following were useful learning activities that helped them learn the course material: class time presentations (73.08%), class time discussion (88.46%), recorded class presentations/discussion (65.38%), in-class work time

(96.15%), training on how to use the 3D printers by the Engineering Student Design Center staff (84.62%), and drawings/homework (92.31%). Only 28% of students agreed or strongly agreed that outside of class help by the student learning assistants was a useful learning activity. Consistent with this result, only a small number of students tend to seek help outside of class. Most students attend the weekly additional help hour (an extension of class time on the same day) or wait until the next class session for aid because of the flexible assignment deadlines.

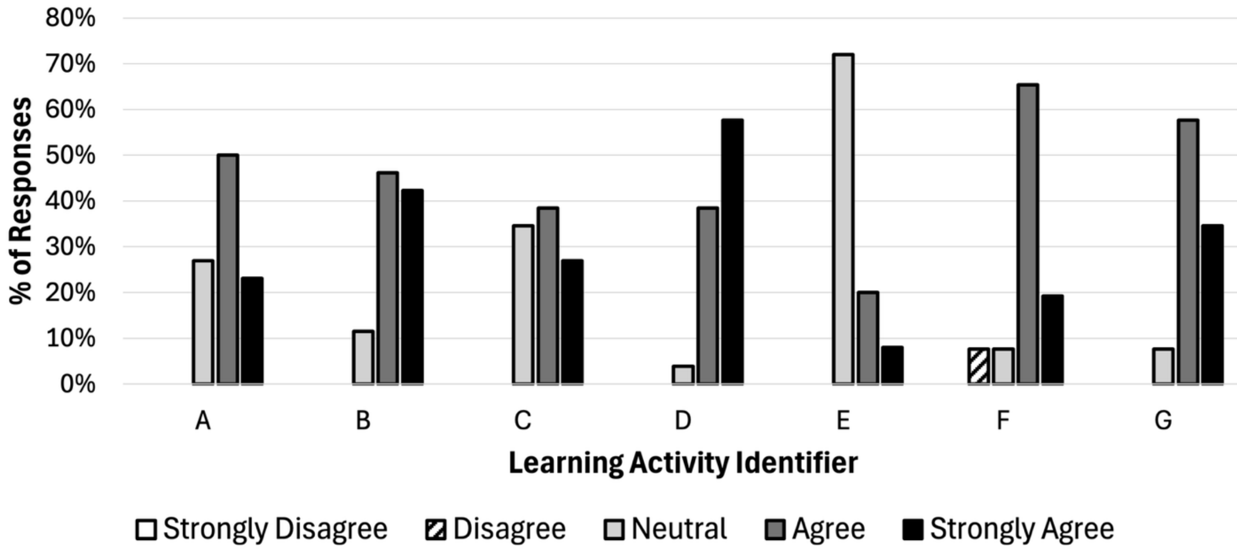

Figure 5. Student Evaluation of Course Learning Activities, Fall 2025. Students responded to survey questions related to the course learning activities. They were prompted to rate their level of agreement, from Strongly Disagree to Strongly Agree, with the following statement: "Learning Activity XXX was a useful tool or activity that helped me learn the course material." The learning activities were A) class time presentations, B) class time discussions, C) recorded class presentations/discussions, D) in-class work time, E) outside of class help, F) training on how to use the 3D printer by the Engineering Student Design Center staff, and G) drawings/homework. Twenty-six of the thirty-two students enrolled in the course responded to the survey (81.25% response rate).

Figure 6 shows evaluation data collected from student participants in Fall 2025 in order to evaluate the course and the student learning assistants. The majority of student participants either agreed or strongly agreed with each of the statements, which included "the class was well organized" (92.31%), "the student organizers/presenters did a good job running this course" (88.46%), "I learned a lot in this class" (100%), "class time was used effectively" (96.15%), "the workload for this class was manageable" (92.31%), and "this class should be offered to future cohorts of interested chemical engineering students" (96.15%).

