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Faculty and Industry Led Workshop to Prepare Students for Successful Internships in Process Control and Automation

Dr. Jason Berberich, Miami University

Associate Professor of Chemical, Paper and Biomedical Engineering

Dr. Gary Robert Rudemiller, The Paper Science & Engineering Foundation at Miami University

After receiving a BS, MS and PhD in the discipline of paper science and engineering, I worked for over 30 years in operations in the paper industry, from process engineering through executive level. This manufacturing experience instilled a robust appreciation of the need for process control and automation expertise in continuous manufacturing, and an awareness that these skill sets are in very short supply.

Mr. PATRICK JAMES DIXON PE, PMP, DPAS

https://www.linkedin.com/in/dixonpatrick/

Faculty and Industry Led Workshop to Prepare Students for Successful Internships in Process Control and Automation

Jason A. Berberich[1], Douglas W. Coffin[1], Gary R. Rudemiller[1], Pat J. Dixon and Keith L. Hohn[1]

[1] Department of Chemical, Paper and Biomedical Engineering, Miami University, Oxford, OH 45056

[2] Dixon Process Automation Services Inc., Lago Vista, TX, 78645

Abstract

Industry demand for engineers with skills in automation and advanced process control is rapidly growing. The increasing reliance upon automation coupled with the loss of process control experts associated with the "silver tsunami" (wave of retirements) is creating unprecedented demand for new talent in this increasingly important field. Introducing students to this area early in their education will not only better prepare students to enter an internship/co-op assignment in automation and process control, but also spark more student interest in pursuing a career in automation. Unfortunately, most engineering student interns have had no coursework in process control since these courses are typically taught senior year. To meet these emerging needs, an intensive three-week workshop was developed to prepare students for targeted internships in advanced process control and automation. The inaugural pilot workshop, titled *Systems Automation Springboard to Internships* (SASI), was held during the winter term of 2021. Students were sponsored by companies, who paid the workshop fee, and offered the students an internship during the summer of 2021.

The content of the SASI workshop, spanning the full spectrum of automation, from field instrumentation through enterprise control systems, is delivered through a mix of lectures, laboratory experiences, programming, and discussions with industry experts. The strength of the workshop lies in the rich depth and variety of materials offered by a mix of eight industrial practitioners and three academic instructors, delivered to students motivated to advance beyond the standard curriculum. The investment of the companies to pre-train their interns has shown great return in terms of more productive internships and more focused workforce development. Feedback from the sponsor companies and students give high marks for the workshop.

Introduction

The technologies embodied by such catch phrases as the Internet of Things and Industry 4.0, including artificial intelligence, automation, control, and big data are transforming all aspects of industry. A natural outcome of this transformation is a shift in required skill for effective engineers. And today most manufacturing companies face a real challenge in hiring engineers equipped with the skill set to work in a plant that has modern controls and automation technology.

Consider these statistics as supporting data for the challenges these manufacturing companies face in staffing their facilities with engineers qualified to maintain, optimize and upgrade to an industry 4.0 workplace. The U.S. Bureau of Labor Statistics *Occupational Outlook Handbook* stated a 2020 to 2030 job growth rate for industrial engineers as 14% and data scientists of 31% compared

to an average projected job rate of 8%. The traditional fields of chemical, mechanical, and electrical engineering had projected growth rates much closer to the average. Employers are quite cognizant of the growing skills gap. The 2021 Institution of Engineering and Technology's *Skills Survey* found that 71% of engineering employers who believe applicants are lacking in technical skills identified that it is specialist skills that are lacking. In the same survey, 46% of respondents thought people entering the workforce had few/none of the necessary technical skills. In addition, 45% of respondents stated that they provide additional training, while 25% end up recruiting fewer apprentices/graduates as a result. Greg McMillian [1] stated that many practicing process control in industry "recognize that there is a gap between graduation and an engineer's being able to implement and manage controls systems." He asked Dr. Russell Rhinehart, emeritus professor at Oklahoma State University, why we are in this state. Dr. Rhinehart's response was as follows:

