Future of Work Skills Integration with Florida Manufacturers' Technician Skill Needs

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Abstract: Different perspectives on the "Future of Work" can cause disconnections between the technician skills needed by industry and those taught by the educational programs preparing technicians to participate in Industry 4.0 (I4.0) manufacturing environments. Variations in the methodology of identifying, grouping, and describing technical skills and skill areas are driven by variations in sources of information and the industries and locales they represent. This paper summarizes for the ATE audience a FLATE (Florida Advanced Technological Education Center of Excellence) project [1]—Technician Future of Work Issues Caucus for Florida Community Colleges and Manufacturers (DUE 1939173)—that compared the skills needed by Florida manufacturers to the skills taught at two-year Florida colleges, and then mapped those skills to the I4.0 skills identified by a national sampling of technology-focused industries carried out by the CORD project Preparing Technicians for the Future of Work (DUE 1839567) [2].

Specifically, the paper (i) reviews the I4.0 technology skills identified by the Boston Consulting Group; (ii) presents I4.0 skill interactions with the results from the CORD and FLATE projects; and (iii) maps Florida-identified technician skill needs to the Cross-Disciplinary STEM Core skills identified at the national level by the CORD project. The paper also summarizes the process for integration of the I4.0 technology-related skills into the AS engineering technology program offered by twenty-two colleges in the Florida State College System [3,4,5].

Introduction

Industry 4.0 (I4.0) environment requires technicians who can drive practical applications of I4.0 technologies by applying the appropriate engineering principles in engineering operation technology (OT) scenarios. To be effective, technician education must provide up-to-date, reliable, and relevant instruction that creates and cultivates professionals across its target workforce. Periodically, events demand alterations and even major adjustments in this education. The manufacture of transistor devices to replace vacuum tube technology and the launch of Sputnik are two 20th-century examples. More recently, technologies that integrate sensors, final control elements, and communication capabilities to send and receive data and operating instructions directly to and from manufacturing systems and subsystems is a dominant driver of innovation in STEM education. Applications of this new wave of I4.0 engineering and engineering technologies are finding their way into many technology areas and demanding societal adjustments.

Methods

The Caucus Process

The skill areas and skill set data reviewed in this paper were acquired using a caucus protocol for two projects supported by the National Science Foundation Advanced Technological Education (NSF ATE) program. In this paper, the projects are referred to as follows:

FL Caucus: Technician Future of Work Issues Caucus for Florida Community Colleges and Manufacturers (DUE 1939173; conducted by FLATE)

FoW: Preparing Technicians for the Future of Work (DUE 1839567; conducted by CORD)

The caucus approach was used because it put the experts in front of each other and allowed for small group activities and open dialog among participants. The projects originally planned for all activities and events to be in-person. Unfortunately, the COVID-19 pandemic caused both to shift to virtual events. FoW began hosting during the ATE leadership caucus, one conference special interest group (SIG) meeting, and its first regional in-person convening. The remaining events had to be conducted virtually. FL Caucus replaced its planned initial caucus with a questionnaire focused on entry-level manufacturing skills and two virtual caucus events separated by several months to provide time to review and analyze the data collected.

Although some of the events went by names other than "caucus" (e.g., "convening," "SIG"), they are all considered caucus events because of their format, agendas, and outcomes. Industry professionals and educators from multiple sectors and disciplines attended all. The attendees heard from subject matter experts and produced and prioritized lists of skills. Project teams reviewed and condensed the lists and distributed them to participants for review and approval. Caucus protocols involved initial exploration, confirmation of findings, and final review. All caucus events included keynote presentations that allowed participants to collectively consider expert views and guidance and focus on the event's overall goal. Both projects found the caucus process productive, whether in-person or virtual and a workable and convenient process for producing the desired outcomes.

