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How We Teach Process Control: 2015 Survey Results

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How We Teach Process Control: 2015 Survey Results

Abstract

The authors present the statistical results of the 2015 AIChE Education Division survey on how chemical engineering courses are taught. This year's survey covers process control. The survey was conducted of faculty members teaching process control courses at their institution during the 2014-2015 academic year. Department administrators were solicited via email requesting that the instructors responsible for teaching process control at their institution respond to the survey, and instructors of record for relevant courses were contacted directly by email when practical. The survey was conducted online using the open-source survey package LimeSurvey. The survey questions this year were developed in consultation with CACHE Corporation and with the AIChE Education and Accreditation Committee. The report consists primarily of the statistical and demographic characterization of the course and its content, with some additional summary responses related to the course from open-ended questions. Additionally, the survey seeks to bring out the most innovative and effective approaches to teaching the course as cited by instructors.

Introduction and Background

The AIChE Education Special Projects Committee conducted surveys of U.S. institutions between 1965-1993, seeking to collect demographic and statistical data regarding undergraduate education. It also probed for innovative and effective teaching methods applied to chemical engineering courses, and so topics were both curricular and pedagogical. The AIChE Education Division resumed this annual survey series in 2009 following a similar model, and this paper reports on the statistical component of the most recent edition of that survey.

The process control course is the topic of the 2015 survey. The previous survey series conducted surveys on the same course in 1975,[1] 1985,[2] and 1993[3]. The structure for this report draws heavily on previous reports published on behalf of the Education Division.[4,5,6,7,8,9] Many of the results were previously presented at the 2015 AIChE Annual Meeting.

The survey was conducted via a web-based interface hosted by <the author's institution> running the open-source software LimeSurvey (limesurvey.org). E-mail invitations to participate were initially sent to all 158 department chairs in the United States requesting participation from the faculty members teaching the relevant course(s). A separate request was sent directly to the instructors of record for process controls courses during the 2014-2015 academic year based on information posted online. From that population, 81 usable responses representing 77 institutions in the United States were received for a 48.7% institutional response rate.

Questions were composed in consultation amongst the authors and were intended to provide some continuity with both the current AIChE Education Division surveys and with historical

surveys. Additionally, the survey questions were critiqued by several CAChE Corporation Trustees and by the AIChE Education and Accreditation Committee with the intent of ensuring that their interests in this topic were queried. The complete survey in print form is provided as Appendix A.

Instructor Characterization

The survey queried the rank or title of instructors along with the quantity of industrial experience. Figure 1 shows the distribution of ranks amongst respondents, with most instructors holding professorial appointments with a bias toward senior faculty members.

Of the 81 process control instructors responding, 18 (22%) indicated they had no prior industrial experience. The average length of industrial experience was 4.1 years amongst all instructors, 5.2 years when omitting those with no experience. The median industrial experience was 2 years. This is notably less experience that those teaching process design, where instructors had an average of 9.0 years' experience, and an average 11.3 years omitting those with no industrial experience.[7]