> *In the United States, there are no control engineering programs. Within the major engineering programs, there is usually only one course related to control, and there is only so much that can be taught in one course. Further, the students are novices; they struggle to model and understand dynamic processes and solve differential equations or code simulators. So, the elements of instrument selection, dynamic modeling, PID control, and the mathematical language is about all that can be learned. Further, since many professors are working 55 hours per week to remain competitive in research, they need exercises and tests that can be graded by teaching assistants (simple, idealized) and are safe to use to defend a course grade (one right answer, no context). Consequently, the topical coverage is relatively shallow and unrelated to context.*

Alford and Buckbee [2]stated that due to the skills gap many employers often send new process engineers to vendor and technical society control courses, and senior personnel spend significant time training new hires. Suggested topics they believe should be included in process control education are: control systems hardware, instrumentation and electronic communications, analytical systems, safety instrumented systems, control strategies, software tools, control performance, abnormal situation management, alarm management, manufacturing execution systems, and documentation.

Industrial process control will be an essential component of automation, yet process/systems control is not a focus of traditional engineering education and there is a problem in attracting students to study and work in this area. Aufderheide and Wilkes [3] captured this issue in the following passage:

> *…control has its own lexicon, notation, and terminology which can be difficult for students to grasp. Without proper care by the Instructor it can quickly become very esoteric and seem devoid of the reality that many of the students will be in front of large machinery with several inputs and outputs that is highly nonlinear in nature and now have to regulate the process so it runs 24 hours a day, seven days a week. It is very daunting without a proper strategy and training to handle the situation Adequately. No control class can handle all the topics in the field be it frequency responses, root-locus design, cascade control, anti-reset windup, gain scheduling, split ratio control, inferential control, model-based control such as model predictive control.*

Targeted industrial internships in the areas of process/systems control and automation provide an avenue to introduce students to this field earlier in their education. According to the *2020 Internship and Co-op Survey Report* of the National Association of Colleges and Employers, 68% of interns were offered full-time employment and the acceptance rate was 86.7%. Liu *et. Al* [4] completed and extensive review of the literature on engineering co-ops and internships. One of their findings was that successful programs integrate the student, the employer, and the academic institution. They further suggest that the students be "proactive, purposeful, and resilient while engaging with the workplace environment to maximize their learning." They also found that student preparedness can vary widely among students, and suggested that providing support and guidance to students is important to bring equity to their experiences.

At Miami University we offer traditional programs in Biomedical, Chemical, Mechanical, and Electrical Engineering. The current engineering programs developed from the University's original niche programs in systems analysis, manufacturing engineering, and paper science and engineering, elements of which are still offered in more classical engineering programs at Miami today. Miami enjoys a unique industrial partnership through the Paper Science & Engineering Foundation, which has had a presence at Miami since 1960. The 39 member companies of the Foundation support the academic program and the students through scholarships, undergraduate work opportunities, permanent jobs, and other means of support. In 2014, member companies voiced their challenge of hiring engineers qualified to function with modern process controls and automation in manufacturing plants. The Department of Chemical, Paper and Biomedical Engineering responded by initiating a Process Control minor in 2016, in which a modest number of students enroll. With the fast evolution of the Industry 4.0 environment, further requests for more skills help from the member companies articulated the growing demands from industry for a workforce with skills in industrial automation, autonomous systems, and artificial intelligence. We likewise want to increase the level of preparedness for students in all our majors to enter a workforce operating in the fourth industrial revolution. For example, Miami has responded with a new degree program in Robotics. Similarly, in response to the needs of Foundation member companies, we have developed a targeted internship program which includes an intensive training workshop that students complete before undertaking a sponsored internship.

The Systems Automation Springboard to Internships (SASI) is a three-week workshop offered during the winter term (January) for engineering students. These students are sponsored by companies who have also hired the student for a paid summer internship in the areas of automation/process control. The pilot workshop was offered in January 2021 and the second cohort just finished the workshop this January 2022. Through this program we can address many of the issues discussed above.

1) Introduce students to process control early in their education (target audience is second-year engineering students);
2) Provide intensive hands-on experience in controls through lab exercises;
3) Provide industrial perspectives on skills-gap knowledge in control and automation;
4) Improve student's awareness of the control and automation field to enhance internship experience, and
5) Provide employers with the opportunity to attract/develop/retain a skill-specific engineering workforce.

The following provides a detailed overview of the SASI workshop and intern program including student and employer feedback. We believe that the approach of preparing students for targeted internships can be applied to other fields and at other institutions.

