Educating and Training the Next Generation of Industrial Engineers to Work in Manufacturing

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Educating and Training the Next Generation of Industrial Engineers to Work in Manufacturing

Abstract

Now more than ever manufacturing in the United States needs a workforce with a blend of both strong hands-on trade skills and the technical problem solving skills typically learned through the completion of a Bachelor of Science in Industrial Engineering program. This paper discusses a holistic approach being taken in an industrial engineering program to increase student interest in manufacturing by providing a hands-on educational experience in a manufacturing processes course while providing ample opportunities for students to gain hands-on manufacturing work experience through undergraduate teaching internships and manufacturing co-ops and internships.

The research shown in this paper discusses the active role that senior undergraduate students with manufacturing internship and co-op experience play in helping to deliver the manufacturing processes course. Senior undergraduate industrial engineering students with manufacturing industry internship or co-op work experience have been helping to deliver a manufacturing processes course through hands-on lab instruction, on site plant visits, industry speakers and networking sessions, and a final course case study.

The paper displays the results of a questionnaire that included a blend of qualitative and quantitative questions administered to the junior and senior level industrial engineering students completing the manufacturing processes course. In addition to data collected on student satisfaction and motivation with course delivery, the survey also collected data inquiring prior student knowledge of manufacturing processes, perception of manufacturing, and student interest in manufacturing careers before and after taking the manufacturing processes course. The survey also inquired on student internship and co-op trends for the industrial engineering students completing this manufacturing processes course.

Background and Motivation

The manufacturing industry is still a significant and viable career opportunity for industrial engineers in the United States of America (USA). In 2013, the manufacturing industry accounted for 12% of the Gross Domestic Product (GDP) for within the United States[1]. Furthermore, for every $1.00 spent in manufacturing, another $1.37 is added to the economy, which is the highest multiplier effect of any industry[2]. In 2013, there were approximately 17.6 million jobs in the USA that the manufacturing industry directly supported[3]. Also in 2013, the average manufacturing worker earned $77,506 in salary and benefits, which is an increase of 24% over the average worker in all industries ($62,546)[4]. By itself, the manufacturing industry sector in the USA would be the 9th largest economy in the world[5].

Unfortunately, a number of future engineers have learned or developed incorrect assumptions and stereotypes regarding the manufacturing industry. Students are under the impression that manufacturing is a floundering industry in the USA and there are limited jobs and limited job growth potential. However, this is an incorrect, and perhaps devastating, misconception. To further compound the problem, there is a skills gap with the baby boomer generation retiring and

a shortage of available workers. For example, in a 2011 survey of 1,123 manufacturing executives 67% of respondents reported a moderate to severe shortage of available and qualified workers, which included 60% stating they were experiencing a moderate to severe shortage of industrial engineers, manufacturing engineers, and/or planners. The survey indicated that within the manufacturing sector there are approximately 600,000 open jobs due to a lack of a qualified and available workforce[6].

The manufacturing industry is looking for ways to shrink the skills gap by partnering with universities, community colleges, and certification providers. In a report co-authored by Deloitte and the Manufacturing Institute entitled "Boiling Point? The Skills Gap in U.S. Manufacturing," it was noted that the lacking skills in college graduates to the manufacturing workforce are those that have the most impact on operations and require the most technical training[7]. The manufacturing industry (which relates to many other industries) is very heavily impacted by students moving away from STEM fields, as the companies and manufacturers are unable to fill technical positions. This manufacturing issue must be fixed within the engineering classrooms across the United States by offering more manufacturing exposure to students in the classroom.

Manufacturing engineering education is often associated with Mechanical and Industrial Engineering. Manufacturing is the production and processes, as well as the required personnel, machines, and equipment to produce a certain product. From this definition, it can be see that Industrial Engineers are concerned with the processes of the production line, whereas the Mechanical Engineers are focused on the components of the systems, such as the machines and lines. Courses are often integrated into these two major fields to allow for some exposure to the manufacturing industry. A paper in the *Journal of Engineering Education* notes that a movement to move to higher course content on manufacturing in both of these disciplines is needed[8]. Many current engineering programs do not emphasize the marriage of design and manufacturing in a modern industrial technical workforce.