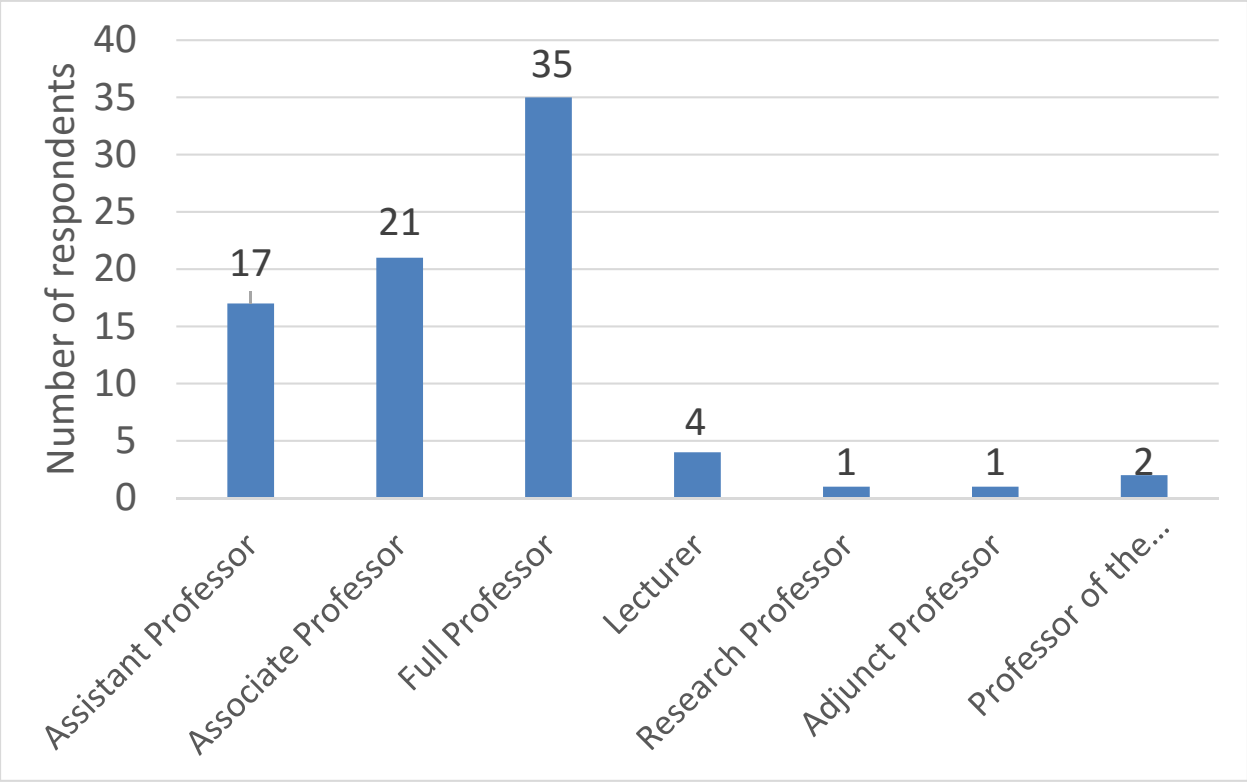

Figure 1. Rank and title of process control course instructors

In addition to the lead instructor, 19 (23%) respondents indicated teaching assistants (TA's) played an instruction role in lectures and/or recitations. Those respondents indicated an average 20% of contact time was led by TA's. Seventeen respondents (21%) indicated use of industrial

partners or adjuncts, with 10% of lectures on average given by industrial guests amongst those reporting. The roles of those partners in addition to lectures include acting as a consultant to the instructor, serving as a source for projects, or in a feedback role via an industrial advisory board.

Quantity of Coverage

Of the seventy institutions responding to the question, 68 indicated they offered at least one course identified as containing significant "process control". Seven had more than one required course on the topic, and two reported coverage in electives in addition to a required course. Two institutions indicated no coverage in a required course but that the topic was covered in electives.

Institutions reported an average of 40 hours lecture, 10.8 hours simulation or problem laboratory, and 7.1 hours of experimental laboratory per course. When the subject was integrated into other courses, the coverage was an average 18.8 hours lecture.

Course Deliverables

Figure 2 shows the distribution of course assessments and assignments as reported by respondents.

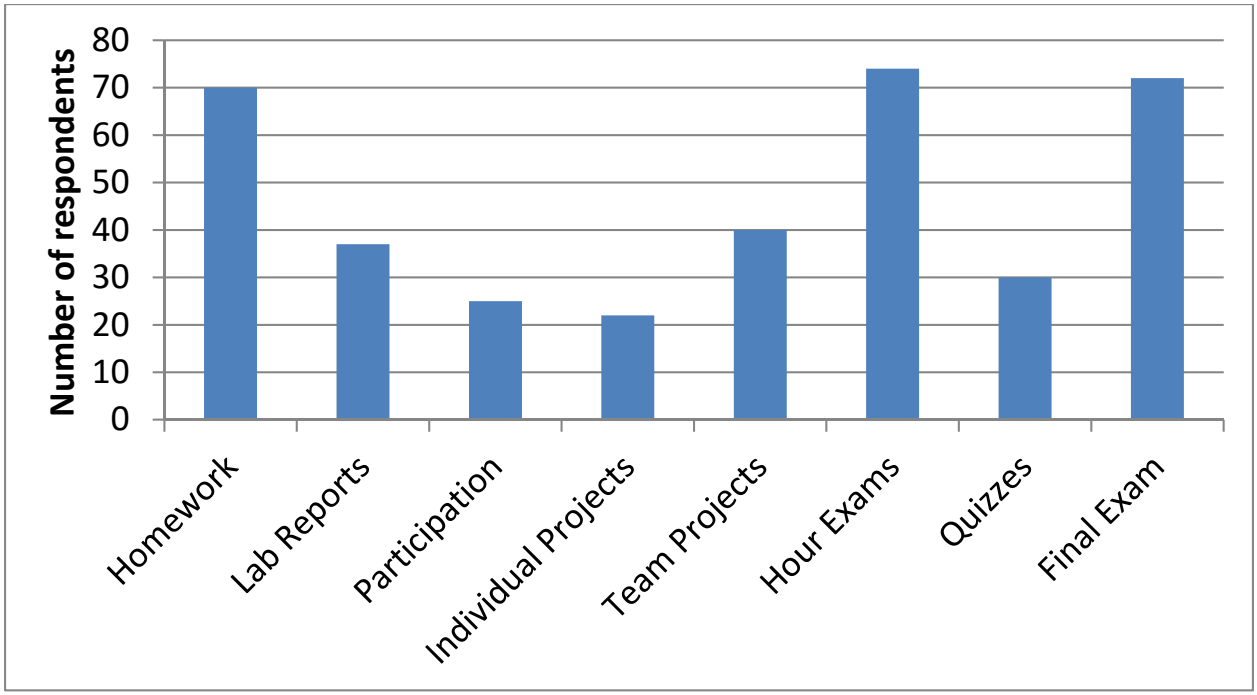

Figure 2. Course deliverables

Computing

A wide range of software usage was reported for the process control course, though most respondents indicated use of Mathworks MATLAB with or without Simulink and Microsoft

Excel. Figure 3 lists the reported usage of process control related software. Figure 4 characterizes the computing facilities offered by responding institutions as available for the process control course.