Course Structure and Implementation

SASI is the result of a more than two-year effort to create a platform to prepare engineering students to enter the Industry 4.0 manufacturing environment. The curriculum for this workshop was developed by Pat Dixon of DPAS Inc and included academic content in the classroom coupled with hands-on application of this content in engineering labs. Pat graduated from the Miami Paper Science and Engineering program in 1987, with focused study on process control. Since that time, his career in industrial automation as both an engineer and project manager spanned several industries and roles. He had been employed by large vendors of automation products, small system integrators, and production facilities, as well as doing contract work for his firm DPAS. From that experience, Pat assembled a curriculum to introduce a comprehensive set of topics intended to show students the breadth of automation. As many students have interest in a career that matriculates to leadership, a final day of soft skill topics such as project management are included. The goal is not to develop mastery of the subject matter, but to introduce and provide initial hands-on experiences of the challenges they may face in their internship and later in their career.

The curriculum was organized sequentially to ensure all material can be covered within a three-week schedule with fundamental topics laying groundwork for later detail. The sequencing also ensures labs are scheduled to reinforce the material (Table I). The topics are sequenced in sections lasting from one to two hours in length. This enables individual topics to be delegated for developing the presentations or labs independently by faculty and industry professionals.

The students participating in the second-year cohort of 19 students was composed of 11 Chemical, 5 mechanical, 2 biomedical, and 1 engineering management students. Most of the students have had little exposure to process control, process dynamics, or process design. The first few days of the program focuses on introducing process control, the major components of a control system and the role of process control in the manufacturing environment. Process Flow Diagrams (PFDs) and Piping and Instrumentation Diagrams (P&IDs) are also covered in details providing students with an appreciation of the interaction between unit operations and the complexity of a commercial manufacturing process. Basic process dynamics is covered introducing the students to first and second order responses and the concept of gains, time constants and time delays. Integrating process response and inverse response are also introduced. The schedule and major topics covered during the most recent 2022 SASI program is summarized in Table I.

A unique aspect of the program is the blend of instructors from industry and academia. Eight different industrial practitioners with varying expertise have been involved with presenting more than half of the program's content. The industrial practitioners have presented in person and via Zoom. The ability to use Zoom as a platform for presentation gives the student's access to a wider variety of speakers with varying expertise and helps to reduce the overall cost of the program. The academic instructors primarily presented the more basic background material to the students and were involved in running the labs and hands-on exercises. Hands on exercises included preparing

and interpreting PFDs and P&IDs, linear and non-linear regression, fitting data to first order plus dead time (FOPDT) and second order plus dead time (SOPDT) models, tuning of proportional integral derivative (PID), cascade and feedforward controllers, and programmable logic controller (PLC) and human-machine interface (HMI) labs.

Another exceptional feature of the program is the amount of material presented that is not typically covered in a traditional engineering program. As noted by Dr. Rhinehart, in a traditional chemical engineering control's course it is difficult to cover material beyond the mathematics, process dynamics, control system instrumentation and PID control [1]. During the SASI workshop, these foundational topics are covered along with more advanced topics and topics specific for those working in automation and controls. This includes topics beyond PID control such as ratio, cascade and feedforward control, model predictive control (MPC) and multiple-input and multiple-output (MIMO) control. Other unique content includes field signals, interlocks and permissives, components of industrial control systems such as the HMI, the historian, distributed control systems (DCS) and supervisory control and data acquisition (SCADA), and batch control. The breadth of focused automation and controls material covered along with industry and job specific examples with context is truly unique and unusual for any program in the United States.

Industrial Sponsorship and Internships

A key element of this program is that the students participating in the SASI workshop will have a targeted internship. We accomplished this by soliciting corporate sponsors who would fund the $1,500 per student workshop fee and provide a paid summer internship to the sponsored student. Sponsoring companies were solicited from various sources, including companies that already interview Miami engineering students, corporate members of the Paper Science & Engineering Foundation at Miami University, and direct solicitations from companies focused on automation and control. We found eight companies interested in potentially sponsoring students.

We sought out interested students via online advertising, posters, and classroom visits. Early in the Fall of 2021, we had 34 students express interest in the program. We then put together a resume book sent to each of the sponsoring companies. Companies then conducted on-line interviews and made offers to students, which the students then chose to accept. At the end of the 2021 Fall semester we had 16 students accept offers from 6 companies. We extended an offer for non-matched students to participate without a company sponsor and had three additional students join the workshop. One of these three students was matched to a company with an internship in the first week of the SASI workshop and a second found a match at another company a few weeks afterwards. At the current time, we are helping the other student find a relevant internship.