Many research studies have assessed the quality of exposure to manufacturing through the senior "Capstone" design project course. McMasters and Lang believe that too few in industry have an understanding of how the current engineering education is set-up. Therefore, if industry partners are brought into the education process through design projects, the education provided to students can be better adapted to reflect the expectations of industry. It is important to define what the industry wants and needs for the current engineering programs[9]. Many universities are exposing students to manufacturing through senior capstone design courses to offer students with a realistic perspective of industry needs.

Another vital area of manufacturing skills needed is within federal government organizations, such as the Department of Defense and the Department of Energy. A report coordinated by the National Academies indicated that remanufacturing of weapons systems and nuclear systems, as well as maintaining facilities for the maintenance and production of systems, is a strategic need for the security of the USA[10]. Furthermore, the Defense Advanced Research Projects Agency (DARPA) has a program for Open Manufacturing to reduce the cost and increase the speed of delivery of high-quality manufactured goods. This program has the capability of supporting advanced manufacturing applications that range from the aerospace, to chemical, to pharmaceutical, to everyday manufactured goods[11].

Review of Recent Engineering Education Literature

There are a number of articles in the engineering education literature that are supportive of internships, cooperative (co-op) education programs, and manufacturing education. A few recent articles are reviewed herein. The first article included an overview of the University of Cincinnati's cooperative education program, which has been operating since 1906. This article provides a history of the program and of a course that introduces students to the cooperative education experience. Topics include professional development skills, job search, interview preparation, workforce representation, and preparation. It was found that the course had a positive impact for students as they entered the cooperative education workforce[12].

There are also findings that discuss the benefits of an internship for both the student and the employer at Texas A&M. The findings of the study indicate that expectations from both parties need to be communicated at the onset of the internship with a firm structure for both the organization and culture of the work[13].

Finally, a recent paper discusses the use of the four pillars of manufacturing knowledge in the education plan for a mechanical engineering concentration of a general engineering program[14]. This differs from the current paper, but it is a similar course (i.e., manufacturing processes). The "four pillars of manufacturing knowledge" was developed and is maintained by the Society for Manufacturing Engineers[15]. The paper presented in 2014 mentions that the four pillars are novel; thus, there has been little use of them to evaluate the existing curricula of university courses. The paper identifies various engineering programs in Michigan with mechanical engineering degrees or concentrations, and then identifies similar course outcomes for a manufacturing processes course. Finally, the paper identifies how these various programs are meeting or not meeting the recommendations of the four pillars, with recommendations to align the university program with the four pillars by recommending different course content for addition and subtraction to the manufacturing processes course (e.g., additional lecture for nanotechnology, subtraction of a lecture for costing and finishing)[14].

As the current workforce in manufacturing approaches retirement, it is of crucial importance that the current generation of college students becomes enthused and interested in manufacturing as a career path. To do this, a Society of Manufacturing Engineers Strategy recommends promoting the wide availability of "creative, high-tech" jobs that can be found in manufacturing careers[7]. Students can be motivated to pursue a certain career path if they see the value and need for skilled engineers. Internships are often useful for students to experience a facet of industry and learn the skills needed to be a manufacturing engineer.

Background on Industrial & Manufacturing Engineering Program

Currently, research and work to increase the number of Industrial Engineers moving toward manufacturing careers is being carried out at Penn State University Park. At this university, manufacturing has been and remains an integral part of the curriculum in Industrial Engineering. The manufacturing boom of the 20th century that would push the United States into a position of world power demanded highly educated students who were trained as both managers and engineers. The industrial engineering program was founded as part of a mechanical engineering department that began offering a two-year program in shop management for juniors and seniors. The industrial engineering program was a spin off from the mechanical engineering program

where instruction in the organization of industrial plants, in factory planning, shop construction, accounting, and kindred lines would be taught. This industrial engineering department became a prototype for other engineering schools[16].