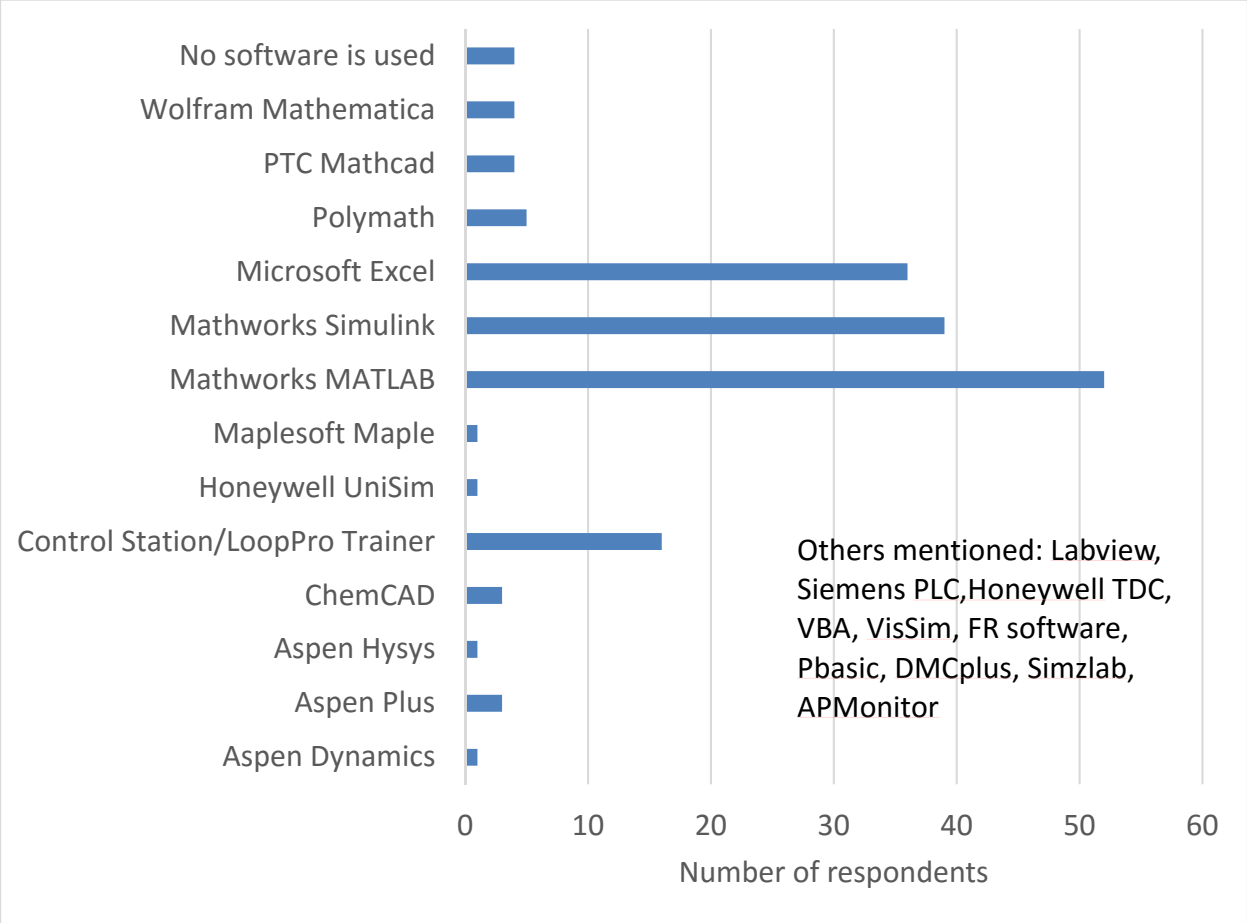

Figure 3. Reported software usage

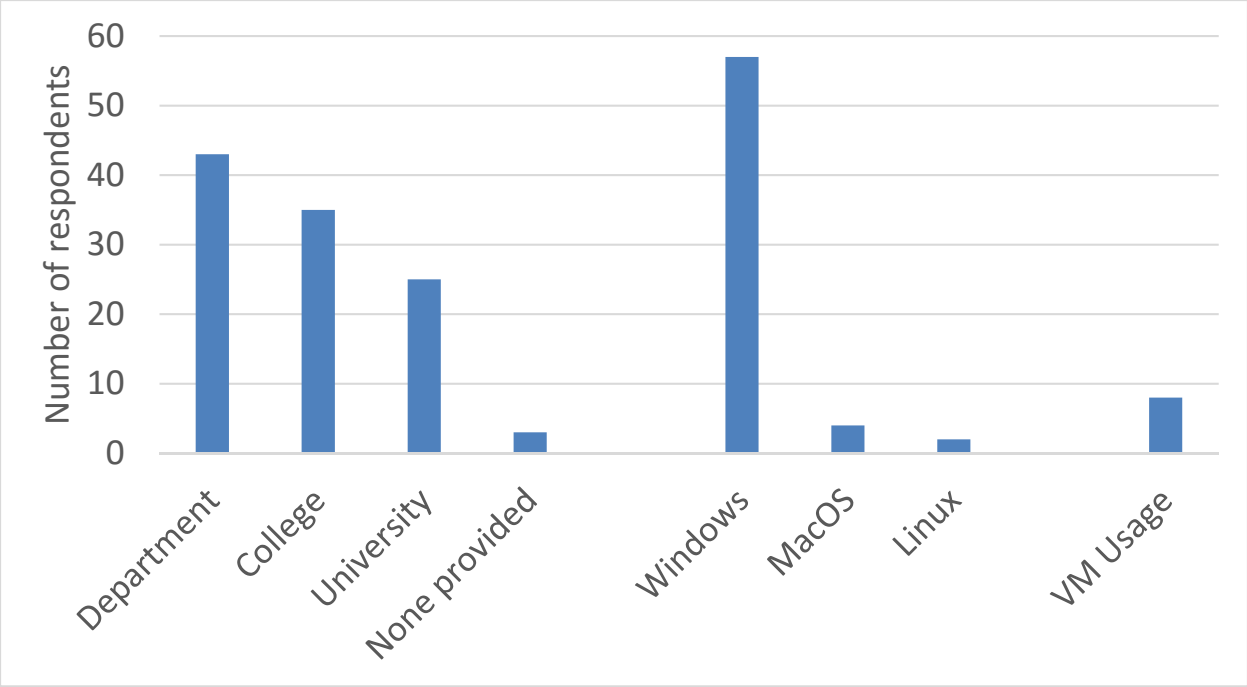

Figure 4. Computing facilities available for the process control course

Textbooks

A fairly wide range of textbooks were reported in use as indicated in Figure 5, with *Process Dynamics and Control* by Seborg et al. currently the most frequently adopted text. Improvements recommended for textbooks by some respondents suggested less emphasis on analysis in the Laplace domain, more laboratory and "real world" components, and more computational laboratory exercises.