Results and Discussion

Industry 4.0 and Future of Work Skill Areas and Skill Sets

Integrated technology systems and subsystems are being injected into industry at an ever-accelerating pace. Figure 1 presents the I4.0 technologies identified by the Boston Consulting Group [6]. These technologies are impacting, and will continue to impact, the technician preparation degree programs supported by the NSF ATE program, as is shown in Figure 2. The items shown in the two figures drove FoW's goal of identifying the I4.0 skills technicians need and what adjustments two-year technical degree programs should make to prepare technicians for this new multi-skill environment. There have been various graphic depictions of Industry 4.0 technologies and their interconnectedness, including anywhere between nine and twelve technologies that might highlight slightly different technologies than the representation developed by the Boston Consulting Group. For example, some, including one by Technord [7] with ten technologies and Digital Twins and MES/Advanced Control Systems. Others include Artificial Intelligence and Machine Learning, which could be considered a technology of augmented and/or virtual reality or digital twins.
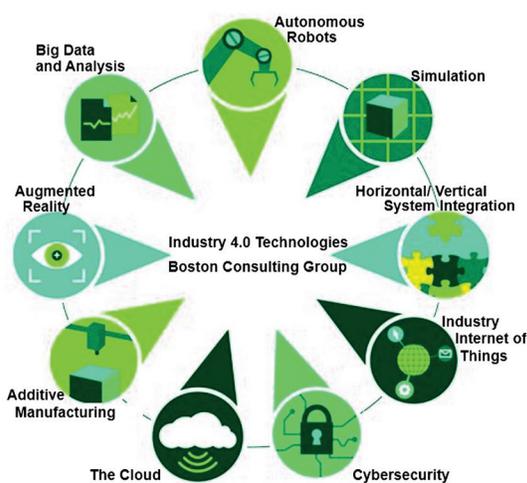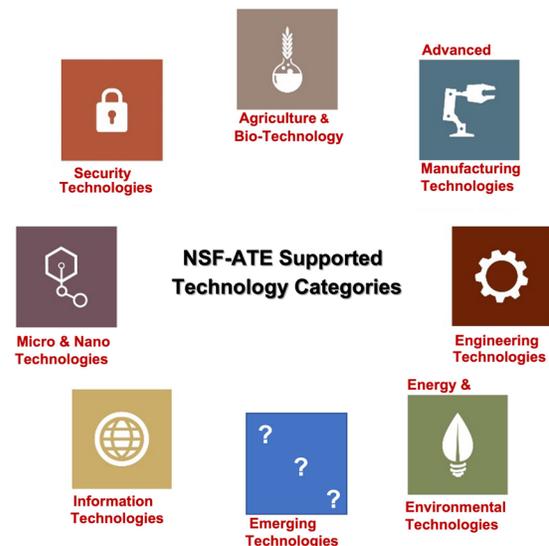

Fig. 1. Industry 4.0 Technology [1]

Fig. 2. NSF-ATE Technologies [2]

FoW began with a data collection phase. A caucus event (NSF ATE Leadership Caucus) was convened in December 2018 in Alexandria, Virginia. It brought together the Principal Investigators from the ATE Centers that support the technologies shown in Figure 2, industry representatives involved in the technologies in Figure 1, the project's Industry Advisory Committee, and program experts from NSF for a two-day meeting. These experts were formed into subgroups to discuss the cross-disciplinary STEM and "soft skills" expectations for technicians in their professional environments.

The FoW team grouped the skills identified by caucus attendees into three areas: Data Knowledge and Analysis, Advanced Digital Literacy, and Business Knowledge and Processes. The three areas are defined as follows:

(i)   Data Knowledge and Analysis: Understanding, interpreting, and manipulating data to resolve issues using Excel and other common software proficiency to accomplish tasks.

(ii)   Advanced Digital Literacy: Understanding digital communications and networking, cybersecurity, machine learning, sensor, programming, and robotics at a higher than introductory level.

(III)   Business Knowledge and Processes: Understanding the value chain and business process of an enterprise and applying principles of ethical adoption of new technologies.

These three skill areas and their associated skill sets were disseminated at regional convenings. Participants in these events represented multiple disciplines and focused on emerging cross-disciplinary skills sets. Their contributions continue to inform the project's outcomes and dissemination strategy. The three skill areas, their associated skill sets, and suggested implementation strategies are presented in the FoW document titled "A Framework for a Cross-Disciplinary STEM Core" [8]. In addition, a 2019 report from the American Association of Community Colleges (AACC), the Arconic Foundation, and the National Coalition of Advanced Technology Centers (NCATC) offers a related view of the need for cross-cutting curriculum updates through the lens of integrating Industry 4.0 technologies [9].

Future of Work Skills in Florida Manufacturing

An early result of exploring I4.0 skill needs on the manufacturing floor at the national level was the recognition that manufacturers in different regions of the country and from different manufacturing sectors have different (though overlapping) expectations for the engineers and technicians in their work environments. Therefore, one of the FL Caucus's goals was to identify what emerging I4.0 skills are required on Florida's manufacturing floors. The project's first step was identifying the I4.0 skill sets expected by Florida manufacturers of the graduates of Florida's two-year AS Engineering Technology (ET) degree program, which focuses on advanced manufacturing.

