How We Teach: Process Control

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How We Teach: Process Control: Survey and Panel Discussion

Abstract

This paper reports results from the 2025 American Institute of Chemical Engineers (AIChE) Education Division survey on how process control is taught in chemical engineering programs in the United States and Canada, along with insights from a panel discussion held at the 2025 AIChE Annual Meeting. Faculty from 85 institutions provided 88 responses describing course structure, instructional priorities, software use, laboratory practices, and recent curricular changes. Results show that most institutions require a standalone process control course, typically lecture-based with substantial simulation or problem-solving laboratory components. MATLAB, Simulink, and Excel were the most commonly used computational tools, and many courses incorporated project- or problem-based learning. Faculty emphasized understanding process dynamics and controller tuning as core goals while noting persistent student challenges with mathematics. Topic coverage remains largely consistent with prior surveys, though more programs now include design-oriented content, Python, and practical examples. The panel discussion highlighted increasing automation in industry, the need to balance mathematical depth with design practice, and the growing role of artificial intelligence in process control. Overall, the findings provide an updated picture of current instructional practices and emerging trends in teaching process control.

Introduction

The AIChE Education Division's Course Survey Committee has a 10-year rotation of course surveys that are completed in the fall of each year [1]. The topic for 2025 is process control, which was last surveyed by the committee in 2015 [2]. The 2015 survey yielded 81 responses from 77 institutions in the US and will be the basis for many time-trend comparisons in this paper. The process control community is quite active in engineering education literature with many articles about labs and modules. Bequette provided a 2019 review of process control in industry, theory, teaching, and textbooks [3]. Rossiter reviewed good teaching practices in process control, core content, equipment, and virtual labs [4] in 2025. The interested reader is referred to those articles for extensive background on teaching process control.

Preliminary results from 73 institutions were presented at the 2025 AIChE Annual Meeting [5]. After the survey results were presented, experienced process control faculty held a panel discussion. Survey collection continued after the AIChE Annual Meeting through December. A parallel industry survey will run through the spring. This paper reports on the collected faculty responses from 85 institutions and the panel discussion at the AIChE Annual Meeting.

Methods

Faculty teaching process control in the US and Canada were surveyed about their courses. The survey was distributed in September – December 2025 via the AIChE Education Division's listserv for department heads, the division's email newsletter, the ASEE Chemical Engineering Division's email newsletter, and the survey session and division business meeting at AIChE. Emails were sent directly to the chair of each Canadian chemical engineering department.

The scope of the survey regarding process dynamics was defined in the survey. Process control inherently involves an understanding of the process dynamics. The ABET Program Criteria for chemical, biochemical, biomolecular, and similarly named engineering programs require that the curriculum include control of processes [6], and so process control was the focus of this survey. Faculty were instructed to limit their responses to process control with process dynamics only as they touch process control.

The survey questions are provided in Appendix A and summarized in Table 1. The protocol IRB-25-50 received approval from the Institutional Review Board at the University of Tulsa. The parallel practitioner survey includes questions about years of experience and industry. Questions 25 – 29 of the faculty survey about process dynamics, performance limitations, control strategies, transmitter signals, and skill ranking were changed to refer to *your work* or *your plant/facility* instead *your course* for the industry survey.

Table 1. Summary of survey questions and types

Short Answer	Multiple Choice/Selection	Open-ended
Faculty experience	Simulation/coding balance	Experimental labs
Course title	Software packages	Effective instructional strategies
Contact hours	Software deliverables	Distinctive features
	Textbooks	Teaching challenges
	Resources	Recent or planned changes
	Learning environments	
	Instructional goals	
	Topics covered	
	Skills ranking	

Respondents, Term System, and Cross-listing

The data were cleaned by removing duplicate, incomplete responses by the same person. Two faculty both responded at three institutions on the semester system, but both responses were retained as indications of the different ways process control is taught. All of the institutions with duplicate responses have a single course with process control content, so the multiple responses are from faculty who taught the same course in different semesters or years. The resulting 88 responses are from the 85 institutions in Appendix B. A small portion, 7 (8%) of the institutions, is on the quarter system. Only 13% of the courses are cross-listed at the graduate level.

Industrial Connections

A frequent concern is that faculty teaching process control do not have industrial experience, and we found this to be true of our faculty respondents. The years of process control experience in both industry and teaching for our respondents are reported in Figure 1. The averages were 2.6 and 9.1 years, respectively, but 58% of the responding faculty had no industrial process control experience. When those with no industrial experience were excluded, the average is 6 years of industrial process control experience. This is a slightly different question from the 2015 survey [2], which asked about any industrial experience rather than process control industrial experience specifically. In 2015, 22% of faculty had no industrial experience, and the average experience was 4.1 years overall and 5.2 years omitting those with no experience. Many more faculty now have no industrial process control experience than had any industrial experience in 2015.

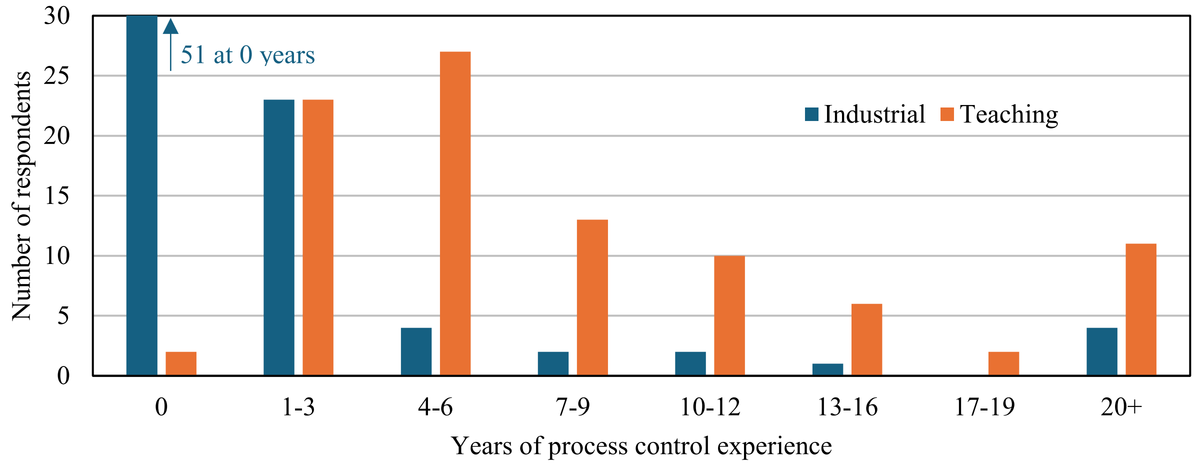

Figure 1. Years of process control experience. N = 87 for industry and N = 88 for teaching. The bar for zero years of industrial process control experience (51) was truncated to show detail in the rest of the figure.

Most of the courses (56%) did not include an industrial collaborator or adjunct instructor with industrial experience in the course. The most commonly reported task for an industrial collaborator was guest lecturer (26% of courses). No industrial collaborator is needed when the instructor or co-instructor has industrial experience, which was the case for 7% of the courses, and 5% of courses gave full course responsibility to the industrial collaborator. Other industrial collaborators assisted with funding, equipment, software, simulations, mentors for projects, career mentoring, tours, and course content review. More courses (44%) used an industrial collaboration in 2025 than in 2015 (21%).

Number of Courses, Course Names, and Contact Hours

An important aspect is how institutions arrange their courses to include the ABET-required process control content. Most common is a required full course in process control, 76% of our 85 responding institutions, and 15% have more than one required process control course. Only one of the institutions with more than one required process control course is on the quarter system. Only 2% of institutions have only a part of a required course with an emphasis on process control, and another 2% have only a part of a required course whose emphasis is not process control. Other combinations (5%) were primarily having a required full course in addition to a part of another required course. Slightly more institutions (88%) had a single required course and fewer had more than one required course (9%) in 2015.

After asking about the number and types of courses of process control, we then asked about their course number(s) and name(s). Faculty responded with 110 names of courses. Of these 110 courses, 82 were standalone or separate courses. There were 29 unique names for this course, but most common were

- [Chemical] Process Dynamics and Control: [8] + 28 = 36 courses and
- [Chemical] Process Control: [6] + 16 = 22 courses.

Most other course names were combinations of *process*, *control*, *dynamics*, *chemical*, *analysis*, and *modeling*. Approximately 10 courses were ones in which process control was incorporated into another course, such as Process Design. Another approximately 10 courses were separate lab courses, and seven of these were specifically process control labs. The others were unit operations or chemical engineering labs. Of the 110 courses described, there were 3% at the 100-level with 1%, 16%, 78%, and 2% at the 200- to 500-levels. The majority of process control courses are at the 400-level, which is commonly in the senior year, with a significant minority at the 300-level. This agrees with a curriculum survey published in 2024 [7].

The majority of the survey questions were about the content and practices of the required, primary process control course(s). There was one question about content in other courses, and 25 institutions described both required and elective courses. In other required courses, five had moderate control content such as process design with a control deliverable or a unit operations lab with an experiment on control. Another 10 required courses mentioned had low control content, such as process design, introductory transport, and process safety courses. There were 13 elective control courses mentioned, frequently named "Advanced Process Control". Four elective courses with moderate process control content included systems and signals courses. Machine learning, bioprocessing, optimization, and process safety were among the 7 elective courses with low process control content.

The median number of hours of different contact types for the primary course teaching process dynamics and control are presented in Table 2 along with the number of courses that reported the contact type. Although we asked about contact hours, about six courses reported low numbers that are probably credit hours, and medians are reported to reduce the effect of these low numbers. The process control course is primarily a lecture course of roughly three credit hours, agreeing with a curriculum survey published in 2017 [8]. Of the 13 institutions with more than one required process control course, 11 still described the primary course as approximately three credit hours of lecture. A quarter of the courses (23) have both lab types, leaving another quarter with only simulation lab and 18% with only experimental lab. For a few courses, simulation is part of the lectures or assignments outside of class. About a quarter of courses have a recitation section. The quarter-system courses have 7 fewer hours of lecture and 4 fewer hours of recitation but the same number of hours of labs. Average contact hours were reported in 2015 with similar values to 2025.