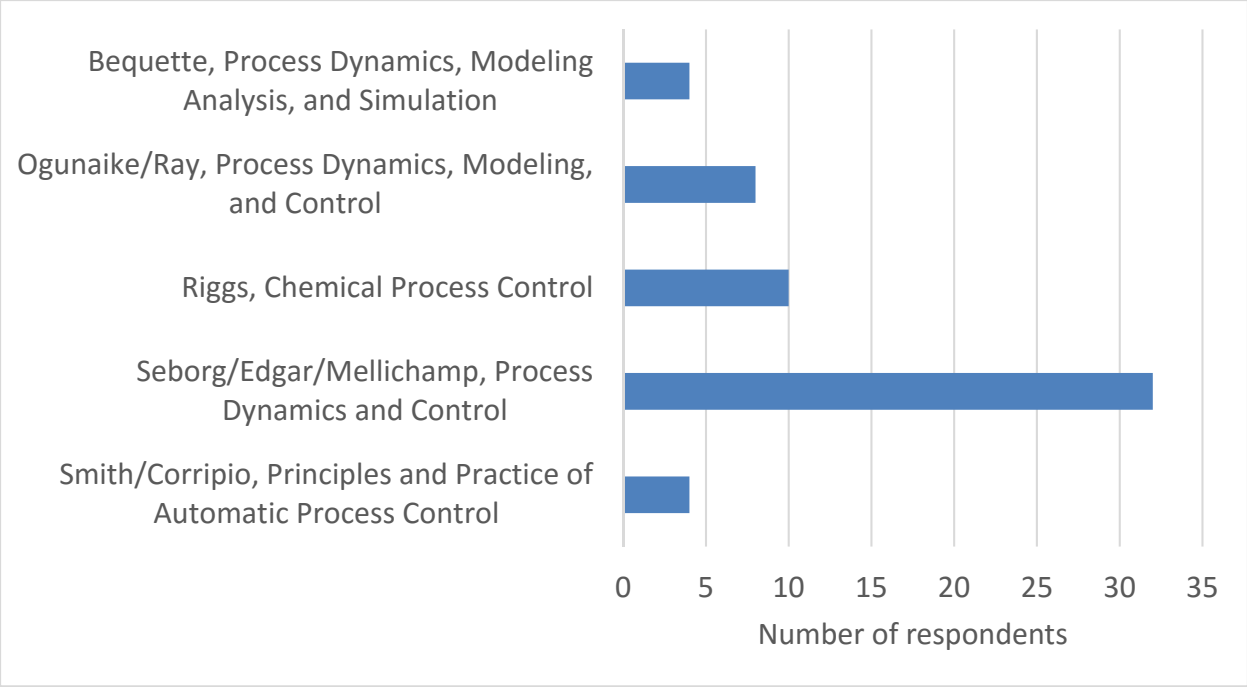

Figure 5. Textbook usage. Other texts receiving mention are: Chau, *Process Control with Matlab*; Cooper, *Practical Process Control*; Crowl, *Chemical Process Safety*; Larsen, *Process Control and Process Dynamics* (unpublished); Marlin, *Process Control*; Ogata, *Modern Control Engineering*; Simon, *Control of Biological and Drug-Delivery Systems for Chemical, Biomedical, and Pharmaceutical Engineering*; Stephanopoulos, *Chemical Process Control: An Introduction to Theory and Practice*; Svrcek/Mahoney/Young, *A Real-Time Approach to Process Control*; class notes.

Course Content

The coverage in the process control is highly variable according to respondents. Figure 6 lists responses to a multiple selection question on which topics are covered in the process control course.

The range of learning activities reported as utilized during a process control course was varied, with a majority of respondents indicating use of problem or project based learning and computer usage, as shown in Figure 7.

Outside of the process control course, the topic does appear in other contexts, such as unit operations laboratory courses and in process design. There were no reported control-oriented tracks, and only nine schools responding offer an advanced or graduate level course in process control.