Four of the nine I4.0 technologies shown in Figure 1 emerged through this exploration: Additive Manufacturing, Autonomous Robots, Cybersecurity, Industry Internet of Things, and Simulation. In Florida, these manufacturer-identified I4.0 skill needs differ according to variables such as the manufacturer's size, its primary products and processes, and where the company is implementing emerging technologies. For example, for the over 130 small-to-medium manufacturers polled, engineers and technicians in their facilities are not currently using Augmented Reality applications.

The next phase of the FL Caucus was to distinguish between skill sets needed by manufacturers and the skills currently being taught in the AS ET program. Figure 3 shows the results of two questionnaires that asked industry personnel and educators to prioritize the top five emerging skills needs. The figure's four blue labels—Autonomous Robots, Simulation, Industry Internet of Things, and Additive/Subtractive & Advanced Materials—correspond to I4.0 technologies shown above in Figure 1. (Whereas Figure 1 refers to "Additive Manufacturing," in Figure 3 we have altered that to "Additive/Subtractive & Advanced Materials" because the manufacturers always combined those technologies during the FL Caucus sessions.
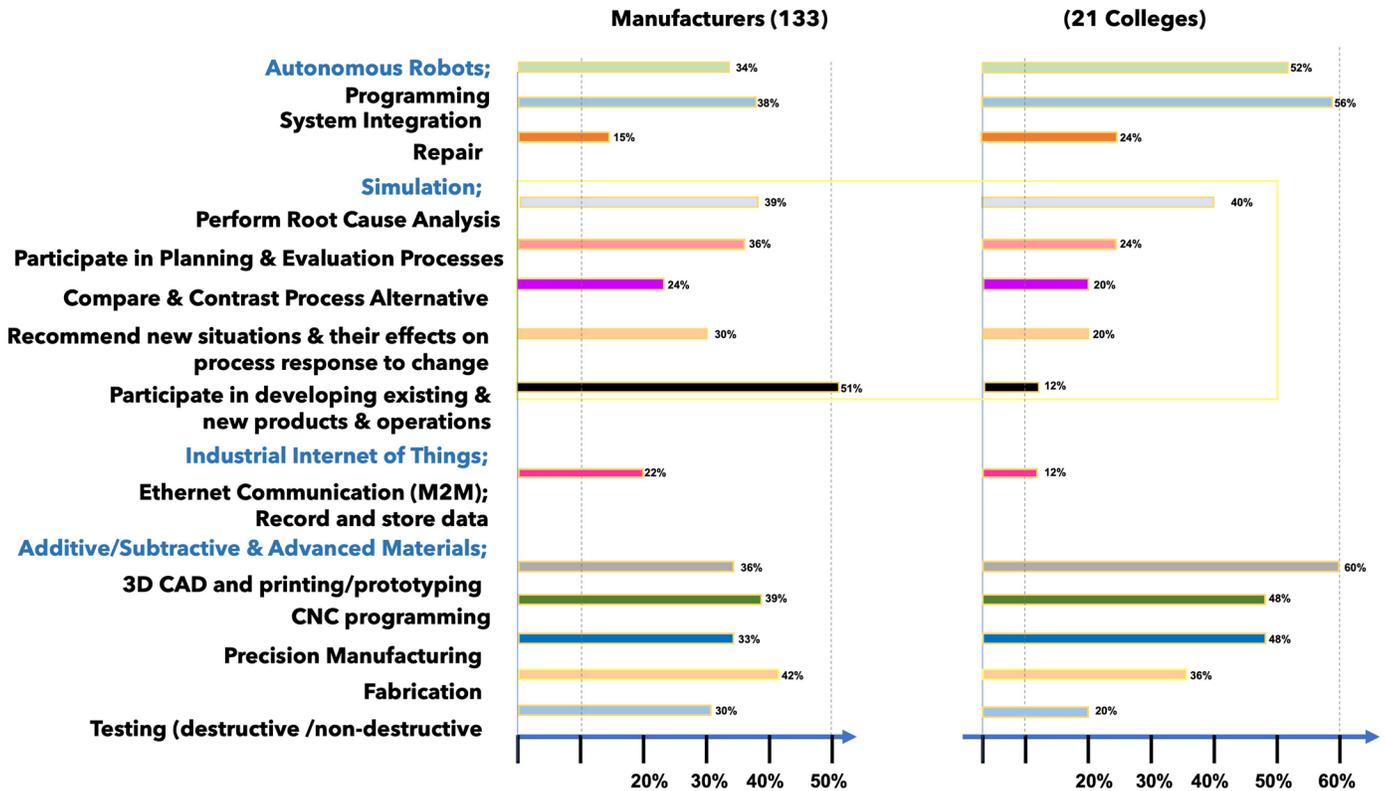
Fig. 3. Industry 4.0 Skills as Prioritized by FL Caucus Participants