Table 2. Contact hours per term, N = 88 courses, with range in parenthesis

	Total	Lecture	Simulation or Problem Laboratory	Experimental Laboratory	Recitation
Median hours	51	42 (2.5 – 100)	8 (2 – 25)	9 (1 – 80)	10 (2 – 30)
Count of courses	88	88	45	39	21
Percent of courses		100	51	44	24

Computing

Given how common simulation labs are in process control courses, software is an important part of the course. Software used in 5% or more of courses is shown in Figure 2, with MATLAB and Simulink having the most use at 60% of courses. Many other programs and languages were used in fewer than 4 courses. Those familiar to the primary author were artificial intelligence/large language models/neural networks, Arduino C++, Aspen Dynamics, Aspen HYSYS, Aspen Plus, Honeywell Experion Process Knowledge System, Honeywell UniSim, MS Visio, NI LabVIEW, PetroSkills, PolyMath Plus, PTC Mathcad, and Wolfram Mathematica. Software that was not familiar to the primary author is listed in Table 3 with links to the supplying website. MATLAB, Simulink, and Excel were the most commonly used programs in 2015, but Simulink was closer to the Excel use in 2015 than in 2025. Python, the 4th most commonly used software in 2025, was not mentioned at all in 2015.

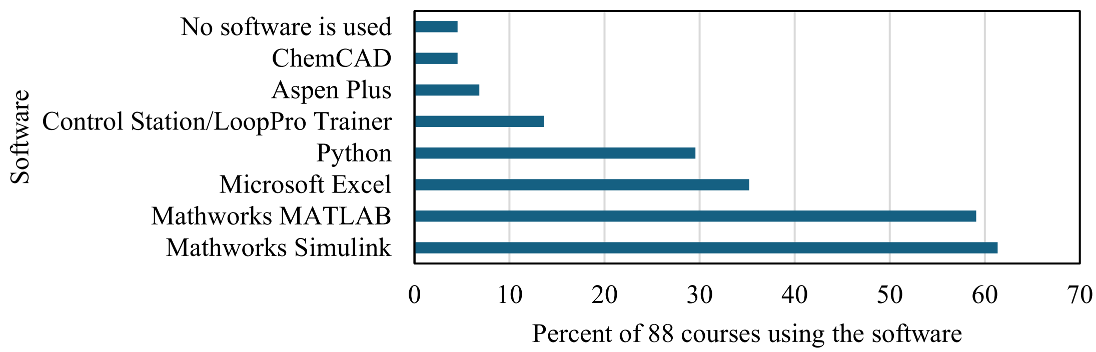

Figure 2. Use rates of software and languages in 88 process control courses. Only MATLAB and Simulink were used by more than 50% of courses.

Table 3. Links to software unfamiliar to the primary author and used in fewer than 4 responding courses

Software	Link
Altair's Embed	https://altair.com/embed
Controlz.jl	https://simonensemble.github.io/Controlz.jl/dev/
Julia	https://julialang.org/
Opto 22	https://www.opto22.com/
PiControl	https://www.picontrolsolutions.com/
Pitops	https://www.picontrolsolutions.com/
Simcet	https://www.picontrolsolutions.com/
SimTune	https://www.apco-inc.com/simtune

Faculty for 84 courses also reported on the relative emphasis of coding (via Excel, MATLAB or Python, for example) versus simulation (Simulink). Although MATLAB and Simulink were used by about the same number of courses, 58% of the courses were described as more simulation than coding. Only 19% of courses were more coding than simulation, leaving 23% with roughly equal amounts. Faculty also stated which assignments used software (Figure 3), with fewer classes using it for exams and quizzes than other assignments. In addition to the categories shown, software was used in lecture demonstrations and take-home quizzes.

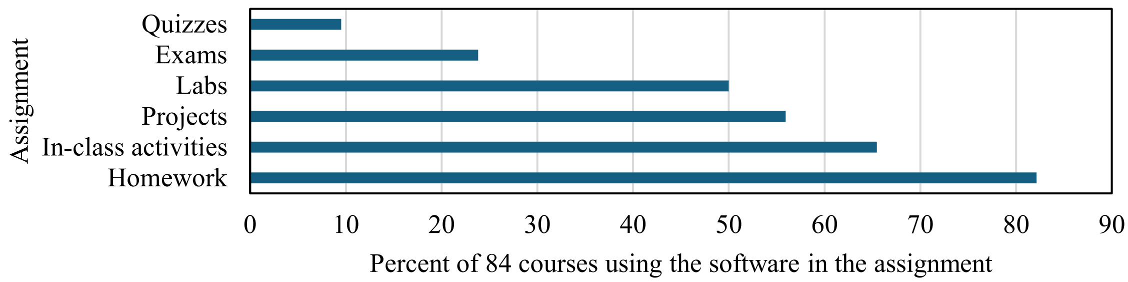

Figure 3. Assignments that use software in 84 courses. Homework was the top assignment that used software in most courses.

While the numbers alone are useful, sometimes the connections between results are also interesting. A Sankey diagram showing the connection between software used and the relative emphasis on coding and simulation is provided in Figure 4. Many trends are as would be expected:

- The process simulators, most of which are grouped at the top right, are not used by courses that emphasize coding.
- The proportion of courses using Simulink decreases from nearly all "roughly equal" courses to most of the simulation-emphasis courses to only 10% of coding-emphasis courses.
- Python is used by a lower proportion of courses that emphasize simulation than other courses.
- Coding-emphasis courses used Excel much less than the other types of courses, which were at about 50%.
- Control Station/Pro Loop Trainer was used primarily by simulation-emphasis courses.

Coding can be done using both Python and MATLAB, but there were differences in which types of courses used which program.

- Coding-emphasis courses are more likely to use Python than MATLAB.
- Simulation-emphasis and "roughly equal" courses are more likely to use MATLAB than Python.

The students must have access to computers for these computational activities, particularly if an exam with software is in-person. Figure 5 shows that the most often situation is that the students use any laptop, as distinct from one recommended or required by the institution. Without recommendations or requirements, faculty may have situations when the necessary software will not run (well) on the student's laptop. College computer labs are more commonly used than departmental or university computer labs, and institutional laptops are rare. In 2015, more departments provided computer labs than colleges did, but now more colleges provide computer labs than departments. Fewer institutions provided computer labs in 2025 than in 2015. The survey in 2015 did not ask about laptops, but virtual machine use has increased greatly from 10% in 2015. Courses which gave exams or quizzes using software in 2025 were about 15% more likely to use a college-maintained computer lab, required laptops, any laptop, and cloud machines than other courses. They were 15% less likely to use recommended laptops.

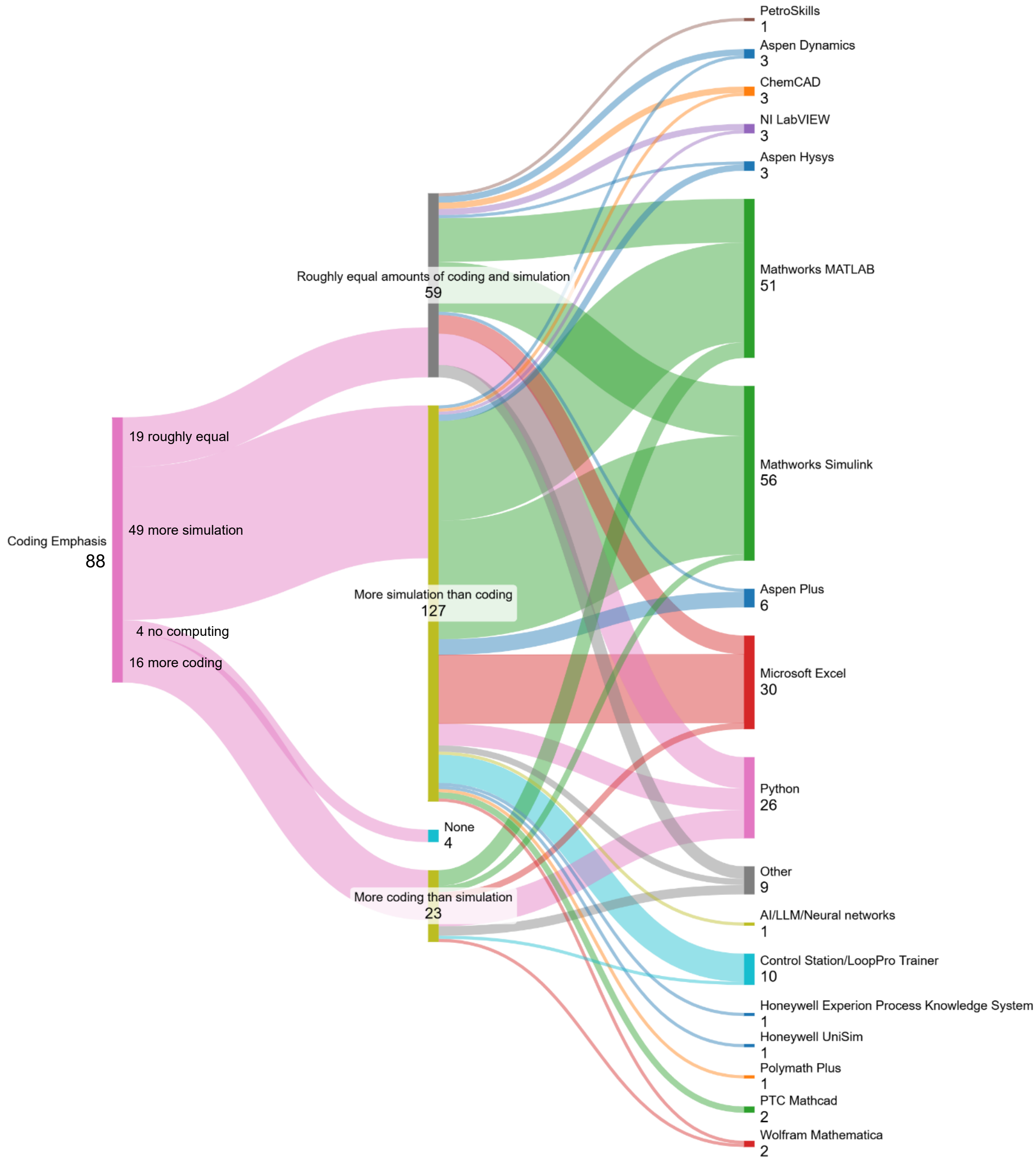

Figure 4. Sankey diagram connecting software packages used to the relative emphasis of simulation and coding for 88 courses. Numbers on the left are the number of courses in each emphasis. Numbers in the middle are the sum of all software packages used by all courses in each emphasis, and numbers on the right are how many courses used each software package.