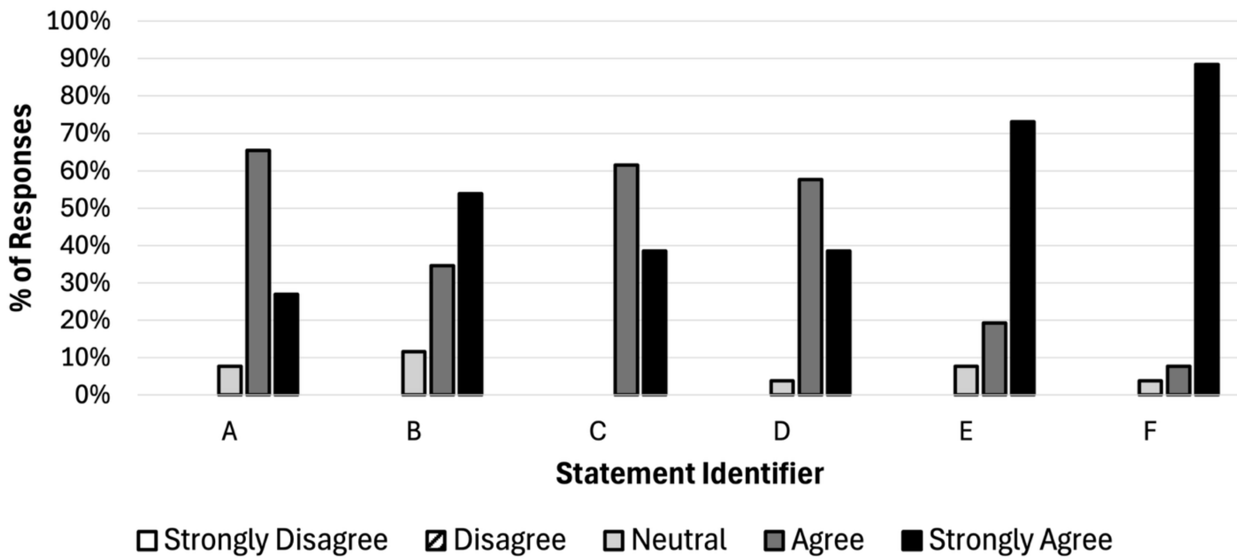

Figure 6. Student Evaluation of the CHEM E CAD Course, Fall 2025. Students responded to survey questions related to the CHEM E CAD course. They were prompted to rate their level of agreement, from Strongly Disagree to Strongly Agree, with the following statements A-F. The statements were A) "The class was well organized", B) "The student organizers/presenters did a good job running this course", C) "I learned a lot in this class", D) "Class time was used effectively", E) "The workload for this class was manageable", and F) "This class should be offered to future cohorts of interested chemical engineering students." Twenty-six of the thirty-two students enrolled in the course responded to the survey (81.25% response rate).

With only a few exceptions, student participants have demonstrated that they achieve CHEM E CAD course learning objectives by the production of physical and virtual products (examples shown in Figures 2-4). This survey data also shows that most students in the most recent CHEM E CAD & Industrial Automation courses feel confident that they have achieved the course learning objectives and have had a positive learning experience.

Anecdotally, the CHEM E CAD courses have been instrumental, in some instances, in helping students gain employment after graduation. Below are a sample of quotes from former students:

In ChemE CAD, we built our own PLC rack, equipped with a controller, IO cards, and hard IO (pushbuttons, VFD, motor). ***This helped tremendously to visualize how control worked in industry****. Furthermore, we created our own ladder logic programs to run on the PLC and built HMI pictures to interface with the program.* ***Learning ladder logic was central to me getting my internship and job.*** *I have since logged near 1,000 hours on Rockwell's Studio 5000 ladder logic and another 200 on GE's iFix and Rockwell's FactoryTalkView HMI.*

The genesis of Chem-E-CAD was terrifying and rewarding. *What started as an idea for a single evening event snowballed via the "Ron Swanson principal" into an enterprise far beyond* *what I ever thought possible. The enthusiastic support and encouragement from the Chem.E. faculty at UC Davis our success possible.* ***The engagement and enthusiasm of participants was been overwhelming, and I feel a great sense of pride and joy at being a part of something that has had positive impact on the lives of many students.*** *The growth in popularity since my time leaves me both humbled and excited for the future of the club.* (*John Davis, Chem-E-CAD Student Founder)*

The skills we developed here weren't seriously fleshed out. ***The things I built are not beautiful,*** *they are not even very strong.* ***But I built them.*** *I only hope at least a few people in ChemECAD got that same feeling as me when I took it; this little thing you made was because you willed it so.* ***Seeing that little light turn on, you can say its because you want it to. It is just a light. But you told it to turn on. I hope the other students can see why that's powerful. Why they're powerful.***

Additionally, four UC Davis chemical engineering graduates have been hired out of the CHEM E CAD program by Lucid Automation, the company that has supported our PLC project since its inception.

Conclusions

In conclusion, the CHEM E CAD & Industrial Automation courses have given a significant number of engineering students at UC Davis the opportunity to gain value added skills in practical computer aided design (CAD) and industrial automation. These courses have also been a successful implementation of peer teaching & learning that has brought value to students in both roles. The chemical engineering program at UC Davis will continue to support, grow, and develop this program to meet student interests and workforce needs.

Acknowledgements

The authors would like to acknowledge John Davis, alumni of the chemical engineering program at UC Davis and currently a Process Engineer at Tokyo Electron, who was a co-creator of the CHEM E CAD & Industrial Automation courses and first student leader. Without John's efforts the CHEM E CAD & Industrial Automation courses would not exist.

The authors would also like to acknowledge and thank our industrial mentors, and particularly the team at Lucid Automation. Thank you Bill Meuller, Jacob Brunner, Marie Fiala, and former UC Davis chemical engineering and CHEM E CAD graduates Natalie Rusca, and Haruka Shudo for your help and mentorship with the PLC project.

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