The bars in the figure reflect the percentages of participant groups that identified skills needed (133 industry participants) and skills currently being taught (21 college faculty). Fifty percent of the manufacturers indicated a need for technicians to "Participate in developing existing & new products & operations," while only about 10 percent of the college faculty indicated that those skill subsets were being taught. In some cases, the colleges placed more emphasis on a given skill area than the manufacturers' need warranted. For example, while only 36 percent of the manufacturers indicated that "3D CAD and printing/prototyping" were needed skills, 60 percent of college faculty said those skills were being taught. Sometimes the two groups were closer to an agreement. Neither the manufacturers (22 percent) nor college faculty (12 percent) showed strong interest in "Ethernet Communications (M2M); Record and store data." (Those relatively low numbers do not reflect on the importance of the Industrial Internet of Things in general but are because few Florida industries are currently implementing those technologies.)

Florida Manufacturer-Identified Industry 4.0 Needed Skills

Participants in FL Caucus also identified the categories of manufacturing-related technician skills needed in Florida. Just as there are regional differences in the pronunciation and meanings of English words and phrases, terminology pertaining to I4.0 skills varies at the regional level. Figure 4 shows an alphabetical list of the 37 skills most frequently identified by the FL Caucus participants. Some of the items, numbers 7 and 27, for example, map directly to a skill in Figure 3: "3D CAD and Printing/Prototyping." Item 36 maps directly to "Perform Root Causes Analysis," a skill categorized under "Simulation" in Figure 3. The skills that do not obviously align were mapped after discussion by the project team and caucus participants.

1 Ask 5 Whys	12 Data Interpretation
2 Brainstorming	13 Destructive Testing
3 Cloud	14 Fishbones
4 Critical Thinking	15 Integrating Systems, PLC
5 Data Integrity	16 Interdisciplinary Skills
6 Programming	17 Material Knowledge
7 Prototyping	18 Material Testing
8 Quality Testing	19 Provide Design Data
9 Test & Executing	20 Reverse Engineering
10 Three D Printing	21 Support Mockup/Test
11 Write SOP	22 Troubleshooting
	23 Use Root Cause Analysis

24 Awareness of the Security Requirements
25 Basic Understanding of Databases & Networks
26 Building/ Assembling Prototypes
27 CAD Layout for Production Processes
28 Diagnose & Understand Full Process
29 Ensure Measurement has Uncertainty Stated
30 Human Factors and Interactions
31 Identify Opportunities for Improved Products
32 Integration Eng. Tech. / Adv. Mfg. / Computing
33 Knowledge of Product Standards and Regulations
34 Math, Communication, Teamwork, Solve Problem
35 Spreadsheet Creation & Manipulation
36 Use Technical Tools to Identify Root Causes
37 Write Technical Reports including Data

Fig. 4. Needed Skills as Verbalized by FL Caucus Participants

Florida Technician Skill Map to Cross-Disciplinary Skills

The FoW project team mapped the 37 Florida-identified skills shown in Figure 4 to the national profile described in the project's "Framework for a Cross-Disciplinary STEM Core." The resulting alignment is shown in Figure 5. (The FL Caucus-identified skills are shown in red.) The headings of the three columns in the figure are the skill areas identified in the FoW Framework: Data Knowledge and Analysis, Advanced Digital Literacy, and Business Knowledge and Processes. The associated skill sets are listed alphabetically: 14 under Data Knowledge and Analysis, 13 under Advanced Digital Literacy, and 15 under Business Knowledge and Processes.