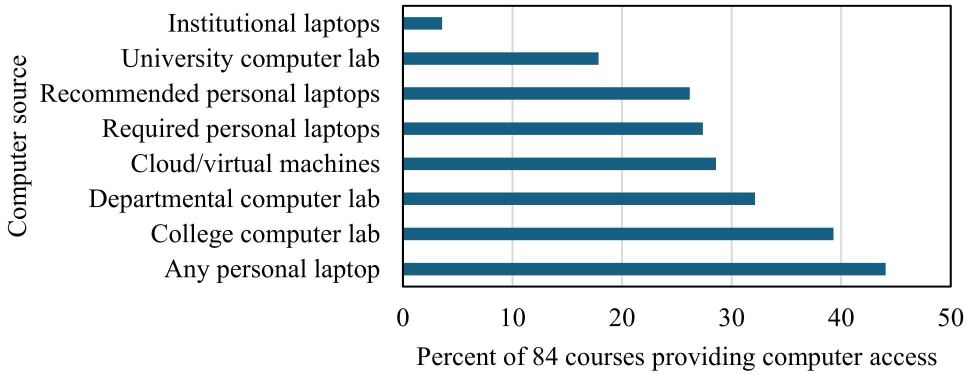

Figure 5. Source of computers (laptops/labs/virtual and department/college/institution) used in 84 process control courses

Experimental Laboratory

The 33 responses describing experimental laboratories were grouped different ways. The first grouping was by the goal of the experiment:

- 26 temperature control,
- 14 level control,
- 7 flow control,
- 6 concentration control (4 pH, 2 salt),
- 3 pressure control, and
- 9 other (control of light level, inverted pendulum, or bioreactor; Boolian logic, gloss on coated surface for experimental design and data analysis, PLC/circuit configuration, unspecified controlled variable).

The primary author looks forward to hearing more about the portable wet control lab that has been under development at the University of Florida. Another grouping was the course containing the lab: five experiments were specifically mentioned as being in a control laboratory course, eight were in another laboratory course, such as capstone or unit operations laboratory, and the rest were not specified. Arduino-based experiments were mentioned 10 times, and seven of these were the TCLab kit [9]. One course has replaced the TCLab with other labs. Many responses described more than one experiment (2 on average for the 33 reporting courses), and process description and PID feedback control were both usually part of the experiment or experiment set.

Teaching Resources and Learning Environment

The next topic is textbook(s) used in the course. Faculty were allowed to select more than one textbook, but 70% used only one text. As shown in Figure 6, the Seborg textbook [10] is used by many more courses than those of Riggs [11], Marlin [12], Ogunnaike [13], Seames [14], Coughanowr [15], Stephanopoulos [16], and Cooper [17]. Other first authors mentioned were Bequette [18], Chau [19], Kravaris [20], Meadowcroft [21], Romagnoli [22], Smith [23], and Smuts [24]. The Seborg text was also the most commonly used in 2015 but by a smaller margin.

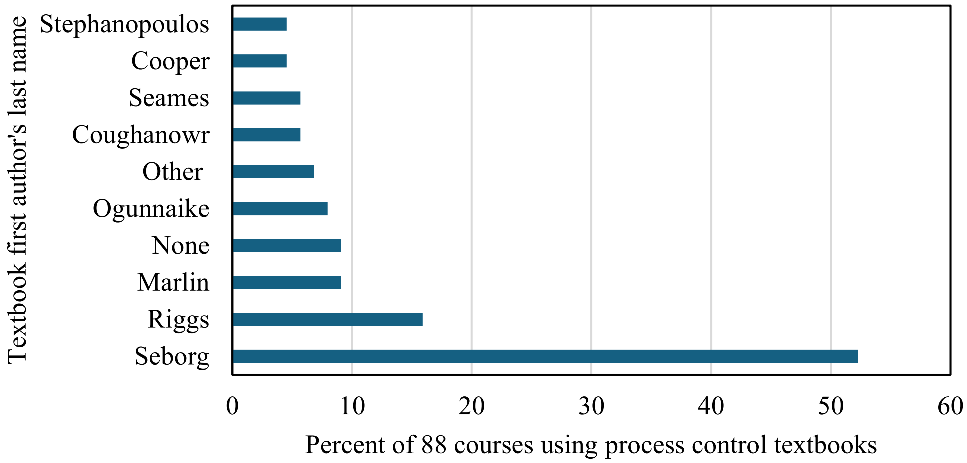

Figure 6. Textbooks used in 88 courses. Seborg is the most commonly used textbook by far.

For the question "How can the content or supplements of/for the text you now use be improved?", 22 respondents expressed a desire for more compelling examples, routinely using words like "practical," "real-world," "real-life" and "drawn from industry." Another 13 respondents expressed interest in resources to support experimental aspects of the course, requesting hands-on laboratory experiments and/or modeling and simulation exercises with linkages to platforms like ASPEN, Python, Simulink or MATLAB. Another 11 respondents mentioned a desire for better alignment with their preferred topical priorities, but no clear consensus was evident from among these eleven. Examples of specific comments included:

- "Focus more on design for process automation rather than dynamic analysis"
- "more integration of multivariable control topics from the beginning"
- "we drive the entire course in the time… I hadn't found a text that focuses on time-domain problem and analysis so if there was one, that would be great."

Most instructors used online resources (Table 4) in addition to their textbooks, although "none" was the most frequent response at 30% of courses. The textbook author's online resources were used by 22% of courses. Some top resources are focused on process control (BYU/Hedengren, Marlin, and LearnChemE virtual lab), while others include many courses (LearnChemE screencasts, AIChE Concept Warehouse, and CACHE resources). Some faculty used online MATLAB resources provided by the institution, and others posted their own personal resources.

The tasks of graduate teaching assistants in the process control course were primarily to grade small assignments and hold office hours, as seen in Figure 7. Some courses (18%) do not use graduate assistants. Other comments made were that there are undergraduate assistants or that the graduate assistants proctor exams, help develop homework and exams, or help with the project, simulation, or experiment. The trends in tasks for graduate teaching assistants match those found by a faculty survey on graduate student instructors [25].

Table 4. Links to online resources and use by percent of 79 courses

Site	Link	% Courses
BYU/Hedengren's resources	https://apmonitor.com/pdc/index.php/Main/HomePage	20
LearnChemE Screencasts	https://learncheme.com/	19
Marlin's website	http://www.pc-education.mcmaster.ca/	14
AIChE Concept Warehouse	https://conceptwarehouse.tufts.edu/cw/CW.php	13
CACHE's Resources	https://cache.org/teaching-resources-center/process-control	10
LearnChemE Virtual Lab	https://laboratory-experiments.herokuapp.com/single-stage-distillation/	5
Control Loop Foundation videos	https://www.youtube.com/@ControlLoopBook/videos	< 5
ControlGuru	https://controlguru.com/	< 5
Kimmel's YouTube channel	https://www.youtube.com/playlist?list=PLVMtY4a1bkRWCe3udew-SE47CtOx_T0jl	< 5
PiControl Solutions	https://www.picontrolsolutions.com/	< 5
U. Notre Dame GitHub Jupyter/ Python repository	https://ndcbe.github.io/controls/	< 5
US CSB reports	https://www.csb.gov/	< 5

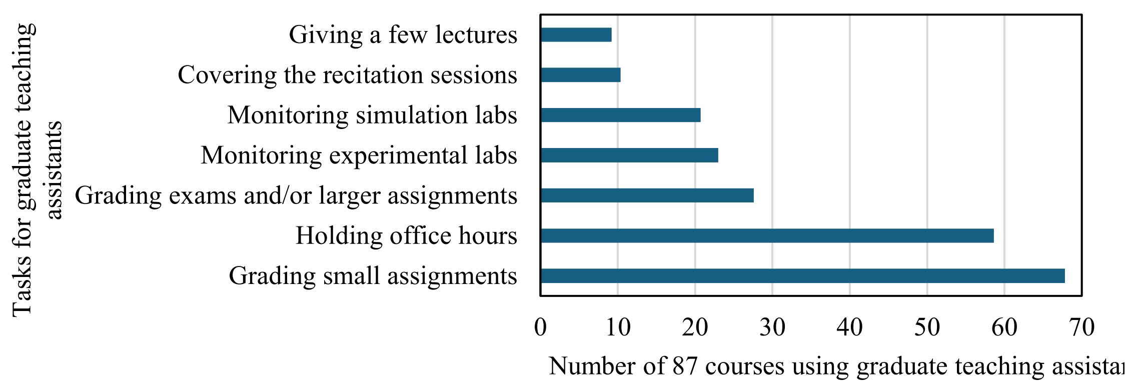

Figure 7. Tasks for graduate teaching assistants in 87 courses are primarily office hours and grading small assignments.

