What's Next? The Future of Work for Manufacturing Technicians

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Richard Gilbert is a Professor of Chemical and Biomedical Engineering at the University of South Florida's College of Engineering . Richard is the Co-PI for an NSF grant that supports FLATE, Advanced Technological Education in Florida ,the the NSF Center of Excellence, which was founded through substantial funding from NSF. FLATE, now funded by the NIST MEP program and the Florida Department of Education, addresses curriculum, professional development, and outreach issues to support the creation of Florida's technical workforce. Richard has over 30 years of experience working with the K-14 education community. Other funded efforts include projects for the NIH and the US Department of Education. The latter was for the development of an engineering curriculum for elementary school applications. The former is for development of electric field mediated drug and gene applicators and protocols. This effort has generated over 20 patents and cancer treatment protocols completing FDA Phase III trials.

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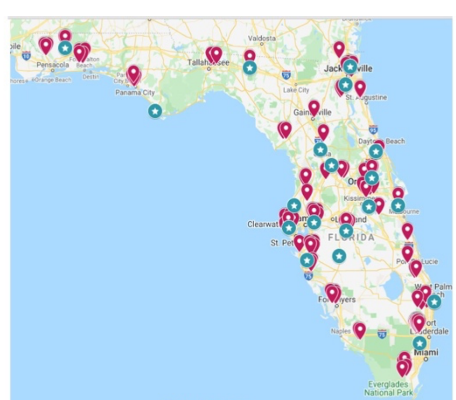
The manufacturing workspace and the technician workforce that supports that space tomorrow is an important issue to deal with today. As Industry 4.0 is absorbed into manufacturing facilities around the country, engineering technicians working in these facilities adjust to make tomorrow today. The National Science Foundation has supported the Florida Advanced Technological Education Center (FLATE) contiguously since 2004. FLATE's intent is to craft a manufacturing workforce that makes Florida manufacturers globally competitive. FLATE crafted and the Florida Department of Education now supported two-year Engineering Technology degree (A.S. ET) is the vehicle for manufacturing education in Florida. The degree is offered in over 85% of the colleges in the Florida College System (FCS) and has over 2,000 students enrolled statewide. The current NSF supported project is to conduct a I4.0 focused Caucus of manufacturers and ET degree college faculty to collectively identify skill issues that will affect manufacturing production efficiency and product reliability.

The project team initially used the nine Industry 4.0 (I4.0) technology areas identified by the Boston Consulting Group and selected four that will directly impact starting technicians working in companies that are already implementing Industry 4.0 technologies: (1) Autonomous Robots, (2) Simulation, (3) Industrial Internet of Things and (4) Additive/Subtractive Manufacturing and Advanced Materials. Technician skills are defined as those needed to set up, operate, troubleshoot, and maintain production and process equipment. Specific skills that fall in the I4.0 technologies identified as relevant for starting technicians were defined to be those that will be needed in the next 3-5 years. Initial questionnaire responses and subsequent data analysis detail are provided. Identified skills gaps as recognized by the manufacturers and faculty are provided and discussed.

The Caucus Event



Preliminary Caucus activities focused on two areas: (i) recruiting statewide manufacturer and faculty participants; (ii) creating and executing a pre-Caucus Questionnaire. The Google map shows questionnaire participant locations. There were 26 faculty from 21 participating colleges representing three related programs. The college locations are indicated by the "star" icon in the blue circle. There were 133 manufacturers, located by the red "tear" shapes on the map, that participated. Note: the large region in the south that includes Lake Okeechobee is primary cattle grazing lands and wetlands (The Florida Everglades National Park) while the region in the upper portion of the state (the "pan handle") has a large lumber and mining industry sector that includes several rural colleges and a lower industry density.

Autonomous Robots: *(1) Programming; System Integration; (2) Repair*
Simulation*: (1) Compare & Contrast Process Alternatives; (2) Recommendation new situations & their effects on process response to change; (3*) Participate in developing existing & new products & operations
Industry Internet of Things: *(1) Ethernet Communication (M2M); (2) Record and store data*
Additive/Subtractive & Advanced Materials: *(1) 3D CAD and printing/prototyping; (2) CNC programming; (3) Precision Manufacturing; Fabrication; (4) Testing (destructive/non-destructive)*

Table 1: Manufacturing Technician Related Industry 4.0 Technologies and Skills Sets

Data Analysis

Table 2 presents the summary of the questionnaire results prior to any analysis steps. Technologies shown in blue are not arranged in any priority. Nor is there an order to the skills assigned to these technologies. The two columns of data reflect participant group preferences. Thus, the first row (under Autonomous Robots) in Table 2, "Programming", was among the top five selections for 34% of the manufacturers and 52% of the college faculty.