Data Knowledge and Analysis		Advanced Digital Literacy		Business Knowledge and Processes	
Analytics Tools	37,23,36	Artificial Intelligence Machine Learning	16	Blockchain	
Data Analysis	19	Automation/Robotics	10,22	Business Cycle	
Computational Thinking	2,22,34	Basic Programing	6	Communication	11,12,30,34,37
Data Backup, and Restoration		Cloud Literacy	3	Customer/Stakeholder Analysis	30,31
Databases	37,25	Digital Fluency		Continuous Process Improvement	31
Data Life Cycle		Digital Twin	32	Entrepreneurship	7,20
Data Fluency	5,29	Edge Computing	32	Horizontal & Vertical Integration	15,22,28
Data Management	37	Function Block Diagram	27	Ethics	12
Data Storage		Programming	6	Lean Processes	1,23
Data Modeling	12	Network Communications	25	Logical Chains	
Data Visualization	37	Human-Machine Interface (HMI)		Market Trends	31
Query Languages		Industry Internet of Things		Overall Equipment Efficiency (OEE)	8,9
Spreadsheets	34,35	Network Architecture		Return On Investment (ROI)	
Statistics	34	Security Controls	24	Risk Management	30,33
				Supply and Demand	

Fig. 5. FL Caucus-Identified Skills Mapped to FoW-Identified Skills

Figure 5 shows the alignment of the FL Caucus-identified skills to the skills identified in the FoW Framework. For example, the first skill set under the heading Data Knowledge and Analysis, Analytics Tools, aligns with FL Caucus skills 37, 23, and 36 in Figure 4. In addition, Figure 5 data indicated that 89 percent of the skills shown in Figure 4 are aligned to FoW Framework-identified skills. By contrast, four skill sets in the Data Knowledge and Analysis skill area of the FoW Framework were not specifically identified by FL Caucus participants as important emerging skills.

Four skill areas shown in Figure 5—Data Backup and Restoration, Data Life Cycle, Data Storage, and Query Languages—may reflect more on the stage of I4.0 implementation by Florida's small/medium manufacturers than on the current need for their technicians to possess those skills. Small/medium manufacturers are investing in new process equipment that supports their manufacturing missions and includes a suite of input/output (IO) communication options. However, sensors and final control elements that use those I/O options are not yet included in their process schemes. It is interesting to note that the Florida manufacturers' responses to emerging needs include several skills that focus on working with data at a higher level, and it would be expected that more specific responses such as "Data Backup and Restoration," "Data Life Cycle," "Data Storage," and "Query" will be brought into Florida technician preparation programs during the 2024 triannual review cycle. Thus, the remaining skill sets are "waiting in the wings" for their call to action. Similar analyses can be made for items in the other two skill areas. Differences in wording and interpretation probably account for most of the remaining non-aligned skills.

Skill Insertion into 2-Year Technician Programs

The next phase of I4.0 skill integration into Florida's ET technician workforce required the insertion of identified Figure 4 skills into AS ET degree programs. Although twenty-three state colleges offer the degree, the curriculum for the degree's first year of study is identical in all those colleges. The second year of coursework is similar among the colleges, with variations that allow each college to address industry sectors in their service areas. Variations in these second-year course options make each program unique and increase the difficulty of maintaining uniformity throughout the state. This uniformity is critical since AS ET degree holders from any of the twenty-three colleges can transfer their degree-related courses into any ABET BS ET program in Florida. The vehicle for unification is the Florida Department of Education (FDOE) Standards and Benchmarks, which apply to all CTE and AS degree programs in the state [10].

The FL Caucus leadership team reviewed relevant FDOE Standards and Benchmarks with the objective of tagging the skills in Figure 4 to existing standards. The team determined that 33 skills were directly tied to FDOE Standards, while there were no connections to four skills: Basic Understanding of Databases & Networks, Cloud, Data Integrity, and Data Interpretation. In addition, five skills were identified as having "questionable connections": Building/Assembling Prototypes, Integration of Engineering and Technology, Advanced Manufacturing and Computing, Interdisciplinary Skills, and Writing Technical Reports, including Data. FDOE oversees updating its standards and benchmarks for each AS degree and CTE program on a three-year cycle. The FDOE review team of educators and industry professionals will need to address the missing and questionable connections to ET degree standards and benchmarks that have been identified by this work during the next review cycle.

Conclusion

I4.0 technologies are being infused into manufacturing environments at an ever-accelerating pace. Consequently, the skill needs of technicians and engineers in the emerging ET workplace demand that technical faculty and their programs take immediate steps to insert knowledge and "hands-on" instruction that focuses on the skills that support I4.0 technologies. For experienced two-year technician preparation faculty, the challenge of doing so may stem more from the new vocabulary associated with I4.0 than from faculty expertise. Results from these NSF projects reveal both linkages and disconnections between existing programs and I4.0 skill needs and demonstrate impact-verifiable facilitating pathways that apply nationally and regionally.

Disclosures. The authors declare no conflicts of interest.

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