When we asked the faculty to describe the learning environment, one of the options accidentally included the text for the next several options. Specifically, the option that should have been "whiteboard space for student groups" became "whiteboard space for student group work computers accessible during class hardware demonstrations (instruments, controlled systems) outside of class web-based lectures (including "flipped" courses)”. The faculty response to this option is included in Figure 8 with the other prompts as simply “student whiteboard space”, but realize that faculty may have responded to the option as requiring everything listed and the value may be an underestimate. The primary author was surprised that so many, 80%, courses were problem- or project-based, which was an increase from 68% in 2015. The fraction of classrooms with accessible computers matches with the fraction of courses with problem or simulation labs, and slightly more computers were accessible to courses in 2025 than in 2015. The fraction of courses using video has increased from 2015 to 2025.

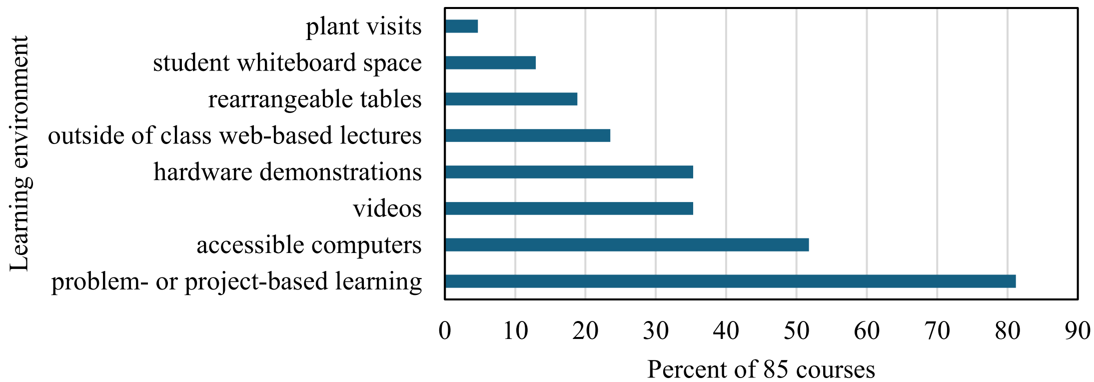

Figure 8. Learning environment for 85 process control courses. Most courses were problem- or project-based.

Course Topics and Goals

We ask the faculty to choose their top three teaching goals from a list of 11 options, and the results are given in Figure 9. Faculty agreed that understanding process dynamics was a top goal, and the goal of controller tuning was considered a top goal by half of the faculty. Although simulation is a large part of the course as indicated by software use, simulation proficiency did not rank in the top half of goals. Faculty also agreed that thinking economically and selection of hardware and instrumentation were not top goals of the course.

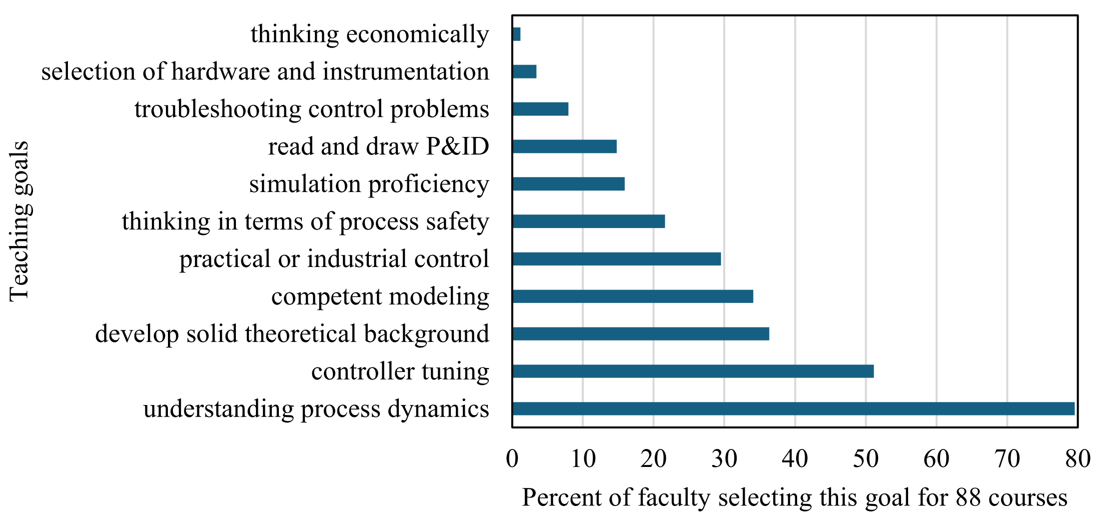

Figure 9. Top three teaching goals. Every faculty member selected three of the options.

No process control topic was covered in all courses, as shown in Figure 10, but many topics were covered in over half of the courses. Over 75% of courses cover several topics in the LaPlace domain, marked by the brace, although the literature [4] has pushed for less math emphasis in the course. State-space, multiloop/multivariable analysis, and frequency response analysis are covered by under half of the courses. A third of the courses cover the design aspect of control, converting process objectives to control objectives and design, and this topic was not on the list of offered topics in 2015. Although there have been slight shifts, there has been very little change in the coverage of topics in Figure 10 from 2015 to 2025.

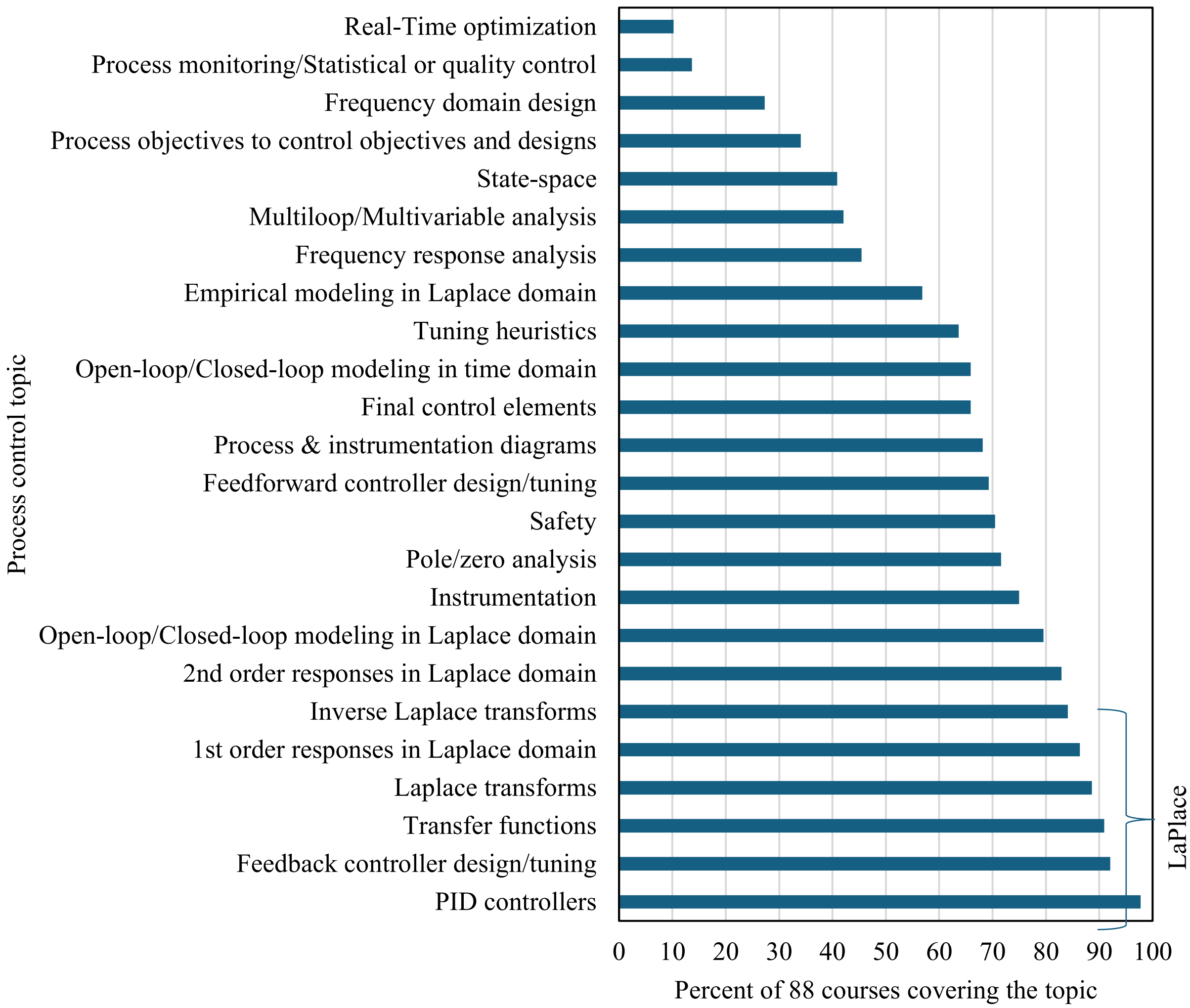

Figure 10. Topics covered in 88 courses. Many LaPlace topics were covered in the majority of courses.

We asked which process dynamics are covered in the course (Figure 11). The primary author was surprised that five other types of process dynamics were covered at more institutions than self-regulating dynamics. It might seem that self-regulating dynamics would be the starting point of comparison for other dynamics, but apparently more courses cover the more interesting dynamics. Even so, self-regulating dynamics are covered at more than half of the institutions.