The plan for the data analysis was to address the five questions summarized in Table 3. The order of the questions in the table does reflect the analysis progression through the aggregated data. Thus, the first order of events was to determine the popular skill selections for manufacturers and educators. Once those selection percentages were reviewed, the degree of popularity by group was explored. After reviewing aggregated responses, the fourteen skills were grouped based on differences between the manufacturers' and educators' responses that led to the analysis questions in Table 3.

The initial data analysis step was to cull row entries in Table 2 based on minimal industry and faculty prioritization. If a row entry (red data values in Table 2) did not achieve 31% support from both groups of the questionnaire participants, that row item was not considered for further analysis. With this criterion in mind: "Autonomous Robots: Repair" (15% manufacturing and 24% faculty), was removed from the data set. In a similar fashion: "Simulation: Compare & Contrast Process Alternatives" (24% manufacturing and 20% faculty) and "Recommend new situations & their effects on

	(21 Colleges)	Manufacturers (133)
Autonomous Robots;		
Programming	52%	34%
System Integration	56%	38%
Repair	24%	15%
Simulation;		
Perform Root Cause Analysis	40%	39%
Participate in Planning & Evaluation Processes	24%	36%
Compare & Contrast Process Alternative	20%	24%
Recommend new situations & their effects on process response to change	20%	30%
Participate in developing existing & new products & operations	12%	51%
Industrial Internet of Things;		
Ethernet Communication (M2M); Record and store data	28%	22%
Additive/Subtractive & Advanced Materials;		
3D CAD and printing/prototyping	60%	36%
CNC programming	48%	39%
CNC Precision Machining	48%	33%
Fabrication	36%	42%
Testing (destructive /non-destructive)	20%	30%

Table 2: Engineering Technicians Industry 4.0 Technologies and Supportive Skills

process response to change" (30% manufacturing and 20% faculty); "Ethernet Communication (M2M): Record and Store data" (22% manufacturing and 28% faculty).

1) Which skills were selected greater than 30%?
2) Which had the greatest gaps between educators and manufacturers?
3) Which skills were selected less than 31%?
4) Which skills were considered more important by manufacturers?
5) Which skills were considered more important by educators?

Table 3: Analysis Questions Established Prior to Caucus Questionnaire Distribution

and "Additive/ Subtractive & Advanced Materials: Testing - destructive/non-destructive" (30% manufacturing and 20% faculty) were also removed from the data set.

Results

For this research project, skills gap issues related to Industry 4.0 technologies are associated with two generalized situations: low and large skills gaps. Setting these as boundary conditions eliminates possible oversight situations and help prioritize the responses. Since the A.S. ET degree in Florida has the flexibility to adjust to specified needs from manufacturers within their service area, these two classifications can also be immediately connected to local situation skills gaps. The reported results are confined by the two gap extremes.

Table 4 addresses the questions in Table 3 and shows the cluster of skills related to the manufacturing technician impacted Industry 4.0 Technologies that were identified as low skills gap issues. Table 4 identifies three subgroups. The first is the upper limit identified as less than 25% difference between the manufacturers and the faculty. The “3D CAD & printing/ prototyping” skill related to the Additive/Subtractive & Advanced Materials Industry 4.0 technology fits within this < 25% category. From Table 4, the 36% of the manufacturers and 60% of the faculty item ("3D CAD & printing/ prototyping") represents the upper limit, 24% difference, for the low skills gap groupings. Table 4 also identifies a less than 20% category and a less than 15% category.

For this study, the authors have defined that a less than 15% skills disparity as not representing a skills gap from the Caucus attendee’s perspective. For example, the 9% difference for the CNC Programming skill associated with the “Additive/Subtractive & Advanced Materials” Industry 4.0 technology does not have the statistical significance to support a gap. Nor is there any merit to assigning the 42% vs 36% disparity for the “Fabrication” skill as indicative of a gap situation. Note: declaring that the disparity for the “CNC Precision Machining” skill is less than 15% when it equals 15% was done as a visual simplification for the table.