This industrial and manufacturing engineering program offers B.S., M.S., and Ph.D. degrees in industrial engineering. There are approximately 425 Bachelor of Science degree students, 105 Master's degree students, and 70 Ph.D. degree students in the industrial engineering program at Penn State University Park. Students can complete manufacturing concentrations at all degree levels. At the undergraduate level, students must complete a 3 course sequence in manufacturing. Junior industrial engineering students must first take a course in product design, specification, and measurement. The second course in the sequence is a manufacturing process course. The students can choose from five different courses: machining processes, solidification processes, additive manufacturing, computer aided drafting and manufacturing (CAD/CAM), and Nano manufacturing. The course discussed throughout this paper is the solidification processes course. The third course in the sequence is a manufacturing systems course. Students can take additional manufacturing processes courses as part of the industrial engineering curriculum. The courses will count as industrial engineering technical elective courses. The students must complete two industrial engineering technical elective courses as part of the B.S. industrial engineering program.

Solidification Processes Course

The solidification processes course is a 15 week course in the industrial engineering program at Penn State University Park, specifically for undergraduate students. Each week, the students are subject to (2) 50-minute classroom lectures and (1) 115 minute laboratory experience in The Factory for Advanced Manufacturing Education (FAME) laboratory at Penn State University Park. The objectives of the course are to introduce industrial engineering students to the theory, principles, mechanisms, and concepts of solidification/ additive manufacturing processes for materials, emphasizing process selection and the effects of process capabilities and limitation on design, costs, and quality. The course includes lectures, laboratories, demonstrations, videos, extension readings, and homework problems. The main course topics covered in the course are mechanical testing and properties, metal casting processes, welding processes, polymer processes, solid state deformation processes, advanced manufacturing processes, and manufacturing process costing.

There are two full time technicians for the manufacturing lab, who help prepare the teaching assistants, teaching interns, and the faculty member, to the layout and use of machines in the manufacturing lab, if necessary. The technicians also help from time to time with the instruction portion of the labs. Typically, the technicians mainly train the teaching assistants or teaching interns in the laboratory; so that they can be the primary teachers during the laboratory period. For this particular course, this course instructor is heavily involved with the technicians in training the teaching assistants and/or teaching interns; however, this is not the overall practice by the faculty. Depending on the course and faculty member teaching the course, technicians may help train the teaching assistants and teaching interns with much less aid from the faculty. With respect to this particular course at this particular university, the course instructor and paper author is currently the only faculty member that teaches the course during each Spring semester. The course is taught by one additional faculty member during each Fall semester. The Fall

semester instructor teaches the lecture component for the course but is much less involved with the laboratory experience in the course. The laboratory component is typically taught by a graduate teaching assistant during the Fall semester. No survey data was available for the Fall semester.

Course Instruction

For the past four years, the course has had the same instructor during each spring semester. The course had 40 students in 2011 and 2012 with two lab sections. The course had 60 students in 2013 and 2014 with three lab sections. Each lab section holds 20 students. The instructor teaches the laboratory along with the help of undergraduate teaching interns (TIs) and a full-time laboratory technician. The instructor seeks out undergraduate students to be teaching interns that show an interest in learning more about manufacturing. In 2011 and 2012, one undergraduate teaching intern was assigned to the course. In 2013 and 2014, two undergraduate teaching interns were assigned to the course.

Cast Metals Industrial Advisory Committee (CMIAC)

The industrial engineering department at Penn State University Park has three advisory boards. The CMIAC, established in 1972, supports the department's metalcasting program. The advisory board is very active in the industrial engineering department at this large university. The instructor of the solidification processes course is a member of the advisory committee. The advisory committee participates in campus metalcasting activities. The department hosts a student metalcasting job fair and banquet each fall and spring semester. The instructor of the solidification course is also the faculty adviser for the student chapter of the American Foundry Society (AFS) in the industrial engineering department at Penn State University Park. The student AFS chapter hosts open foundry nights three times each semester for students to learn about metalcasting while utilizing the foundry laboratory in the industrial engineering department at this university to make castings. The CMIAC helps to provide student scholarships, provides summer internships, co-op experiences and full-time employment in the metal casting industry.

