Industry 4.0 Technology Skill Expectation Integration into Engineering Technology Technical Workforce

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Abstract

There are many approaches to identifying Industry 4.0 Technology driven skills that need to be integrated into Engineering Technology education. This presentation will review a manufacturer and faculty Caucus method. Once the skill needs are identified there are challenges associated with the delivery of appropriate level and intensity of the skill instruction in the implementation phase.

This paper (I) reviews the Industry 4.0 skill areas and skill sets as identified by the Boston Consulting Group; (2) presents the results from an NSF-funded special project, "Preparing Technicians for the Future of Work" that identifies skill areas and skill sets cross-discipline framework for technician preparation; (3) presents the results from NSF-funded projects "Conference to Explore the Impact of Future of Work Issues on Technician Education in Florida," and (4) presents the process for integration the Industry 4.0 technology-related skills into the BS Engineering Technology degree program at Daytona State College. This paper and presentation report on these strategies and illustrate the overlap of important skills needed by many engineering technicians in many of the advanced and emerging technologies.

Prelude

Engineering technology (ET) drives the successful practical application of engineering principles in every engineering discipline and application. Engineering technology education is the primary vehicle that delivers the needed relevant and related knowledge and "hands-on" skills to students focused on technician and engineering careers in the ET workspace. Engineering technology education, by its very nature, must provide reliable and repeatable instruction that constantly creates and replaces professionals in its target workforce.

Periodically events demand alterations and even major adjustments in ET education. The Russian successful launch of Sputnik is the 20th century example that quickly comes to mind. Today's technologies that integrate sensors, final control elements, and communication capabilities to send/receive data as well as operating instructions into manufacturing subsystems and systems are and will continue to be the trigger for ET education innovation in the 21st century. This new wave of engineering, engineering technology and, for that matter, society adjustments is conveniently identified as Industry 4.0.

Industry 4.0 Skills in Engineering Technology Technical Workforce

Industry, at an accelerated pace, is injecting integrated technology subsystems and systems into their environments. Figure 1 presents tight bundles of these expansive technologies as industry 4.0 technologies as identified by the Boston Consulting Group. These same technology sets have been adopted by the NSF (DUE 18-39567) future of work special project, “Preparing Technicians for the Future of Work,” for insertion into the two-year technician preparation

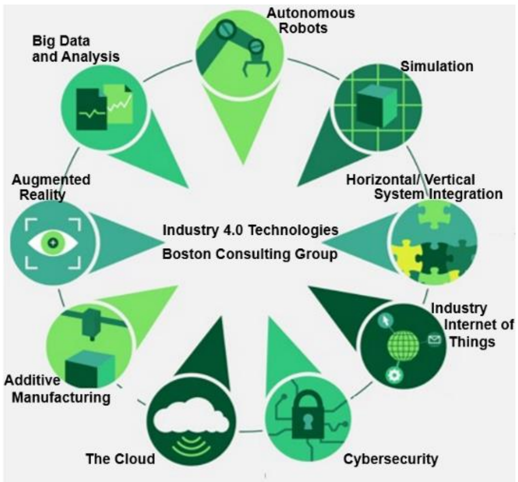


Fig. 1. Industry 4.0 technologies [1]