Question 4 and question 5 in Table 3 shift attention from a skill selection to a skill consideration mind set. These two questions deal with the more important skills from the two separate participant group perspectives. These two skill question groupings also relate to large and small skills gaps based on the definitions for this study. 51% of the manufactures indicated that "Participation in developing existing & new products & operations" was an important skill while only 12% of the educators agreed. By contrast, 60% of the educators stated that "3D CAD and printing/prototyping" is important while 36% of the manufacturers concurred.

I 4.0 Technologies	Faculty	Manufacturers	Disparity
Autonomous Robots;			
Programming	52%	34%	<20%
System Integration	56%	38%	<20%
Simulation;			
Perform Root Cause Analysis	40%	39%	<15%
Participate in Planning & Evaluation Processes	24%	36%	<15%
Additive/Subtractive & Advanced Materials;			
3D CAD and printing/prototyping	60%	36%	<25%
CNC programming	48%	39%	<15%
CNC Precision Machining	48%	33%	<15%
Fabrication	36%	42%	<15%

Table 4: Small Skill Gaps for Technician Focused Industry 4.0 Technologies

Returning the reader's attention to Table 2 emphasizes the large and small skills gaps grouping identified via Table 3 questions 4 & 5. The two items in this group are indicated in purple and identify the most popular manufacturers' and educators' skill selection. The "Participate in developing existing & new products & and operations" skill grouped as one of the needed manufacturing skills within the Simulation Industry 4.0 Technology also suggests a large skills gap situation. Fifty-one percent of the manufacturers (their most popular choice) vs 12% of the faculty indicated this skill to be within their top 5 selections and reveals a significant 39% difference of opinion. Flipping to the most frequent skill selected by faculty, 60% of them identified "3D CAD & printing/ prototyping" skill within the Additive/Subtractive & and Advanced Materials Industry 4.0 technology. Only 36% of manufactures selected this item, resulting in a small 24%, disparity between the educator and industry responses.

Discussion

Lag exists in every process and the magnitude of that lag impacts process performance and product quality. Preparing a high-quality manufacturing workforce is not exempt from the impact of lag. The Florida state-wide A.S. Engineering Technology has the bandwidth to create the desired workforce within the state's diverse college service areas. However, the state's iconic geographic footprint does nurture lag situations expressed as technical skills gaps.

The thread of this research presentation, skills gaps related to manufacturing technician involvement in Industry 4.0 technologies, accents Florida's geographic situation. The pre-Caucus questionnaire activity included manufacturers and college faculty that span this large State. Table 2 indicates the pre-Caucus questionnaire consensus within the two Caucus participant groups.

Table 4 accents a tighter alignment among the faculty, typically 40% agreement or higher, than their industry participants. The industry group only had one skill higher than 40% consensus.

Within this consensus limitation, Table 2 also reflect the extremes between the groups participating in the Caucus. For one case, the manufacturers are convinced that "Participate in developing existing & new products & and operations" is an important high demand skill for manufacturing technicians, but that skill is currently missing in their workforce. Only 12% of the college faculty considered this skill as a significant skill for their graduates to possess. For the other case: "3D CAD & printing/ prototyping" is extremely popular, 60%, among faculty but a moderate, 36%, at best priority among the manufacturers. Thus, in Florida, an industry identified skills need, "Participate in developing …" is not currently a priority for the faculty and subsequently not incorporated regularly in the curriculum, while the State-wide faculty interest in "3D CAD & printing/ prototyping" is extensively presented in the E.T. programs across Florida (taught in most colleges) but it is not a skill of overwhelming interest of manufacturers. These two identified skills gaps reflect ineffective use of technical education resources and/or a serious miscommunication between faculty and industry personnel as well as an important discussion point during the virtual Caucus.

The absence of the Boston Consulting Group's "Industrial Internet of Things" Industry 4.0 Technology related skill area, "Ethernet Communications (Machine to Machine), and Records & Store data", from Table 4 is a significant result. The Caucus participants basically rejected this I4.0 technology and the supportive skills (22% manufacturers, 28% faculty) as not significant to their manufacturing enterprise or college curriculum content. A surprising result but perhaps due to misunderstandings of the meaning of the terms used and will be researched to better understand the data.