Student Survey Results

During the last week of the spring 2014 semester, a survey was given to the students enrolled in the solidification processes course. The survey was given to gather data on the perception and knowledge of manufacturing among the students. The survey was also administered to gather data on internship and co-op opportunities secured by the students during the spring 2014 semester. In addition, the survey gathered data on the satisfaction of the students with the course.

Demographics

Out of the 60 students enrolled in the course, 56 students completed the survey. Out of the 56 students, 17 were female and 39 were male students. All 56 students were industrial engineering students; 37 students were juniors while 19 were seniors. 51 of the students were taking the course as their manufacturing process course requirement while 5 of the students were taking the course as an industrial engineering technical elective. The students taking the course as an industrial engineering technical elective course had already completed one of the four other manufacturing process elective courses.

Manufacturing Knowledge

When asked about prior knowledge of manufacturing processes, 37.5% of the students (21 out of 56) said they had no knowledge or very little knowledge of manufacturing processes before taking the solidification processes course. 60.7% of the students (34 out of 56) said they had some basic knowledge while only 1.8% of the students (1 out of 56) said they had a strong knowledge base of manufacturing processes prior to taking the solidification processes course.

Manufacturing Perception

The students were asked what their perception of manufacturing was before taking the solidification processes course. One half (50%; 28 out of 56) of the students responded to the question. A breakdown of the student responses is shown in Table 1 below.

Table 1: *Responses for Student Perception of Manufacturing before taking the solidification processes course*

(4) Manufacturing is for making or producing goods through processes
(3) No Idea
(3) Worked in Manufacturing Company on Internship
(3) High production factories or on the floor at a facility
(2) Making products in a high volume, efficient or cheap manner
(2) Lots of machines, dirty work
(1) Manufacturing is an important branch in industry
(1) Manufacturing "was" an important part of today's world
(1) Manufacturing is a good field to pursue
(1) Production lines such as Ford's assembly lines
(1) Operations that occur after a piece is made
(1) The scope and design of manufacturing processes
(1) Production when materials are already supplied
(1) Making some stuff with different machines
(1) Mainly a hands-on field that requires working with many different machines and people
(1) Materials and Processes
(1) There are different types of manufacturing

The students were asked questions regarding working in manufacturing. Prior to taking the solidification processes course, over 41% of the students (23 out of 56) said they would not have ever considered a career in manufacturing. The remaining 59% of the students (33 out of 56) said they would have considered a career in manufacturing prior to taking the course. After taking the course, only 12.5% of the students (7 out of 56) said they would not consider a career in manufacturing. The remaining 87.5% of the students (49 out of 56) said they would consider a career in manufacturing after taking the solidification processes course. By taking the solidification processes course, the number of students that would consider a career in manufacturing increased by 28.5%. All 56 of the students (100%) said that after taking the solidification processes course, they feel as though it is important for industrial engineering students to have a strong working understanding of manufacturing processes.

Internship/ Co-Op

Out of the 56 students completing the survey, 50 of the students reported looking for an internship or co-op opportunity for summer 2014. Out of the 50 students that reported looking for an opportunity, 46 said they were successful in landing an internship or co-op opportunity at the time of the survey. After the survey, the course instructor helped 2 of the students obtain summer internship opportunities with metalcasting companies. By the end of the semester, 96% of the students that looked for summer internship opportunities were successful in obtaining an internship or co-op opportunity. One finding from this study was that international students at Penn State University commonly find it much more difficult to obtain internship, co-op, and full-time opportunities in the U.S. due to citizenship issues.

The students were asked how they secured their internship or co-op opportunity. Table 2 below shows results of how students were able to obtain the internship and co-op opportunities.

Table 2: *Responses for How Students Secured Internship or Co-Op Opportunities*

(14) University Wide Fall/ Spring Career Days
(9) Networking Through Family or Friends
(5) College of Engineering Career Fair
(5) University E-Career website
(5) Metalcasting/ Manufacturing Career Event in IE Department
(3) Internet/ Web
(1) College of Business Supply chain Career Fair
(1) IIE (Institute of Industrial Engineers) IE Department Career Event
(1) Industrial Engineering Department Webpage
(1) Emailed a PSU Alum
(1) Company Hosted Networking Event

When asked if the internship or co-op experience was with a manufacturing company, 66.67% of the students (32 out of 48) said that 'Yes' the experience was with a manufacturing company.