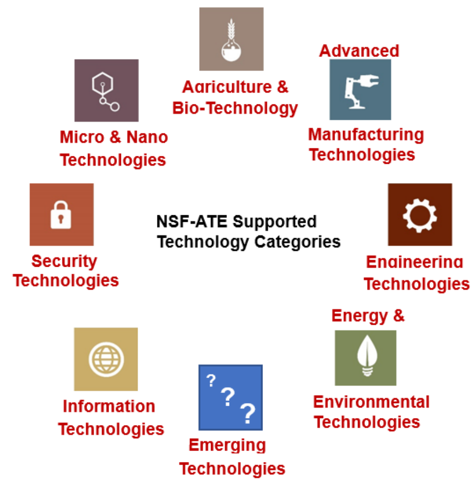
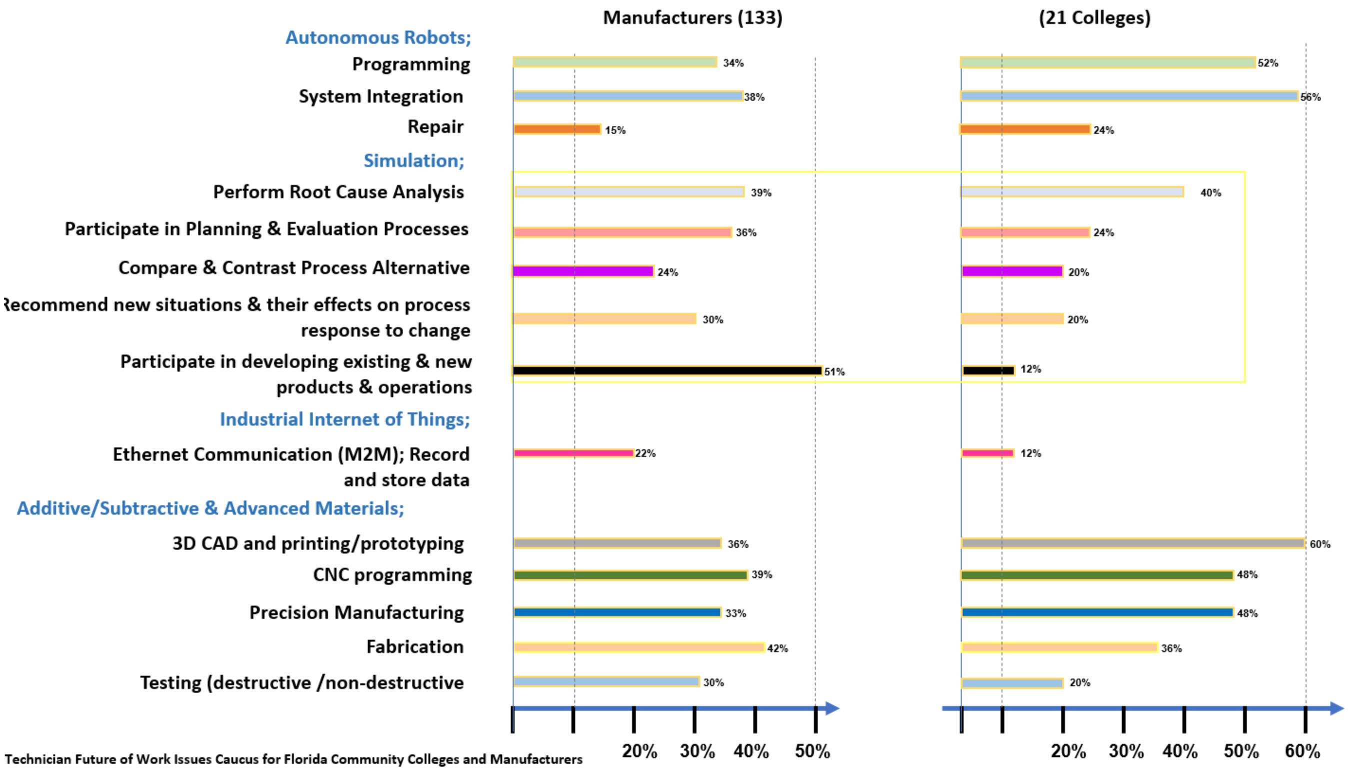


Fig. 2. NSF ATE technology [3]

degree programs within the technology groups as supported by the NSF Advanced Technological Education program (NSF-ATE) and visualized in Figure 2.

An early result of this exploration of Industry 4.0 skill area needs on the manufacturing floor was the fact that manufacturers have separate expectations for the engineer and the technician in that work environment. The cluster of skill areas for technicians, as identified in Figure 1 are additive manufacturing, autonomous robots, cybersecurity, Industry Internet of Things, and simulation. This alphabetized but not prioritized list may catch the reader off guard. However, manufacturer identified Industry 4.0 application technician skill needs reflect on the size of the manufacturer and where that company is in the broad spectra of new advanced technology applications. In addition, for the over 130 small to medium manufacturers in Florida involved in this specific skills investigation project, engineers or technicians in their plants are not involved in augmented reality applications nor need those associated skill requirements.

An initial step in this project's NSF supported Manufacturer and Faculty Caucus conducted in Florida was an assessment of the Industry 4.0 skill sets needs by the manufacturers that expect them and the faculty that teach them. Figure 3 shows these



Fig, 3. Prioritized Industry 4.0 skills.

results in a graphic format. (The blue labeled print are the I 4.0 skill groups while the black print are the skills involved in that group.) The bar lengths reflect the percent of participants,133 manufacturers and 21 college, that indicated skills needed (Industry participants) or taught (college participants). Thus, it is easy to see that over 50% of the manufacturers indicated a need for technicians to "Participate in Developing Existing & New Products & Operations" while slightly more than 10% of the colleges indicated that those skill subsets were taught in their Engineering Technology technician preparation programs.