At the conclusion of the summer internship, we solicit feedback from both the employers and the students to help assess the program. For the 2023 SASI program, we plan to work with Miami's Career Services to market the SASI program directly to companies interviewing on campus and incorporate it into their hiring plans. Our goal for 2023 is to have 30 sponsored students in the workshop.

Table I. Three-week schedule of material covered during the 2022 SASI Program.

	Week 1				
Times	**M**	**T**	**W**	**R**	**F**
AM Session	Welcome Introduction to Process Control and Examples	Field Signals, Inter locks and Permissive	Basic Dynamics	HMI, Historian, DCS and SCADA	PLC Registers and Programming
		Control loops and Alarms	Simulation of Dynamic Systems with Simulink		
Lunch					
PM Session	Important Terminology	PFD, P&ID, Tag Names	Big Data Analysis	Linear and Non-linear Regression	PLC Demos and Labs
			Data Analysis Labs	Motors	
	Introductory Lab Activities	Exercises with P&ID			

	Week 2				
Times	**M**	**T**	**W**	**R**	**F**
AM Session	PID Control	First Principal Models	Steady-State Identification	Advanced Control	MIMO
	PID Simulation Lab		Statistical Process Control	Advanced Control (MES & ERP)	Paper Machine/ Model Predictive Control
Lunch					
PM Session	Group A PLC and HMI Labs Group B Process Oriented Control Labs	Group A Process Oriented Control Labs Group B PLC and HMI Labs	Group A PLC and HMI Labs Group B Process Oriented Control Labs	Group A Process Oriented Control Labs Group B PLC and HMI Labs	Additional Lab Time

	Week 3				
Times	**M**	**T**	**W**	**R**	**F**
AM Session	MLK Day (No Classes)	Group A PLC and HMI Labs Group B Advanced Process Control Labs	Auxiliary Systems	Connectivity	Industry Expectations
				Batch Control	Management of Change and Writing Specifications
Lunch					
PM Session		Group A Advanced Process Control Labs Group B PLC and HMI Labs	Instrumentation and Valves	Big Data, AI and Industry 4.0	Acceptance Testing
					Project Management
					Wrap Up

Assessment

Since this workshop represented a new and unique way to address a growing industry need, we did frequent assessments during the inaugural year to ensure frequent touchpoints with the students and the sponsoring companies. During the inaugural 2021 SASI workshop, we asked for feedback from the students at the conclusion of each week to assess their grasp of the material. In each of the three informal queries, the feedback indicated that they were challenged with the content, but they were engaged in learning the material and applying it in the engineering lab exercises. At no point did any concerns surface that any student was lost or feeling left in the wake of rapid content delivery. Feedback indicated that the lab exercises anchored the academic content and reinforced the learning process. The two comments from students at the end of the workshop captured the essence of what the students gleaned from the workshop:

> *"This final week was also really good. It was cool to see a little bit about how DeltaV systems work when Drew was talking about batch control. I also really enjoyed when Russ was talking about first principles models because it connected what I learned in differential equations, material & energy balances, and what we had previously learned in the SASI program. Talking to Pat and Bill was super helpful, and being able to see PID control in action (rather than modeling it) with Luigi was pretty awesome."*

> *"I think this workshop will be an overall positive impact for me for my internship in the summer. I have learned many new things and new ways to think about and approach problems that may arise in process control. I like that it provided people like Pat Dixon and Walker Reynolds were able to instruct us. However, I think I learned the most in the labs, such as programming HMIs/PLCs and Tuning PID controllers. I also had the most fun while working in the labs trying to actually troubleshoot the problems myself compared to just hearing how similar problems were dealt with in the field."*

This feedback suggested that the students absorbed many concepts and were prepared for their process control internships. At the end of the summer, we queried both the students and their managers in the sponsoring companies to assess the student's level of technical preparedness for the process control internships and their performance in this role. The feedback indicated that the workshop hit the target:

Assessment at the conclusion of the process control internships.
(seven student responses, 5 suspervisor responses)