Undergraduate Teaching Interns

Over 94% of the students (53 out of 56) said they liked the idea of having industrial engineering undergraduate students with internship experience as their lab teaching assistants. Likewise, over 94% of the students (53 out of 56) said the undergraduate teaching assistants added value to the delivery of the course (i.e., increased students satisfaction with course delivery). Approximately 84% of the students (47 out of 56) felt as though the undergraduate teaching assistants sparked their interest in the manufacturing process course topics. 93% of the students said that the undergraduate student involvement (i.e. teaching assistants) made it easier for them to approach the assistants to ask questions. Undergraduate teaching assistants are welcomed in additional industrial engineering courses; 84% of the students (47 out of 56) said that from their experience working with the undergraduate teaching assistants in this course, they would like to have industrial engineering undergraduate students with internship experience more involved with the delivery of other industrial engineering courses.

The students were asked to rate how important they felt as though it was for the undergraduate teaching assistants to have relevant manufacturing work experience on a scale from 0 (not important) to 10 (very important). Table 3 below shows the distribution of the 55 student responses.

Table 3: *Results of student responses on need for undergraduate teaching assistants to have relevant manufacturing work experience.*

Rating	**0 (not important)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 (very important)**
Number of Responses	0	0	0	1	0	3	3	8	18	11	11

Overwhelmingly the students felt as though the undergraduate teaching assistants should have manufacturing work experience. On average, the students rated relevant manufacturing work experience importance as 8.1 out of 10 for undergraduate teaching assistants working in the solidification processes course. Over 87% of the students rated the importance of having relevant manufacturing work experience as 7 or higher on a scale from 0 to 10.

At Penn State University Park, most industrial engineering teaching assistants are graduate students working in the undergraduate classes. The graduate students are typically fully supported with tuition, stipend, and health benefits. With budget cuts and the need to shrink teaching support costs, undergraduate and graduate students working as wage payroll hourly assistants have become an attractive option as enrollment in the college of engineering at Penn State University Park has soared. When asked to compare their undergraduate teaching assistants in this manufacturing process course to their graduate student teaching assistants in other IE courses, the students in this course responded as shown in Table 4 below:

Table 4: *Results of student responses on the effectiveness of undergraduate teaching assistant effectiveness compared to graduate teaching assistants.*

Undergraduate Teaching Assistants are:	**Less Effective**	**Equally Effective**	**More Effective**
Number of Responses	1	15	40

The vast majority of the students (71%) actually said the undergraduate teaching interns were more effective than their graduate student teaching assistants. Note, the students were asked to compare their experience with graduate teaching assistants that they had encountered in other courses with respect to the teaching interns servicing this course; no demographical information was collected on graduate teaching assistants (e.g., gender, ethnicity, race, citizenship status, English competency, manufacturing experience). It was unknown to the faculty member of any relationships or conflicts of interest the teaching interns may (or may not) have had with the students in the course; likewise, the faculty member did not know of any relationships or conflicts of interest with graduate teaching assistants in any course. Any grading that was carried out by the teaching interns was carried out after being supplied a detailed rubric with detailed instructions by the course instructor. The instructor met with the interns to explain the grading procedures before any grading was carried out and the instructor also met with the interns after the grading to ensure accuracy and consistency in all course grading. By utilizing

undergraduate students as teaching assistants in the manufacturing courses, this department can cut teaching support costs and also help train undergraduate students for jobs in manufacturing.

Teaching Intern Survey Results

During the last week of the spring 2014 semester, a survey was given to the two undergraduate teaching interns for the solidification processes course. The survey was given to gather data on their experience as a manufacturing teaching intern.

Demographics

One of the interns was female and one was male. Both teaching interns had previous manufacturing work experience. Both of the interns grew up in families that were small business owners. One family owned an asphalt company while the second family owned pharmacies and floral shops. One of the interns worked for 7 summers at the family owned Asphalt Company while the second intern worked for the family pharmacies for multiple summers and also worked a summer in a small cast iron and steel metal casting company. The contact for the metal casting company internship came from the CMIAC job fair held in the industrial engineering department at Penn State University Park.