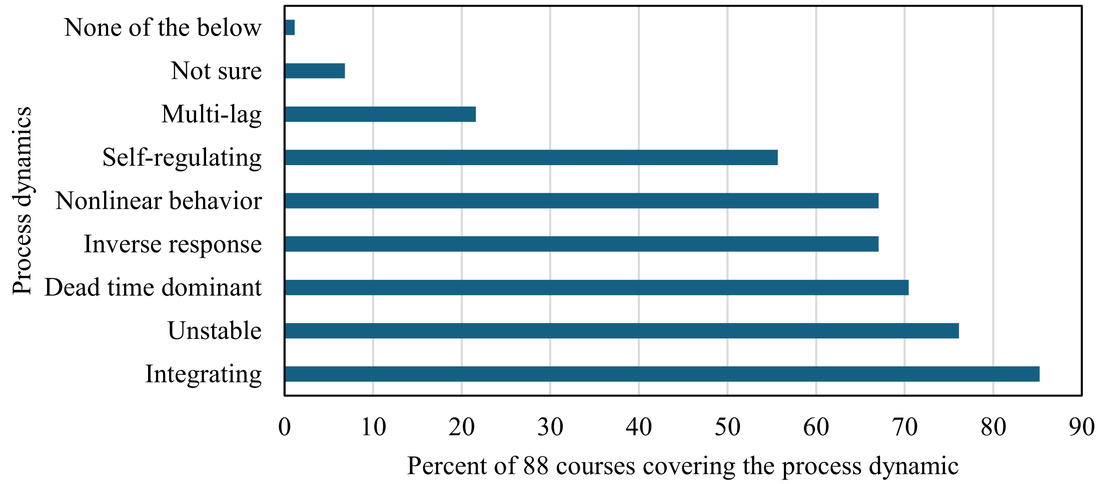

Figure 11. Process dynamics covered in 88 courses. Several other process dynamics were covered in more courses than self-regulating dynamics.

Although troubleshooting control problems was not a common top three teaching goal for the course (Figure 9), some reasons for performance limitations were covered at half of the institutions, as shown in Figure 12. Performance limitations received lower coverage than the topics in Figure 10 and process dynamics in Figure 11.

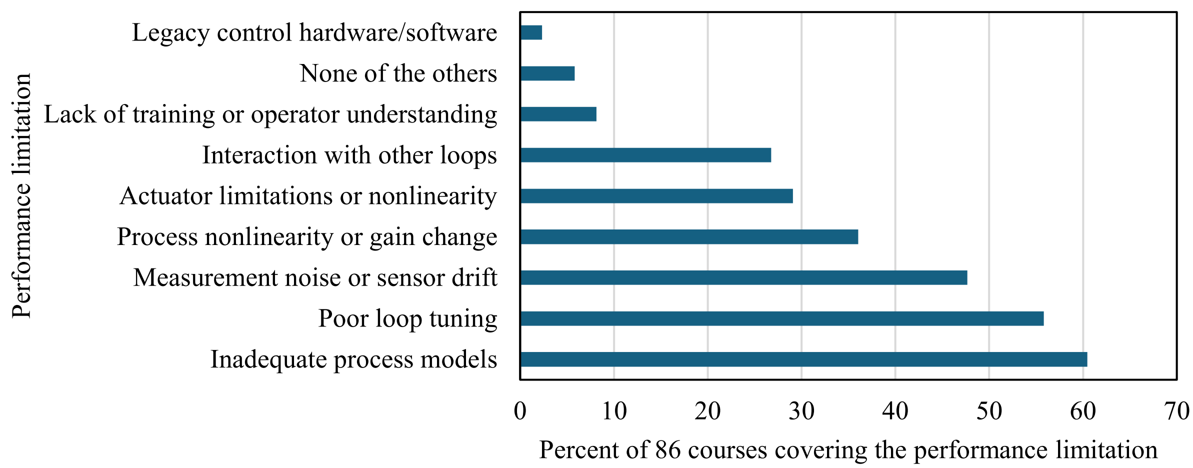

Figure 12. Performance limitations covered in 86 courses. Limitations were covered in fewer courses than other topics.

The next topics question was control strategies, Figure 13. There was no single control strategy that was covered at all institutions, but there was broad agreement on covering PID feedback, feedforward, and cascade control strategies. There was a substantial dropoff to the next strategy, ratio control. Other control strategies that were mentioned are two degree-of-freedom and override control. Another faculty member mentioned that the selected ones were not all covered equally, which applies to many of the topics presented here. The fraction of courses covering batch control has increased since 2015, and those covering adaptive control and MIMO control have decreased.

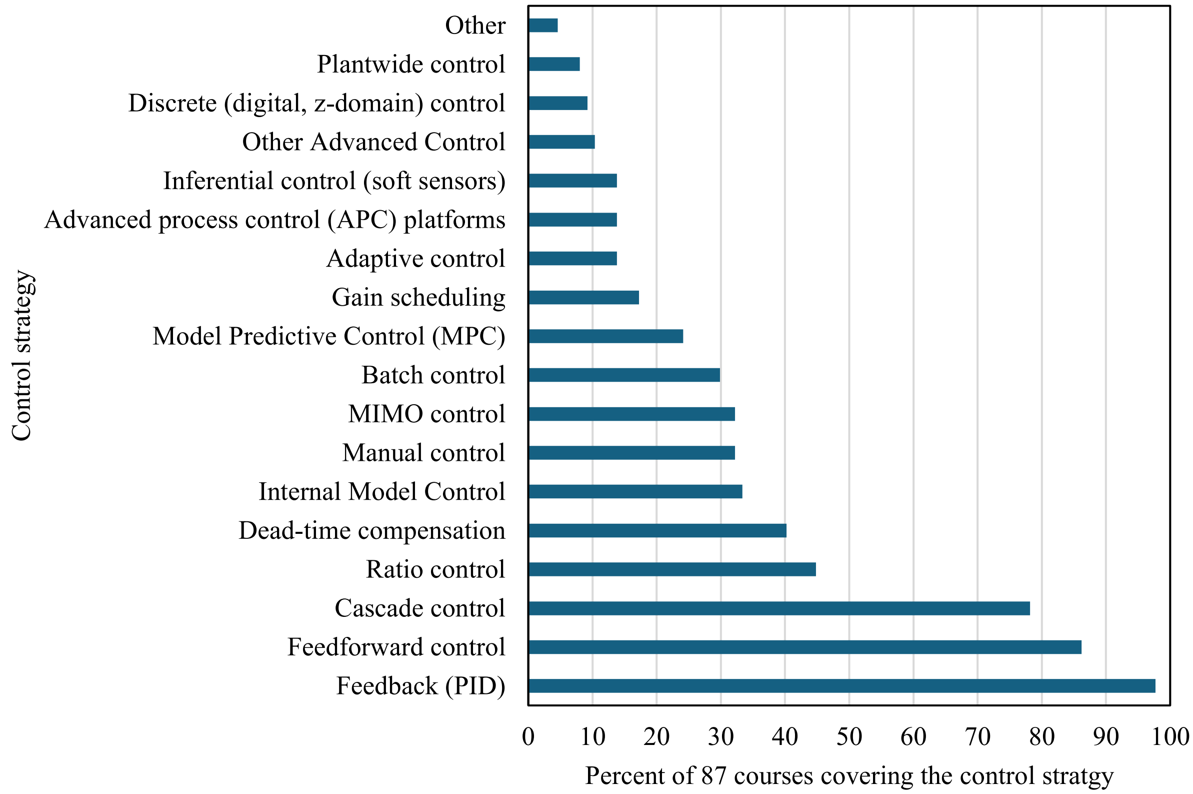

Figure 13. Control strategies covered in 87 courses. The core stratgies covered are feedback, feedforward, and cascade.

Regarding transmitter signals, 93% of courses cover electrical signals, 83% pneumatic, 51% digital wired, and 16% digital wireless. Only 81 courses reported on the signals covered.

For the last topics question, we asked the faculty to rank order a list of 10 process control skills for alumni working in industry, with “1” being the most important. We calculated an average rank for each skill from Equation 1.

$$R_{ave} = \frac{\sum N_i R_i}{\sum N_i} \tag{1}$$

where R_{ave} = average ranking,
N_i = number of instructors selecting the current skill for the i^{th} rank, and
R_i = i^{th} rank.

Averaging the ranking flattens out the ranks – instead of 1 to 10 for the individual ranks, the average ranks are 2.4 to 7.9. The average rankings are presented in Figure 14. The top skill is design and tuning of PID loops, which matches with the high coverage of the topic in Figure 10 and that controller tuning is near the top in top three goals for the course in Figure 9. Similarly, the low ranking of frequency domain analysis matches the lower coverage in the course when compared to PID controllers. A parallel survey of industrial process control engineers is ongoing, and the authors are particularly interested in the industry ranking of skills so that faculty have a better understanding of the industrial needs.