In a separate but related NSF activity, FLATE reviewed Toyota's FAME program (Federation of Advanced Manufacturing Education) as integrated into its primary feeder technician college, Bluegrass Community and Technical College. The comprehensive briefing provided by Toyota process engineers at their Georgetown facility (two new vehicles are built every 55 seconds 24 hours per day) never used or categorized the technologies or expected technician skills as "Industry Internet of Things". The Toyota vocabulary centered on "edge computing" and its role in their manufacturing facilities. The technician skills expectations were then parsed as IT technician (Cloud side) and as manufacturing or operations technician (inside the manufacturing facility) skill expectation. Their manufacturing technicians were expected to deal with the Ethernet installation/maintenance issues related to process inter and intra sensor communications.

The nature and results obtained from this pre-Caucus process are significant when Florida's situation is kept in perspective. Florida has only one Florida Department of Education two-year manufacturing technician preparation program. Each college has degrees of freedom as to the technical topics taught in the 2nd year but manufacturers in 2021 now expect any graduate from any college in the state to exhibit command of the same manufacturing skills. Thus, FLATE's focus is to encourage colleges and manufacturers to be picky and specific about technician skill expectations. (At this interaction level the expectations: workers are drug free, go to work, and show up on time are not entertained as discussion points.) As the skill expectations focus sharpens, manufacturing technician contributions to product production and quality will increase dramatically.

Application of this caucus methodology (pre-caucus questionnaire followed by two sequential participant caucus events) in other regional situations merits a caution. It is not likely that the participating colleges will have the same state-level framework since they have number of credits, program names, and learning content focus choices. If these items are part of the discussion mix among the faculty cohort participating in a reginal or state level caucus, manufacturers will not express interest in listening to or sorting out the nuances among the programs nor will they easily connect any identified skills gap to a program's curriculum. This curriculum connection is the goal of the exercise since it will be curriculum content adjustments that shrinks the skill gaps identified in this process and ultimately improves manufacturer's productivity.

Conclusions and Next Steps

For Florida, this paper's presentation question, "What's Next: The Future of Work for Manufacturing Technicians", is clearly driven by the research results encapsulated in the pre-Caucus questionnaire of Industry 4.0 skills as itemized in Table 2. The expectation is skills identified by manufactures and this must be the focus of attention. Summarizing the skills that need addressing in priority by importance to manufacturers, FLATE's initial questionnaire triggered response action items are now dictated by the identified skills deficiencies. The prioritized short list is found in Table 5.

Manufacturing Technician Related I 4.0 Technologies	
Autonomous Robots;	
System Integration	**38%**
Simulation;	
Perform Root Cause Analysis	**39%**
Participate in developing existing & new products & operations	**51%**
Additive/Subtractive & Advanced Materials;	
CNC programming	**39%**
Fabrication	**42%**

Table 5. Manufacturer Prioritized Skills to be initially addressed in Florida's A.S. Engineering Technology Degree for Advanced Manufacturing

FLATE will return to the ET degree community of practice with these five identified skills gaps using two pathways. First, an overview approach, the results obtained will be reviewed at the Engineering Technology (ET) Forum. FLATE uses its ET Forum to keep the ET program faculty and administrates up to date with Florida Department of Education, NSF, and participating college new initiatives and activities. The ET Forum meets twice a year with a typical 80 participants from education and industry. Second, a specific approach, by directly interacting with individual colleges and their manufacturing advisory boards at a more regional level.

Every college that offers the ET degree program must have an industry advisory board and many of the colleges are actively involved with the FloridaMakes (part of the NIST Manufacturing Extension Partnership (MEP) national network) supported Regional Manufacturing Association. These direct connections to manufacturers within a target college's service area will steer curriculum content adjustments for that college to the appropriate skill gaps identified in Table 5. If these local curriculum adjustments are projectable to other colleges, FLATE will bring this subset of faculty together to increase the likelihood that the new content is uniformly infused into the ET degree program. If the skills in question reflect a novel technology unfamiliar to the faculty, professional development activities will also be provided.

Longer term research will explore the details of the smaller gaps between faculty and manufacturers. Research will be done to explore why the skills defined under the Industry 4.0 technology labeled "Industrial Internet of Things" were not expected to be needed. Lastly, the research team will investigate what it is about "Simulation"; "Participate. new products & operations" that manufacturers deemed important to the point that they prioritized it as the highest,39%, skills gap issue.