Manufacturing Knowledge

Prior to being the teaching intern for the solidification process course, both of the students completed the course the previous spring as their manufacturing process elective course. Before being teaching interns for the course (i.e. after their manufacturing internships and completion of the solidification processes course), both interns said they had a strong manufacturing knowledge base. They both said before being the TI they would have considered a career in manufacturing and they both said they would consider a career in manufacturing after completing their manufacturing teaching internship. Both felt as though after completing the semester teaching assistantship that it was important for industrial engineering students to have a strong understanding of manufacturing processes. When asked to rate how important the interns felt having manufacturing work experience was to be a teaching intern for a manufacturing process course, they answered 8 and 9 out of 10 for an average of 8.5 on a scale from 0 (not important) to 10 (very important).

Manufacturing Employment

Both of the teaching interns accepted full time positions with manufacturing companies after completing the manufacturing teaching internship. One intern noted that contact with the company initiated at a College of Business Supply Chain Career Fair while the second intern said they networked through an industrial engineering manufacturing faculty member.

Impact on Students in Manufacturing Process Course

Both teaching interns felt as though they added value to the delivery of the solidification processes course. They both agreed they sparked student interest in the manufacturing process course topics. The interns also felt as though by being undergraduate students they made it easier for students to approach the assistants to ask questions. Judging from their TI experience in this course, they both noted they would like to have industrial engineering undergraduate students with internship experience more involved with the delivery of industrial engineering courses in the future. When compared to graduate student teaching assistants they had in other

IE courses, the teaching interns said they were equally or more effective than their graduate teaching assistants.

The teaching interns were also asked to provide answers to questions regarding their perception and knowledge of manufacturing prior to taking the solidification processes course spring 2013, one year prior to serving as teaching interns for the spring 2014 course.

Perception of Manufacturing

One of the interns said they had no knowledge or very little knowledge of manufacturing processes before taking the solidification processes course. This intern perceived manufacturing to be all about factories and production lines with conveyors and automation. The second intern said they had some basic knowledge of manufacturing processes and perceived manufacturing to be the process of making something. The intern said "Everything we use is manufactured somehow." This intern admitted growing up around manufacturing as the intern's father worked for a well-known steel manufacturing company close to home. The intern knew from sixth grade on that engineering was going to be their profession of choice. In addition to the family asphalt business, the intern's family hobby was sports cars. Both of the interns said they considered careers in manufacturing before and after taking the solidification processes course. After taking the course, both interns felt as though it was important for industrial engineering students to have a strong working understanding of manufacturing processes.

Both of the teaching interns felt as though the perception of manufacturing in today's undergraduate students is based on where they grew up. As teaching interns, they observed students "getting dirty" for the very first time in their life in the industrial engineering manufacturing lab. They felt as though these students had a very different perception of manufacturing than students that grew up around manufacturing facilities and had relatives working in manufacturing.

Both interns noted that taking the solidification process course and networking with the CMIAC members at job fairs and metalcasting events was an important piece in keeping them interested in manufacturing and continuing to want to learn more and gain on the job manufacturing work experience.

Teaching Intern Effectiveness

The teaching interns were asked to provide feedback on their experience working with the teaching interns for their solidification course spring 2013. Both of the interns felt as though the spring 2013 interns added value to the delivery of the course, helped to spark their interest in the course topics, and they felt as though the undergraduate interns made it easier for them to approach the course assistants to ask questions. From their experience working with the undergraduate teaching interns in the solidification processes course, they both felt as though they would like to have industrial engineering undergraduate students with internship experience more involved with the delivery of their industrial engineering courses. When compared to graduate student teaching assistants they had in other IE courses, the teaching interns said their undergraduate teaching interns were equally or more effective than their graduate teaching assistants.