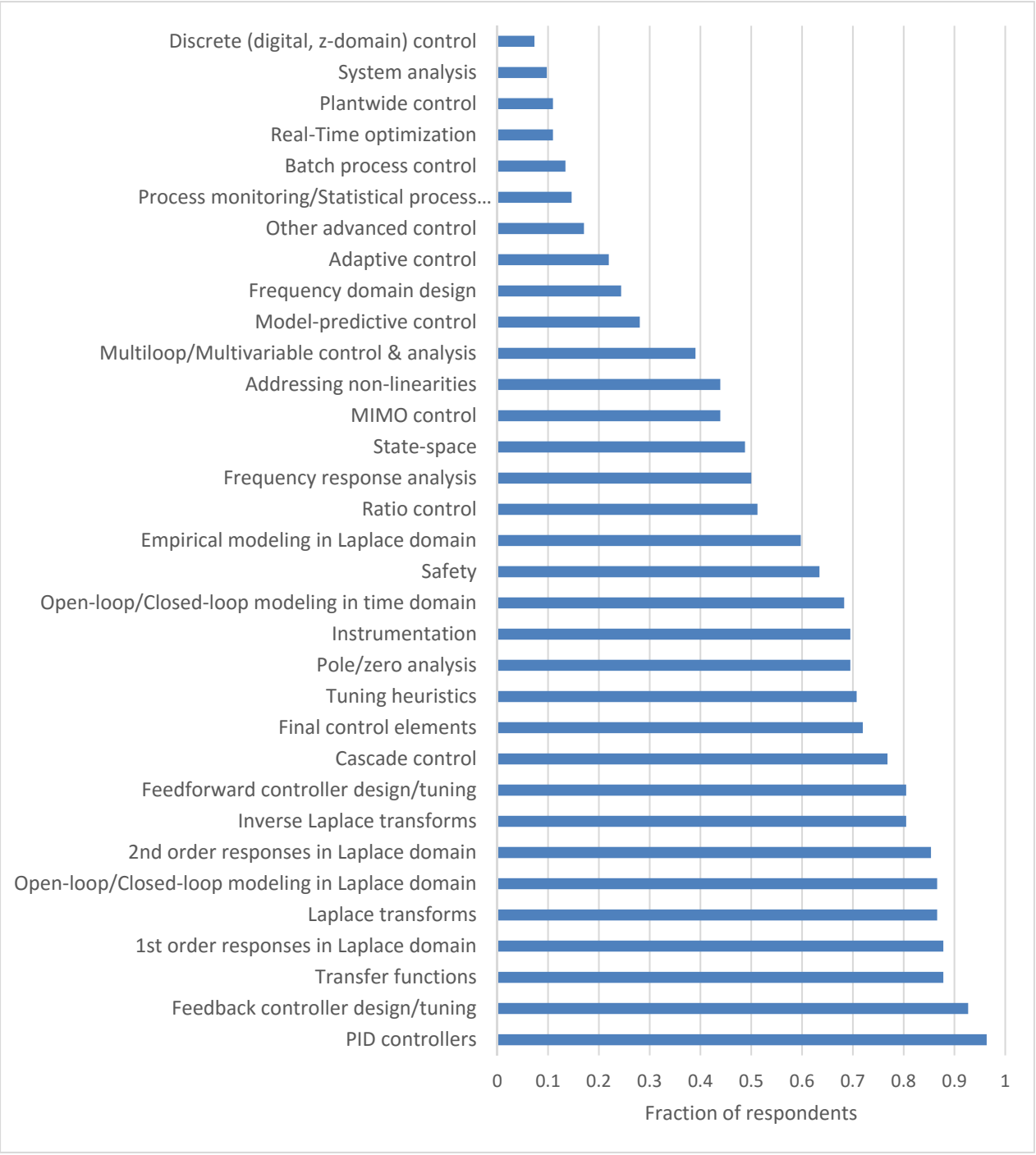

Figure 6. Process control topics covered

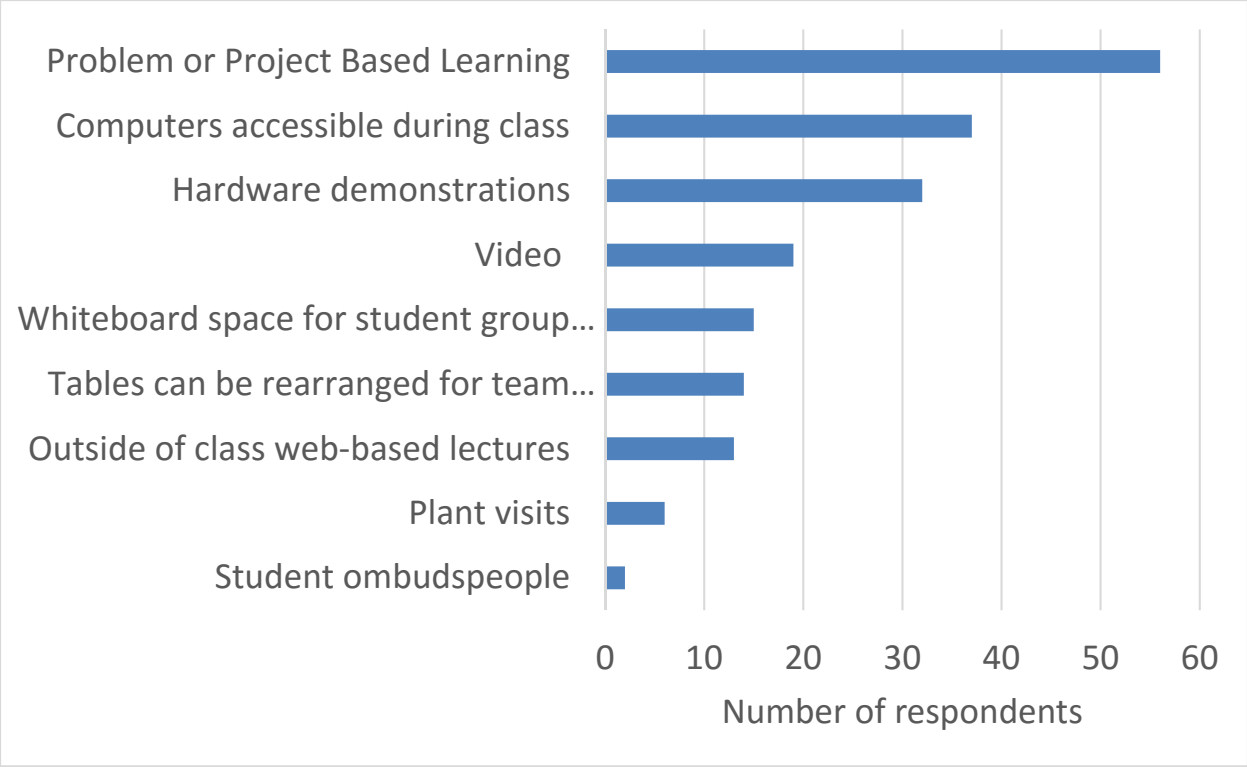

Figure 7. Learning activities utilized in process control courses

Qualitative Responses

Respondents were also asked to describe some of their observations from teaching the process control course.

The biggest teaching challenges cited by the respondents included:

- MATH (by far most comments)
- The need for more connections to the "real world"
- Time and timing (senior year, often; one semester only, often)
- Class size
- "Students with co-op/internship experience seem to be WELL ahead of those that lack it."