The next step was to connect the identified I4.0 skills to the vocabulary for these skills used in Florida. Just as there are different dialects and even meaning for English words and phrases across the country, the national vocabulary of I4.0 skills will vary at the regional level as well. Figure 4 has identified a larger set of skills that were most popular with caucus participants. The figure has these 37 skills prioritized only as alphabetical lists in sets arranged for easy visual assimilation. Some of the items in this figure, for example, items 7 and 27 map “one-to-one and onto” to a skill, 3D CAD and printing/prototyping, in Figure 3 or item 36 with the Perform Root Cause Analysis also in Figure 3, while the others were mapped after brief discussions with

1 Ask 5 Whys
2 Brainstorming
3 Cloud
4 Critical Thinking
5 Data Integrity
6 Programming
7 Prototyping
8 Quality Testing
9 Test & Executing
10 Three D Printing
11 Write SOP

12 Data Interpretation
13 Destructive Testing
14 Fishbones
15 Integrating Systems, PLC
16 Interdisciplinary Skills
17 Material Knowledge
18 Material Testing
19 Provide Design Data
20 Reverse Engineering
21 Support Mockup/Test
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 caucus participants.

caucus participants.

The follow-up activity was to map these 37 Florida identified technician skill needs to the cross-disciplinary skills identified at the national level in the NSF Future of Work project, DUE 18-39567, and shown here in Figure 5. The figure has three skill areas: data knowledge and analysis; advanced digital literacy; and business knowledge and processes. The skills sets within these skill areas: 14 in data knowledge and analysis; 13 in advanced digital literacy, and 15 in business knowledge and processes are only prioritized alphabetically. data knowledge and analysis (i), advanced digital literacy (ii) and business knowledge and Processes (iii) are defined, respectively as

(i) Understanding, interpretation, and manipulation of data to resolve issues using Excel and other common software proficiency to accomplish task.
(ii) Understanding digital communications and networking, cybersecurity, machine learning, sensors, programming, and robotics at higher than introductory level.
(iii) Understanding the value chain and business proactive of an enterprise and applying principles of ethical adoption of new technologies.

Figure 5 shows the alignment determined by the project leadership team with some of the Caucus identified essential skills assigned to the cross disciplinary frameworks skill identified in the NSF special project future of work project. For example, the first skills set in data knowledge and analysis, analytics tools, is also aligned with caucus essential skills 37, 23, and 36 in Figure

4. The data indicated that 89% of the skills presented in Figure 4 are aligned to the nsf future of work project identified skills.

The next phase of Industry 4.0 technology skill integration into Florida's engineering technology technician workforce required the insertions of identified Figure 4 skills into the expectation of the AS Engineering Technology technician preparation degree in Florida. Although there are 23 state colleges that offer the two-year AS Engineering Technology degree, the curriculum for the degree's first year of study is identical in all these colleges. The second year of the course work is similar among the colleges with variations that allow each college to address the industry

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. Florida ET essential skills alignment to cross-disciplinary skill areas/skill sets.

within their service area. These second-year course options represent the hall mark for the degree but generate a challenge related to keeping the degree uniform throughout the state. The vehicle for unification is the Florida Department of Education (FDOE) Standards and Benchmarks at all CTE and AS degree programs must adhere to.

The project 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 of these skills were directly tied to standards while there was no standards connection to 4 skills: basic understanding of databases & networks, cloud, data integrity, data interpretation. In addition, there were 5 skills that were inserted into a "questionable connection" category. This grouping allowed assumptions that they connect to current standards or need more clarity. The six skills in this collection include building/assembling prototypes, data interpretation, integration of engineering technology, advanced manufacturing and computing, interdisciplinary skills, and writing technical reports including data. The Florida Department of Education reviews for revision its standards and benchmarks for each AS Degree and CTE program on a three-year interval. The information the FDOE needs to address the missing or questionable connections to ET degree skills has been submitted for the next review cycle.

As indicated in this paper's abstract, the last phase, (item iv), of this caucus-driven mechanism for the integration of Industry 4.0 technology related skills into Florida's technical workforce is to recognize that some of the skills in Figure 3 might be beyond the expectations of a starting technician with an .AS ET degree. The two-year ET degree program has adjusted to this reality with extensive interweaving interactions with the .BS Engineering Technology degree program at Daytona State College. The first action was the creation of an AS degree Advanced Technical Certificate (ATC) to address advanced I.4 driven skills at the ET advanced technician and starting BS Engineering degree level**.** Figure 6 lists this ATC course collection.