Teaching Intern Job Placement Statistics

Over the past four years, the instructor of this course has worked with six different undergraduate teaching interns supporting this manufacturing process solidification processes course. All six (100%) of the teaching interns accepted full time jobs to work in manufacturing upon graduation with their bachelor of science degree in industrial engineering. In addition to the six teaching interns taking jobs in manufacturing, the instructor reports that four additional undergraduate students volunteered to help provide teaching support in the solidification process laboratories over the past four years. All four (100%) of these students also accepted jobs in manufacturing. The solidification course has a heavy emphasis on metal casting and welding processes. Out of the 10 students mentioned, five of the students accepted full time jobs in the metal casting industry and one accepted a metal casting sourcing/ quality engineering position with a large U.S. corporation.

Metalcasting Internship and Co-Op Job Placement

As mentioned, the industrial engineering program Penn State University Park is fortunate to have a cast metals industrial advisory committee (CMIAC). The metalcasting program at Penn State University Park has seen a record number of students accepting metalcasting internships and co-ops the past three years for the data available going back almost 25 years. The program has had 13 or more summer interns or co-ops in metalcasting production and supplier facilities the past three summers. For a manufacturing community that has been shrinking for the past decade, this is a significant amount of students getting on the job training in metal casting from this industrial engineering program.

Discussion and Conclusions

The overall engineering education goals of this study were to determine if industrial engineering students had prior stereotypes with respect to the manufacturing industry, knowledge of manufacturing processes, and an interest in manufacturing careers. Students were questioned before and after a manufacturing processes course. Data were also collected on student internship and co-op trends for the industrial engineering students completing this manufacturing processes course. The manufacturing processes course consisted of both laboratory and lecture course meetings, and included undergraduate teaching interns to assist with the laboratory components.

The results were primarily positive. For example, 96% (48 of 50) students that were seeking a summer internship were successful in obtaining one, and 67% of those were with manufacturing companies. Also, the undergraduate teaching interns were seen as positive influences for the learning process, and a majority indicated that they were as effective (or more effective) than graduate student assistants. The six undergraduate teaching interns that have worked with the instructor for this course have all accepted full-time employment with manufacturing companies.

The results of this study show that retooling the manufacturing industry with industrial engineering students is achievable. The industrial engineering program at Penn State University Park is doing its part to place industrial engineering graduates in the manufacturing industry. It is crucial to offer courses in manufacturing that allow students work in a hands-on manufacturing laboratory. In addition, the course instructors and manufacturing student society advisers and

manufacturing program advisory committee members need to be actively involved in cultivating the manufacturing educational experience for the students. Developing the technical skills needed to work in advanced manufacturing environments in the new manufacturing era is not simply learned through textbooks and lectures. In addition to course laboratories, allowing students to work as teaching assistants in manufacturing courses and hosting open manufacturing time can help students develop some of these skill sets. Ultimately, having a strong network of manufacturing companies aggressively recruiting industrial engineering students for summer internships and co-op opportunities is crucial to attracting students to manufacturing and developing the necessary manufacturing skill sets in the industrial engineering students.

This study does lead to questions of further inquiry:

- Is the pursuit of manufacturing careers aligned due to the region in which the student and/or university is located? For example, can this program be replicated in another state with a different level and network of manufacturing companies and industry support?
- Are their additional manufacturing topics that are needed and appropriate for the undergraduate industrial engineer (e.g., additive manufacturing, open manufacturing)?
- Can the undergraduate teaching interns effectively replace graduate teaching assistants in other courses? In addition, most universities allow graduate teaching assistants to grade undergraduate student work; whereas, they do not allow undergraduate student interns to grade student work. Perhaps this policy is outdated?
- Can this teaching intern paradigm be replicated at other universities and programs, with other faculty members, and with other course topics (beyond manufacturing)? Perhaps other engineering programs at universities without graduate programs already have a similar model in place for upperclassmen students to aid in teaching. However, what makes the model presented in this paper unique is that the teaching interns not only had taken the manufacturing course, but they also had work experience via internships and co-op in the manufacturing industry. This additional requirement of industry work experience is novel with respect to the hiring of undergraduate teaching interns. Would anyone with manufacturing experience have done as well as the teaching interns in this study?

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