Recent changes to the teaching of process control cited were:

- Videos for "real-world connections"
- Course management systems
- Textbook websites
- Online software tutorials

When asked for the "distinctive features" of the process control course as they taught it, responding instructors gave responses typified by the following:

- Practical
- Integrated lab experience (hands on or simulations)
- No Laplace
- Group/Design project
- "Class starts with a simulation game in which the students manually control the flow rate of a reactor that can blow up. The average squared error is tracked and the 3 students who complete the simulation with the lowest error receive award certificates. Approximately half of the class blows up. Then the performance of the same simulation under a well-tuned PI controller is shown. It far surpasses the best manual performance. This motivates the class."

A more thorough analysis of open-ended responses and specific recommendations from the authors is outside of the scope of this initial report.

Conclusions

The 2015 AIChE Education Division survey characterized the current offerings of process control as marked by transition. Both Laplace and time domain approaches are being utilized, computing tools and modern pedagogies are changing teaching approaches, and increasing enrollments are challenging the incorporation of physical laboratory exercises. Even with the commonalities the course shares across implementations, like many chemical engineering courses there remains a wide range of approaches to teaching the course and a diverse selection of topics taught.

Acknowledgements

The authors would like to thank all of the instructors who completed this survey; the department chairs who forwarded the request; Frances Petrozelli who collected online information about course instructors of record; CACHE Corporation and its Trustees who reviewed the survey drafts; and the University of Kentucky Engineering Computing Services which hosted the survey.

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Appendix A. Print version of online survey.

AIChE Best Practices in Teaching 2015

This Year's Theme: **Process Control**.

Welcome to the 2015 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). 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 are 34 questions in this survey

Part 0: Your information

To start, we have a few questions about the person completing this survey and other personnel involved in the course.

1 [1-Respondent]What is your name?

Please write your answer here:

2 [2-Email]What is your e-mail address? *

Please write your answer here:

Your email address will not be shared with anyone or used outside of the context of this survey.

3 [3-University]What is the name of your institution? *

Please write your answer here:

4 [Rank]What was your rank / position during the term you most recently taught the process control course?

Please choose **only one** of the following:

- ○ Assistant Professor
- ○ Associate Professor
- ○ Full Professor
- ○ Lecturer (all ranks)
- ○ Adjunct Professor (all ranks)
- ○ Professor of the Practice/Teaching Professor (all ranks)
- ○ Research Professor (all ranks)
- ○ Other [ ]

5 [Industrial Experienc]How many years of industrial experience do you have?

Please write your answer here:

[ ]

6 [QuSe]For the 2014-15 academic year, what term system did your institution use?

Please choose **all** that apply:

- ☐ Quarter
- ☐ Semester

7 [4-ReportCopy]Should we send the summary findings to you?

Please choose **only one** of the following:

- ○ Yes
- ○ No

8 [5-Colleagues]If this course is team taught, multiple courses on the subject are taught with different instructors, or multiple sections are taught by different instructors, please give the names and email addresses of your colleagues. Alternately, we request that you forward the invitation you received to those instructors.

Please write your answer here:

Part 1: The Course

When more than one process control course is offered, please respond based on the *first* course in the sequence unless otherwise specified.

9 [6-NumC]How is process control primarily taught in your undergraduate curriculum? If you offer multiple tracks, please only consider the "traditional" or most common track.

Please choose **only one** of the following:

- ○ One required course
- ○ More than one required course
- ○ An elective course or courses
- ○ Part of a required course whose emphasis is not control
- ○ Part of a required course whose emphasis is not control, and one or more elective courses

10 [7-Titles]What are the course number(s) and title(s) of those courses (the standalone or course in which control is incorporated)?

Please write your answer here:

11 [8-Time]About how much time is spent on control during the primary course teaching 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.

Please write your answer(s) here:

Lecture	
Simulation/Problem laboratory	
Experimental laboratory	

12 [Grading]Which of the following activities are explicitly counted for a grade in this course (or course sequence)?

Please choose **all** that apply:

- ☐ Homework
- ☐ Lab reports
- ☐ Participation
- ☐ Individual project
- ☐ Team project
- ☐ Exams (hour or longer, not a final)
- ☐ Quizzes (shorter than exams)
- ☐ Final Exam
- ☐ Other:

13 [12-Software]Which of the following software packages do students typically use as part of the process control course?

Please choose **all** that apply:

- ☐ Aspen Dynamics
- ☐ Aspen Plus
- ☐ Aspen Hysys
- ☐ ChemCAD
- ☐ Control Station/LoopPro Trainer
- ☐ Honeywell UniSim
- ☐ Maplesoft Maple
- ☐ Mathworks MATLAB
- ☐ Mathworks Simulink
- ☐ Microsoft Excel
- ☐ Polymath
- ☐ ProSim
- ☐ PTC Mathcad
- ☐ Superpro Designer
- ☐ Wolfram Mathematica
- ☐ No software is used
- ☐ Other:

14 [CompLabs]Do your students have computing laboratories available?