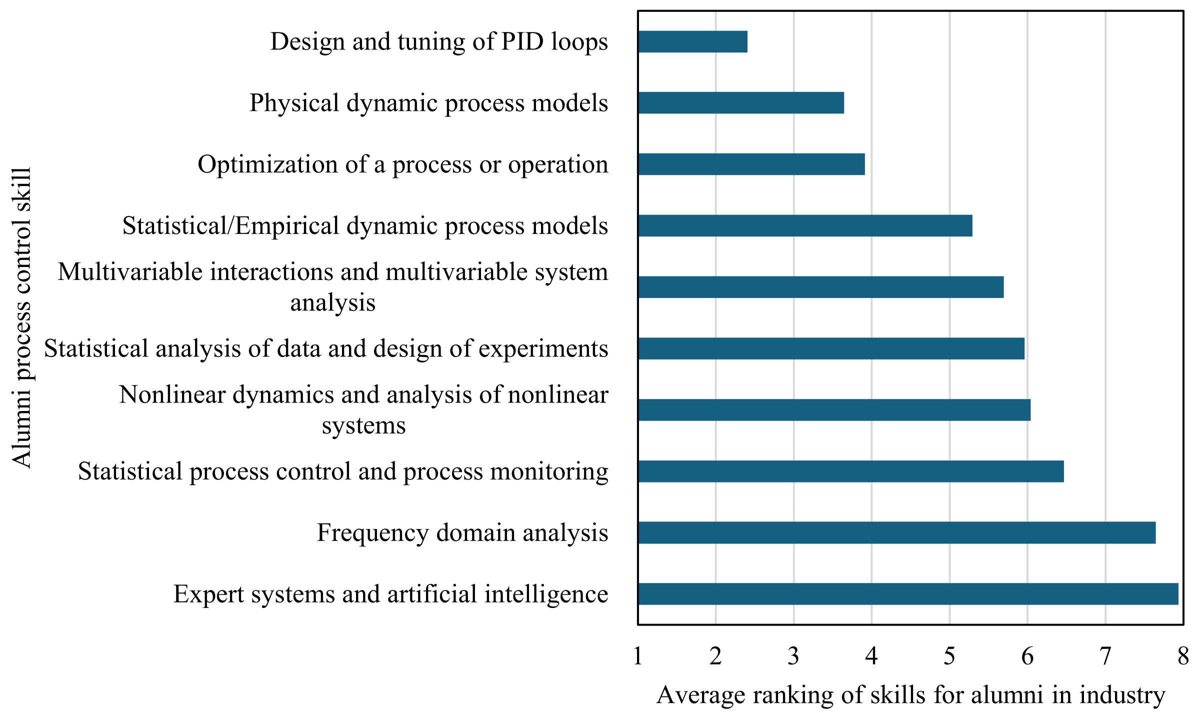

Figure 14. Averaged faculty ranking of skills needed by alumni in industry, 79 respondents. 1 = highest ranking

Overall, the courses provide the suggested core content of reference [4]: importance of control and feedback, system behavior, and simple control loop design with PID emphasis, all with the use of software. Laboratories are fairly common, but the 2025 survey did not ask specifically about the encouraged case studies or visualization. There is a heavy emphasis on mathematics, particularly LaPlace transforms, that many would like to see diminish, but there is an increase in the design aspects of control.

Challenges in Teaching Process Control

The top challenge in teaching process control (Figure 15) is unchanged since 2015: MATH. Comments included lack of facility with LaPlace transforms but also weak algebra skills. The comments in the category “lack of industrial training or awareness” were about the lack of *faculty* industrial training, not that the students lacked an industrial context. The lack of faculty industrial training was not mentioned as a challenge in 2015. Student internship or co-op experience was mentioned as a positive factor in 2015 and not mentioned in 2025. In “lack of student interest or focus”, many students think they will not use the theory, modeling, or analysis of dynamics from the course in their careers. They are also distracted by capstone design and job searches.

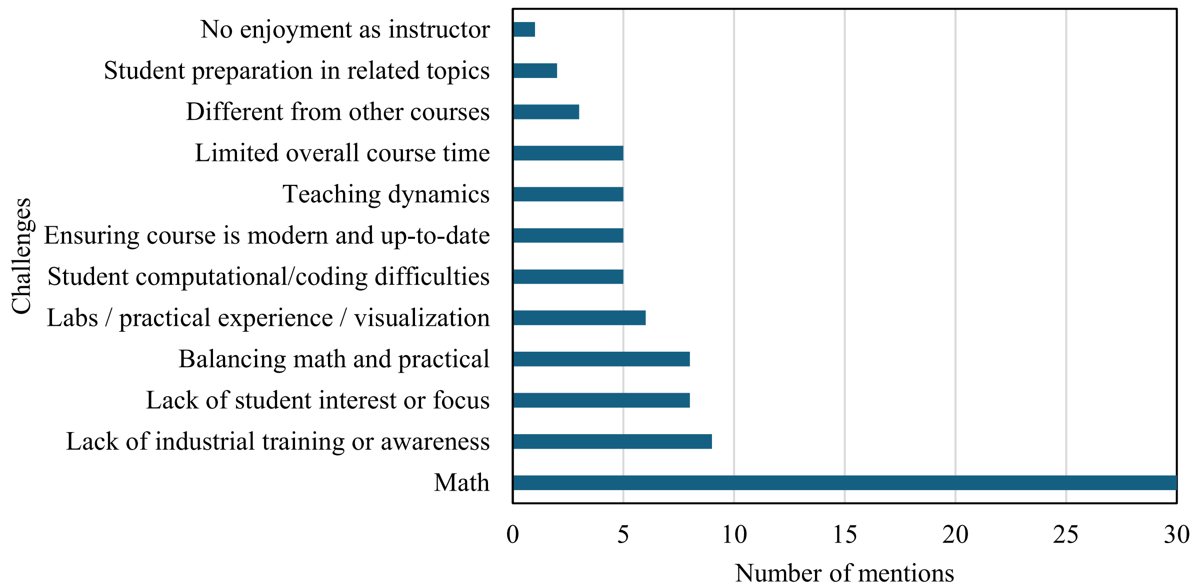

Figure 15. Challenges in teaching process control. Math was mentioned more than three times as many as the next most-common challenge.

Effective Teaching Strategies for Process Control and Course Distinctives

The survey contained open-ended questions aimed at uncovering effective pedagogical practices used in process control courses and distinctive features of those courses. Many of the reported effective practices are well-documented in the literature. For example, flipped classrooms [26], [27], [28] were commonly reported, as was the use of "notes with gaps" [29], [30]. Simulations with (presumably) the software mentioned in Figure 2 were frequently conducted, an approach that aided rapid comparisons between control schema or amongst tuning approaches. Some of those simulation approaches were tied together with a common scenario that was developed throughout the course of the term. Clicker-based quizzes were also used to engage students in the classroom.

Another common theme was connection to practice or practical physical behavior. Video from real operations (including U.S. CSB videos [31]) tied to simulation models or course topics was cited, as were experimental exploration. Many of those experiments used Arduino-based devices including TCLab [9]. Others used unit operations laboratory facilities. Another approach to connecting with practice as "war stories" as told by practitioners. Model predictive control was taught by one instructor with industry experience in applying the technique.

Other instructors cited what they considered to be distinctive features of their courses. Extending the discussion to non-engineering examples of control systems was mentioned, such as shower temperature control, cruise control, and toilet tank level control. Some incorporated specialized areas of research like synthetic biology, while others used more traditional or emerging practical contexts like batch process design, systems integration, or alignment with capstone design projects. Some courses called on students to generate instructional or tutorial videos for other students as part of the course. Artificial intelligence (AI) was used to facilitate

Socratic discussions between the instructor or with the students (at different institutions). A few programs mentioned teaching in state space and using frequency response analysis as marks of distinction.

Changes in Teaching Process Control

We asked the faculty how teaching process control has changed over the past two or three years, and we also asked how they expect it to change over the next several years. Of the 63 responses, five were that there were no changes made or planned, and these were frequently from faculty new to the course. Responses were coded, grouped, and reported in Table 5. There were many different changes made and planned, and our co-author analyst is confident in the numbers for each category in the left-hand column. Dividing responses into sub-topics was more subjective, leading to lower confidence, and the sub-topics were grouped simply as none/one/few. Only sub-topics with multiple mentions, marked with **XX** and bolded, are given in Table 5. The other single-mention changes are listed in Appendix C. Faculty specifically said that some changes were due to COVID: removing the lab and that it takes longer to get through material now. Some changes were because students' math skills are weaker.

Table 5. Changes implemented in the past 2 – 3 years or those planned in the next several years. **XX** indicates multiple faculty mentions, and X is a single mention. The total mentions for a category are in parentheses after the category name. More single mentions are in Appendix C.

Category	Topic	Implemented	Planned
Non-AI/ML Topic changes (26)	Eliminate/Reduce Frequency Response Content	**XX**	
	Simplified Math	**XX**	
	Less Theoretical Controller Design	**XX**	
AI/ML (14)	AI	**XX**	**XX**
	LLM/ChatGPT	**XX**	**XX**
	AI for Advanced Process Control		**XX**
Computational Tools (14)	Expanded Use of Python	**XX**	X
	Expanded Use of MATLAB, Simulink, Live Scripts	**XX**	
Practical Applications (10)	More Practical Examples	**XX**	**XX**
Pedagogical Changes (16)	Added Project/Project-Based	**XX**	
Laboratory Improvements (11)	Use/Expand Use of Arduino Microcontrollers	**XX**	X
	Add More Experiments		**XX**
	Use TCLab	**XX**	X

With the exception of the contact hours question, our survey questions are only if the topic is covered, not how much time is dedicated to the topic. Because we did not ask about the time dedicated to topics, changes in time spent on a topic are not reflected elsewhere in the paper. The changes implemented and mentioned in Table 5 do agree with data presented elsewhere in this paper about the increase in the use of Python and project-based courses.

The recent changes mentioned in 2015 had a pedagogical or resources focus instead of content focus: videos for real-world connections, course management system, textbook websites, and online software tutorials.

Panel Discussion

The AIChE Annual Meeting panel discussion had three panelists: Dr. Matt Kipper of Colorado State University, Dr. Thomas Meadowcroft of Rowan University, and Dr. David Silverstein of the University of Mississippi. Matt has 13 years of experience teaching process control, and he has an online course in which the students synthesize the chemical engineering curriculum into complex systems and control their behavior. Tom has 10 years of experience teaching process control and 25 years of experience in batch and continuous process control with Union Camp Corp., International Paper, General Electric, Omnova Chemicals, and Dover Chemical Corp. His control course is a design course emphasizing the translation of process design and objectives into control design and objectives. He discussed his approach in a recent paper [32]. David has over 25 years of experience teaching process control. He described his inductive experiential teaching approach for process control in a publication [33]. The summary below is the consensus of the panelists.