This certificate's focus is senior technical expertise that meet manufacturer's advanced technician skill holder expectations. This generates three degrees of freedom. First, new AS ET degree holders have an avenue to immediately acquire some of this expertise. This is especially pertinent to a new technician that has been inserted into manufacturing scenarios that require that expertise. Second, seasoned technicians can "cash in" on that expertise and acquire transferable credit into the BS ET degree program at Daytona State College. The details for that BS ET degree and the complete pathway from high school student to an ET degree holding professional engineer in Florida are discussed in a published ASEE paper, ".AS Degree Career Pathway within the Florida State College System That includes a Professional Engineering License" and presentation at the 2022 ASEE National Conference. However, Figure 7 does repeat the figure that illustrates the planned elective group options that concentrate on Industry 4.0 technology supportive skills.

A.S. Advanced Technical Certificate	
Applied Data Base I	***COP 4813***
Applied Data Base II	***COP 4834***
Information Technology Project Management	***CIS 4510***
Web Systems I	***COP 4814***
Web Systems II	***COP 4835***

Fig. 6. ATC BS degree transferable courses

Industrial Fundamentals (IF) **(Select two from ETI 4205, ETI 4186, ETI 3116, ETI 4640 and ETI 4704)**	Energy (E) **(Select one from list) ETM 4220, ETM 4331, EGN 3334**	Materials (M) **(Select one from list) ETI 3421, ETG 3533/L, ETG 4241/L**	Programming (P) **(Select one from list)) COP 2360, COP 2800 EGN 3214**
Applied Logistics	Energy Systems	Materials and Processes	C# Programming
Applied Reliability	Fluid Mechanics	Strength of Materials	Java Programming
Engineer Quality Assurance	Thermodynamics	-	-
Operational Management	-	-	-
Operational Safety	-	Construction Materials & Lab	Programming for Engineering

Fig. 7. BS ET degree elective course group options.

The third degree of freedom imbedded in the Advanced Technical Certificate removes faculty constraints in the AS program to comply with FDOE Standard and Benchmarks. All the courses listed in Figure 6 have appropriate connections to the standards for all the lessons presented in their syllabus. Thus, two-year faculty can insert any of those lessons in any course in the AS degree curriculum an remain within standard and benchmark expectations. At this point, the reader may think that the authors just have a standards and benchmark obsession. This is only true in the sense that maintaining a single uniform Engineering Technology AS degree presented in 23 independent state colleges all over Florida is a challenge. The insistence that the colleges follow Florida Department of Education Standards and Benchmarks is an excellent tool for achieving degree continuity.

Summary

The important 21st century engineering technology challenge is the infusion of Industry 4.0 technologies into manufacturing environments. This challenge is accented by the fact that, at an accelerated pace, industry is implementing integrated subsystems and systems that have both process data collection and process control capabilities. The preparation of technicians and engineers for integration into the engineering technology workforce demands that faculty and their respective programs immediately insert knowledge and hands-on skills-based instruction that is focused on the skill areas and skill sets that directly support Industry 4.0 technologies. For some faculty this might be the case similar to teaching vintage dogs new tricks. However, this is not likely because of the faculty expertise but the new vocabulary tagged to Industry 4.0. Thus, the results of these NSF projects generate facilitating pathways that involve matching regional skills need vocabulary with the national trend as well as securing the instruction of Industry 4.0 skills in the curriculum at a level that is identifiable and impact verifiable.

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Biographies

MARILYN BARGER is the senior education advisor for FLATE and FloridaMakes, a Manufacturing Extension Partnership Center. She was the PI and executive director of FLATE, an ATE Center focused on manufacturing technology education in Florida for over 18 years. Today FLATE is part of the FloridaMakes Network (www.floridamakes.com), the NIST Manufacturing Extension Partnership Center in Florida and continuing its NSF mission supporting manufacturing education as a member of the MEP Network. Dr. Barger taught environmental engineering at Hofstra and FAMU-FSU College of Engineering, is registered professional engineer in Florida, member of the National Academy of Inventors, and a Fellow of American Society of Engineering Education.

RICHARD GILBERT is a retired professor of Chemical and Biomedical Engineering at the University of South Florida and the co-author of several books and articles that deal with sensor, instrumentation, and programmable logic controllers. In addition, he has created and conducted short courses and training sessions for the Instrument Society of America. Dr. Gilbert has over 20 biotechnology patents and is a member of the National Academy of Inventors as well as a former resident research scholar for the Air Force Office of Scientific Research. Dr. Gilbert has had previous grant support from NSF, NIH, and DOD and is currently the co-principal investigator of an NSF Advanced Technological Education project focusing on the future of work for technician education.