Please choose **all** that apply:

- ☐ Yes, maintained by the Department
- ☐ Yes, maintained by the College
- ☐ Yes, maintained by the University
- ☐ No

- ☐ Are primarily Windows PCs
- ☐ Are primarily Apple PCs
- ☐ Are primarily Linux PCs
- ☐ Access on cloud/virtual machines

15 [14-Textbook]Which textbook is primarily used in the course?

Please choose **only one** of the following:

- ○ Bequette, Process Dynamics, Modeling Analysis, and Simulation
- ○ 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
- ○ Ogunaike/Ray, Process Dynamics, Modeling, and Control
- ○ Riggs, Chemical Process Control
- ○ Romagnoli/Palazoglu, Introduction to Process Control
- ○ Seborg/Edgar/Mellichamp, 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
- ○ Other [ ]

If you are an author and your textbook is not listed, please accept my apologies and send me your textbook information which I will add to the list. The current list is based upon the bookshelf contents of the survey author.

16 [17-Num Sections]How many lecture sections of the course were taught in 2014-15? If you have multiple courses, please only consider the first course.

Please write your answer here:

[ ]

17 [18-Enrollment]What was the average enrollment in each lecture section?

Please write your answer here:

18 [19-GTA]Did graduate teaching assistants present any lectures or run recitation sessions in this course?

Please choose **only one** of the following:

- ○ Yes
- ○ No

19 [Adj]Do you utilize industrial collaborators or adjuncts with industrial experience in the course?

Please choose **only one** of the following:

- ○ Yes
- ○ No

20 [IndRole]Please describe the role of industry in contributing to the course. If input has come from your industrial advisory board, please describe and cite that source.

Please write your answer here:

21 [20-GTA Lectures]What percent of lectures or recitations were given by persons other than the instructor?

Please write your answer(s) here:

Graduate Teaching Assistants	
Industrial Guest Lecturers	
Others	

22 [Topics]Which of the following topics are taught in your course:

Please choose **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

- [ ] 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
- [ ] Ratio control
- [ ] Cascade control
- [ ] Adaptive control

- [ ] MIMO control
- [ ] Other advanced control
- [ ] Discrete (digital, z-domain) control
- [ ] Multiloop/Multivariable control & analysis
- [ ] Real-Time optimization
- [ ] Model-predictive control
- [ ] Process monitoring/Statistical process control/Statistical quality control
- [ ] Batch process control
- [ ] Plantwide control
- [ ] System analysis
- [ ] Addressing non-linearities

23 [OtherTracks]Please describe other process control courses offered in your department for other "tracks" or specializations, such as bioprocess control. If control is covered in other contexts in your curricula, please describe.

Please write your answer here:

Part 2: Making the Course Even Better

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. We understand you are time constrained, so if you cannot answer any or all of the questions on this part of the survey, please click through to the wrap up page.

24 [27-Textbook] How can the content or supplements of/forthe text you now use be improved?

Please write your answer here:

25 [29-TLE]How would you describe your learning environment? Check all features which apply. There is some use of...

Please choose **all** that apply:

- [ ] student ombudspeople
- [ ] plant visits
- [ ] Problem or Project Based Learning
- [ ] video
- [ ] 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)
- [ ] Other:

26 [32-Explanations]What are some explanations of concepts in the course that you have found particularly effective?

Please write your answer here:

27 [33-Challenges]What do you see as the particular challenges in teaching process control?

Please write your answer here:

28 [Changes]How would you describe how your course and the way you teach it have changed over the past two or three years? How do you expect it to change over the next several years?

Please write your answer here:

29 [35-Web]How do you use the internet in this course? Do you have materials we can see? Do you use your textbook's site? Are there textbook supplements (online or otherwise) you find particularly useful? Do you use course management systems? What elements of those systems do you find most effective?

Please write your answer here:

30 [36-AIChE]Would you be willing to discuss your answers to the questions on this page with a breakout group or the entire audience at a special session at the 2015 AIChE National Meeting in Salt Lake City (November 8- 12)? Participation would be subject to your availability and the moderator's discretion. Invitations to participate will be extended early in the fall.

Please choose **only one** of the following:

- ○ Yes
- ○ No

Part 3: Wrapping up

We'll conclude with an opportunity for you to offer your closing comments on the course and survey. Your help is appreciated, and we truly appreciate the time you invest in this survey.

31 [30-Goals]What are your primary goals when teaching this class? Some possibilities would be practical control, competent modeling, using simulators, thinking economically, etc.

Please write your answer here:

32 [28-Distinctive]Please describe the distinctive features of the course as you teach it.

Please write your answer here:

33 [3.1]Any other comments regarding the process control course experience of your chemical engineering students would be welcome.

Please write your answer here:

34 [3.2]Any comments regarding this survey would be welcome.

Please write your answer here:

Thank you for your participation. If you have requested a copy of the results be sent to you, expect to see that in the spring of 2016

11-21-2015 – 00:00
Please fax your completed survey to: 270-534-6292
Submit your survey.
Thank you for completing this survey.