An early discussion was how ubiquitous computer access has changed control and how AI will change control. Plants are much more automated than decades ago, which is better for safety and environmental concerns. Although computer controllers are everywhere, the engineers will handle only simple dynamics with simple-to-tune controllers and many sequential logic controllers (60% of the value in chemical industry is batch). Students are now familiar with control systems before they arrive in the course from drones and adaptive cruise control (constraint control) because of widespread computer use. There are opportunities with AI, process control, and big plant data. AI needs dense training data, but our control events are not dense. AI will be used in an advisory role rather than in the control loop and in predicting preventative maintenance needs. There will also be an increase in monitoring and statistical control.

Regarding teaching with ubiquitous computer access, LockDown Browser will allow access to MATLAB online and an online spreadsheet, but MATLAB is adding AI to their software. We can ask the students to interpret the results of a simulation rather than produce the simulation.

Another discussion area was how to move to a more, but not entirely, design-oriented approach to control. In addition to the ideas in Tom's paper [32], faculty can teach just enough LaPlace domain to explain the process time constant and process gain from transient balances. They can then switch to symbolic MATLAB calculations, followed by design practice. Faculty can emphasize conceptual questions, such as

- What would you test now?
- How do you expect things to change if you change this?
- What are the performance limits?

Faculty can also use the "Things to think about" questions at the end of the chapters of the Stephenapoulos text [16].

A practical item that students should be aware of is that 80% of control problems are because the control valve is old and has hysteresis and stiction. The valves should be changed every 2 years, and many plants are moving to variable speed drives, which have fewer problems than control valves. The remainder of control problems are split between the sensor and a controller that was never properly tuned.

Luyben and Luyben's second process control law is that "you must understand a process before you can control it" [34]. Conversely, understanding how to control a process will increase the students' understanding of the process itself.

Summary

Most institutions offer a standalone, required process control course, typically at the 400-level and structured around lectures with simulation or problem-solving laboratories. MATLAB, Simulink, and Excel remain the most widely used software tools, with Python showing a notable increase in adoption since the previous 2015 survey. Many courses include project- or problem-based learning, and roughly one quarter have associated experimental laboratories. Industrial collaborators are used in 44% of courses, most commonly for guest lectures.

Survey results indicate strong agreement on core teaching priorities, with understanding process dynamics and controller tuning consistently ranked among the most important goals. Topic coverage remains broadly similar to 2015, although more programs now include design-oriented content and practical examples. Traditional Laplace-domain material continues to dominate despite ongoing discussions about reducing mathematical emphasis. Faculty reported persistent challenges in students' mathematical preparedness.

The paper also summarized commonly used textbooks and online resources, teaching assistant responsibilities, and the learning environments in which courses are delivered. A review of changes implemented in recent years shows increased use of Python, more practical examples, expanded project-based learning, and initial incorporation of AI/LLM resources. Planned future changes point to continued growth in AI-related content, additional laboratory development, and further shifts toward design-oriented instruction.

Panelists at the AIChE Annual Meeting emphasized the impact of increasing automation in industry, the continued importance of simple dynamic systems and PID control, and the emerging advisory role of AI in industrial practice. They also discussed strategies for balancing mathematical rigor with practical design considerations.

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Appendix A. Survey

Q1 This Year's Theme: Process Control. Welcome to the 2025 AIChE How We Teach survey. This year we will be seeking to develop a picture of how Process Control is taught. Our goals with this survey are to improve our teaching and inform our topic selection in this course. You add your unique style to how you teach your course. One purpose of this survey is to gather and share your innovative ideas about how we teach the course selected for this year's theme. In addition, we collect basic information about course design to compare and contrast both what is presently taught and what was taught at the time of previous surveys on this subject (1975, 1985, 1993, 2015). Please share your approaches with us so that we can summarize the "state of the art" and have a "sharing session" at the annual AIChE meeting.

There is a parallel survey of industry. If you have industry experience in process control in the past 3 - 5 years, please email Laura Ford at laura-ford@utulsa.edu for a link to that survey.

This study has been determined by the University of Tulsa to qualify as human subjects research. Information about participation in this study is available here: Informed Consent . If you consent to participation in this study, please continue with the survey. If you do not consent to participation in the study, please close this survey.

Q2 Clarification on the survey scope: Process control inherently involves an understanding of the process dynamics. Because control is ABET-required and it is the focus of this survey, please limit your responses here to process control with process dynamics only as they touch process control.

Q3 What is your name?

Q4 If you want the presentation slides resulting from this survey sent to you, please enter your email address.

Q5 What is the name of your institution?

Q6 How many years of industrial process control experience do you have?

Q7 How many years have you taught process control?

Q8 For the 2024-25 academic year, what term system did your institution use?
o Quarter
o Semester

Q9 ABET requires the incorporation of process control content in the curriculum. How does process control content appear in the required parts of your curriculum? (Please do not consider any content that is part of an elective or is not taken by all students.)
▢ One required course (even if from a selection)
▢ More than one required course
▢ Part of a required course (or selection or series of courses) whose emphasis is control

▢ Part of a required course (or selection or series of courses) whose emphasis is not control
▢ other (please describe)

Q10 What are the course number(s) and title(s) of those courses (the standalone or course in which control is incorporated)?

Q11 About many contact hours are spent on control during the primary course teaching process dynamics and control? For example, a dedicated 3-hour course on control in a 17 week semester would have about 51 total hours of instruction. Please use a 50-minute "hour" and report times in hours. For primary coverage as part of another course, please estimate the hours within that course with a control focus.
o Lecture ____
o Simulation/problem laboratory ____
o Experimental laboratory ____
o Recitations ____
o Other (please describe) ____

Q12 Is this course cross-listed as a graduate-level course?
o No
o Yes

Q13 Which of the following software packages do students typically use as part of the process control course? Please select all that apply.
▢ AI/LLM/Neural networks
▢ Aspen Dynamics
▢ Aspen Hysys
▢ Aspen Plus
▢ AVEVA Process Simulation
▢ ChemCAD
▢ Control Station/LoopPro Trainer
▢ Honeywell Experion Process Knowledge System
▢ Honeywell UniSim
▢ Maplesoft Maple
▢ Mathworks MATLAB
▢ Mathworks Simulink
▢ Microsoft Excel
▢ NI LabVIEW
▢ PetroSkills
▢ Polymath Plus
▢ ProSim
▢ PTC Mathcad
▢ Python
▢ Simtronics
▢ Superpro Designer
▢ Wolfram Mathematica
▢ No software is used
▢ Other (please list) _

Display this question:
If Which of the following software packages do students typically use as part of the process control... = No software is used

Q14 What is the relative emphasis of coding (Excel, Matlab, Python) versus simulation (Simulink) in your course?
o More coding that simulation
o Roughly equal amounts of coding and simulation
o More simulation than coding

Display this question:
If Which of the following software packages do students typically use as part of the process control... = No software is used

Q15 How is the software used in your course? Please select all that apply.
- ▢ Exams
- ▢ Homework
- ▢ In-class activities
- ▢ Labs
- ▢ Projects
- ▢ Quizzes
- ▢ Other (Please describe) ____

Display this question:
If Which of the following software packages do students typically use as part of the process control... = No software is used

Q16 How do your students access software used in the course? Please select all that apply.
- ▢ A computer lab maintained by the Department
- ▢ A computer lab maintained by the College
- ▢ A computer lab maintained by the University
- ▢ Students provide their own laptops as required by the institution
- ▢ Students provide their own laptops as recommended by the institution
- ▢ Students provide their own laptops (no requirement, no recommendation)
- ▢ Students use laptops provided by the institution
- ▢ Access on cloud/virtual machines

Display this question:
If About many contact hours are spent on control during the primary course teaching process dynamics are spent on experimental laboratory Text Response Is Greater Than 0

Q17 Briefly describe the physical experiments used in your course.

Q18 Which textbooks are primarily used in the course? If you are an author and your textbook is not listed, please accept my apologies and send me laura-ford@utulsa.edu your textbook information which I will add to the list.
- ▢ Bequette, Process Control, Modeling, Design, and Simulation
- ▢ Cooper/others, Practical Process Control
- ▢ Coughanowr/Leblanc, Process Systems Analysis and Control
- ▢ Luyben, Process Modeling, Simulation and Control for Chemical Engineers
- ▢ Luyben/Luyben, Essentials of Process Control
- ▢ Marlin, Process Control
- ▢ Meadowcroft, Process Control Design and Practice
- ▢ Ogunaike/Ray, Process Dynamics, Modeling, and Control
- ▢ Riggs/Karim/Alford, Chemical and Bio-Process Control
- ▢ Romagnoli/Palazoglu, Introduction to Process Control

- ☐ Seames, Designing Controls for the Process Industries
- ☐ Seborg/Edgar/Mellichamp/Doyle III, Process Dynamics and Control
- ☐ Smith/Corripio, Principles and Practice of Automatic Process Control
- ☐ Stephanopoulos, Chemical Process Control An Introduction to Theory and Practice
- ☐ Svrcek/Mahoney/Young, A Real-Time Approach to Process Control
- ☐ Woolf, Chemical Process Dynamics and Controls
- ☐ Other ____
- ☐ None

Q19 What online resources did you use? Please select all that apply.

- ☐ AIChE Concept Warehouse
- ☐ BYU/Hedengren's resources (notes, tools, code, temperature control experiment)
- ☐ CAChE's Teaching Resources page
- ☐ Control Loop Foundation videos
- ☐ LearnChemE screencasts
- ☐ LearnChemE Virtual Lab (Control of a Single-Stage Distillation Column)
- ☐ Marlin's Teaching Process Control website
- ☐ Textbook author's resource page
- ☐ University of Notre Dame GitHub Jupyter/Python repository
- ☐ Other ____
- ☐ None

Q20 How do you use industrial collaborators or adjuncts with industrial experience in the course? Please select all that apply.