	Student Self-assessment		Supervisor Assessment	
	Proficient	Familiar	Proficient	Familiar
Technical preparedness	2	5	2	3
	Quickly	Slowly	Quickly	Slowly
Came up to speed on project	7	0	5	0
	Yes	No	Yes	No
Continue to offer SASI	7	0	5	0

All stakeholders were pleased with the deliverables of the workshop and the technical preparedness of the SASI students. Based on the collective of this feedback, small adjustments were made to year two of the workshop, and upon completion of this second workshop, an online student assessment of the program was evaluated. All of the 19 students responded to questions about the 2022 SASI workshop, its content, and their perception of what they gained from participating in the workshop. In the category of overall workshop perception, the student responses to the five questions overwhelmingly conveyed the benefits and value of the education received in preparing them for a controls and automation internship; only 1 of 19 students felt that they were not interested in pursuing a career in this area. A few specific comments follow:

> *"I believe I have a much better understanding of what I might be doing during my internship. I also appreciate the range of knowledge I was given even if it was a more of a surface level understanding."*

> *"During the SASI program we learned about concepts that directly relate to controlling operations, which is where I will be spending my time this summer. In addition, certain topics such as 6 sigma, have been brought up in presentations I have seen from my [sponsoring company]."*

> *"I am familiar with a lot of the technology and lingo that I will be using in my internship and that should help get me started.*

Students were asked to choose the subjects that they viewed as most beneficial, The subjects that received the highest marks were field signals, interlocks and permissives, control loops and alarms, basic dynamics and simulink, HMI Historian, DSC, and SCADA, PID control and Simulation, First Principal Models, Steady State ID and Statistical Process Control, Advanced Control, and Instrumentation and Valves. The topic identified by the majority of the students as most beneficial was learning about Industry 4.0 concepts:

> *"I really liked the sessions that talked about industry 4.0 and the need for automation engineers."*

The lab experiences also were identified as very beneficial for reinforcing the academic content:

> *"The labs were the most meaningful experience for me. I found it much more enjoyable to be able to learn hands-on rather than going through slideshow presentations."*

Interestingly, the subject mentioned by the students as least beneficial was Big Data and Statistical Analysis, seemingly because a set of students was already were well-versed in the subject, reflected in this specific student comment:

> *"I would say the statistical lab was the least beneficial due to my own previous experiences with Excel."*

From the student perspective, we believe that year two of the SASI workshop has again succeeded in meeting our goal of introducing students to process control and automation, and providing intensive hands-on experiences. Students feel that they have an improved industrial perspective,

and we have helped close the skills-gap of technical knowledge. We will again assess the effectiveness of how the workshop experience translates to the internship experience by querying the students and sponsoring companies upon completion of the Summer 2022 internships.

Conclusions

There is a growing need for engineers with skills in automation and advanced process control. The SASI program was developed to better prepare students to enter an internship/co-op assignment in automation and process control and to create more student interest in pursuing a career in automation. The SASI program is a unique three-week intensive workshop with lectures and lab activities that exposes sophomore level students to material on dynamics and process control that they would not typically see until their senior year. In addition, it also introduces them to other areas related to automation and advanced controls taught by industrial experts that provide real world examples and context. Feedback from the sponsor companies and students give high marks for the workshop. The success of the program is highlighted by the doubling of participating students offered internships in the two years that the program has been offered.

There are several key aspects that we believe lead to the success of the program.

1) This an experiential experience for students and they are open to learning advanced subjects at a fairly rapid pace without the pressure of an assigned grade.
2) We have extensive contributions from industrial experts that focus on closing the skills-gap.
3) The direct tie-in with an internship improves focus for both students and employers.

Next year we hope to have 30 sponsored students enrolled in the workshop and to expand the number of participating companies.

References

1. McMillan, G. *The real deal with process control education*. Control Global Online 2020 [cited 2022 01/24/2022]; Available from: 2020/the-real-deal-with-process-control-education/.
2. Alford, J. and G. Buckbee, *Industrial Process Control Systems: A New Approach to Education.* CHEMICAL ENGINEERING PROGRESS, 2020. **116**(12): p. 35-42.
3. Aufderheide, B. and M. Wilkes, *Process Control Class for the Future Process Engineer.* 2019.
4. Liu, Q., et al., *Engineering co-op and internship experiences and outcomes: The roles of workplaces, academic institutions and students.* 2018.