- ☐ We don't use industrial collaborators or adjuncts with industrial experience
- ☐ Full course responsibility
- ☐ Funding
- ☐ Guest lecture(s)
- ☐ Mentors for case studies or projects
- ☐ Software support
- ☐ Others (please describe) ____

Q21 How do you use graduate teaching assistants in the course? Please select all that apply.

- ☐ We don't use graduate teaching assistants in the course
- ☐ Grading small assignments
- ☐ Grading exams and/or larger assignments
- ☐ Giving a few lectures
- ☐ Covering the recitation sessions
- ☐ Holding office hours
- ☐ Monitoring simulation labs
- ☐ Monitoring experimental labs
- ☐ Other (please describe) ____

Q22 How would you describe your learning environment? Check all features which apply. There is some use of...
▢ student ombudspeople
▢ plant visits
▢ problem- or project-based learning
▢ videos
▢ tables can be rearranged for team work
▢ whiteboard space for student group work computers accessible during class hardware demonstrations (instruments, controlled systems) outside of class web-based lectures (including "flipped" courses) [later prompts were accidentally included]
▢ computers accessible during class
▢ hardware demonstrations (instruments, controlled systems)
▢ outside of class web-based lectures (including "flipped" courses)
▢ other (please describe) ____

Q23 What are your primary goals when teaching this course? Please select only your top three.
▢ competent modeling
▢ controller tuning
▢ develop solid theoretical background
▢ practical or industrial control
▢ read and draw P&ID
▢ selection of hardware and instrumentation
▢ simulation proficiency
▢ thinking economically
▢ thinking in terms of process safety
▢ understanding process dynamics
▢ troubleshooting control problems

Q24 Which of the following topics are taught in your course? Please select all that apply.
▢ Laplace transforms
▢ Inverse Laplace transforms
▢ Transfer functions
▢ State-space
▢ Empirical modeling in Laplace domain
▢ 1st order responses in Laplace domain
▢ 2nd order responses in Laplace domain
▢ Pole/zero analysis
▢ PID controllers
▢ Instrumentation
▢ Final control elements
▢ Process & instrumentation diagrams
▢ Open-loop/Closed-loop modeling in Laplace domain
▢ Open-loop/Closed-loop modeling in time domain
▢ Frequency response analysis
▢ Frequency domain design
▢ Feedback controller design/tuning

- ▢ Feedforward controller design/tuning
- ▢ Tuning heuristics
- ▢ Safety
- ▢ Multiloop/Multivariable analysis
- ▢ Real-Time optimization
- ▢ Process monitoring/Statistical process control/Statistical quality control
- ▢ Translation of process objectives into implementable control objectives and designs
- ▢ None of the above

Q25 Which of the following process dynamics are included in your course? Please select all that apply.

- ▢ Dead time dominant
- ▢ Integrating
- ▢ Inverse response
- ▢ Multi-lag
- ▢ Nonlinear behavior
- ▢ Self-regulating
- ▢ Unstable
- ▢ Not sure
- ▢ None of the above

Q26 Which common reasons for performance limitations in control loops are included in your course? Please select all that apply.

- ▢ Actuator limitations or nonlinearity (e.g., valve stiction)
- ▢ Inadequate process models
- ▢ Interaction with other loops
- ▢ Lack of training or operator understanding
- ▢ Legacy control hardware/software
- ▢ Measurement noise or sensor drift
- ▢ Poor loop tuning
- ▢ Process nonlinearity or gain change
- ▢ Other (please specify)
- ▢ None of the above

Q27 Which control strategies are included in your course? Please select all that apply.

- ▢ Adaptive control
- ▢ Advanced process control (APC) platforms
- ▢ Batch control
- ▢ Cascade control
- ▢ Dead-time compensation
- ▢ Discrete (digital, z-domain) control
- ▢ Feedback (PID)
- ▢ Feedforward control
- ▢ Gain scheduling
- ▢ Inferential control (soft sensors)
- ▢ Internal Model Control

▢ Manual control
▢ MIMO control
▢ Model Predictive Control (MPC)
▢ Other Advanced Control
▢ Plantwide control
▢ Ratio control
▢ Other (please specify) ____
▢ None of the above

Q28 Which types of transmitter signals are included in your course? Please select all that apply.
▢ Digital wired
▢ Digital wireless
▢ Electrical
▢ Pneumatic

Q29 Please rank order the following list of process control skills, with 1 being the most important for alumni working in industry.
______ Design and tuning of PID loops
______ Expert systems and artificial intelligence
______ Frequency domain analysis
______ Multivariable interactions and multivariable system analysis
______ Nonlinear dynamics and analysis of nonlinear systems
______ Optimization of a process or operation
______ Physical dynamic process models
______ Statistical analysis of data and design of experiments
______ Statistical/Empirical dynamic process models
______ Statistical process control and process monitoring

Q30 Please describe other process control courses offered in your department including different contexts, "tracks," or specializations, such as bioprocess control.

Q31 If process control content appears in elective courses, please give the name of each course and a brief description of the process control content.

Q32 Many would argue this is the most important part of the survey, where we ask you to share what you do in the course that can help other instructors improve their teaching. You may not have an answer for each question, but please try to share the information that makes your particular rendition of the course effective, unique, and valuable. Your help is appreciated, and we truly appreciate the time you invest in this survey.

Q33 How can the content or supplements of/for the text you now use be improved?

Q34 What are some explanations of concepts in the course that you have found particularly effective?

Q35 What do you see as the particular challenges in teaching process control?

Q36 How have your course and the way you teach it changed over the past two or three years? How do you expect it to change over the next several years?

Q37 Please describe any other distinctive features of the course as you teach it.

Q38 Any comments about the survey itself can be made here.

Appendix B. Responding institutions (number of responses if not 1)

Arizona State University
Brigham Young University
Bucknell University
California Baptist University
CCNY ChE
Christian Brothers University
Clarkson University
Clemson
Colorado State University
Cornell University (2)
Drexel University
FAMU-FSU College of Engineering
Florida Institute of Technology
Georgia Institute of Technology
Iowa State University
Kansas State University
Lafayette College
Lehigh University
Louisiana State University
Louisiana Tech University
Michigan State University
Missouri University of Science & Tech.
New Jersey Institute of Technology
New Mexico Institute of Mining and Tech.
New Mexico State University
New York University
Ohio University
Oklahoma State University
Oregon State University
Pennsylvania State University
Prairie View A&M University
Purdue University
Rice University
Rowan University
Texas Tech University (2)
The Cooper Union
The Ohio State University (2)
The University of Arizona
The University of Texas at Austin
Trine University
Tufts University
Tuskegee University
UCLA
University at Buffalo
University of Alabama
University of Alabama in Huntsville
University of Alberta
University of Arkansas Fayetteville
University of British Columbia
University of Cincinnati
University of Colorado at Boulder
University of Dayton
University of Florida
University of Houston
University of Idaho
University of Illinois at Urbana-Champaign
University of Louisville
University of Maine
University of Maryland, Baltimore County
University of Maryland, College Park
University of Massachusetts Amherst
University of Michigan
University of Minnesota
University of Minnesota Duluth
University of Missouri Columbia
University of Nevada, Reno
University of North Dakota
University of Notre Dame
University of Pennsylvania
University of Rhode Island
University of South Carolina
University of Tennessee
University of Toledo
University of Tulsa
University of Utah
University of Virginia
University of Washington
UT San Antonio
Vanderbilt University
Villanova University
Washington State University
Washington University in St. Louis
West Virginia University
Worcester Polytechnic Institute
Youngstown State University

Appendix C. Changes implemented in the past 2 – 3 years or planned in the next several years

Table C. Changes implemented in the past 2 – 3 years or those planned in the next several years. X is a single mention. Changes with multiple mentions are in Table 5 in the body of the manuscript. The total mentions for a category are in parentheses after the category name.

Category	Subtopic	Implemented	Planned
Non-AI/ML Topic changes (26)	Instrumentation/EE Concepts	X	
	Allow Students to Take Automation Design Course in Place of Dynamics and Analysis Course	X	
	Reduced Focus on Hardware (Control Valves, etc.)	X	
	More Plant-Wide Control	X	
	More Focus on Communication Skills	X	
	Added Lambda Tuning	X	
	More Computer-Based Analysis	X	
	Model Predictive Control		X
	Integrate Control Into Capstone		X
	Data-Driven Control		X
	Statistics/Statistical Process Control		X
	Optimization		X
AI/ML (14)	Machine Learning for Controller Tuning	X	X
	ANN Models		X
Computational Tools (14)	AVEVA Process Simulation to prepare P&IDs	X	
	Simulation Software to Provide Real-World Experience	X	
	Use Dynamic Capabilities of CHEMCAD		X
	Digital Twins		X
Practical Applications (10)	Review P&IDs Provided by Industry Partners	X	
	More Emphasis on Process Safety/Sustainability	X	X
	Use AVEVA Process Simulation to Prepare P&IDs		X

Table C continued. Changes implemented in the past 2 – 3 years or those planned in the next several years. X is a single mention. Changes with multiple mentions are in Table 5 in the body of the manuscript. The total mentions for a category are in parentheses after the category name.

Category	Topic	Implemented	Planned
Pedagogical Changes (16)	More Short Autograded Quizzes/Completion Quizzes	X	
	Flipped Classroom	X	X
	More Whiteboard Presentations	X	X
	More Practice Time for Students	X	
	Discussion Sessions		X
	Classroom Demonstrations	X	
	Removed Project	X	
	Lab Reflections	X	
	Supplemental Videos	X	
	Practice Quizzes	X	
	More Visualization	X	
	More Example-Driven Teaching	X	
	Worksheet-Driven Teaching	X	
Laboratory Improvements (11)	Bring Back Lab	X	X
	Use LabView	X	
	Major Upgrade of Process Control Lab	X	