Graduate Student Perceptions for Industry 4.0 Topics: Are Undergraduate Programs Preparing Students for Industry 4.0?

James Kribs
North Carolina A&T State University

Abstract

As Industry 4.0 technologies, such as the industrial Internet of Things (IIoT), cloud computing, or additive manufacturing, have become increasingly implemented in manufacturing environments, the question is how well-prepared students are after graduating in these topics. As part of a graduate course in a technology management program, students were asked as part of a pretest prior to the start of the course their knowledge and perceptions of their skill levels in various Industry 4.0 topics. This course serves as a broad overview of digital and smart manufacturing topics, and relevant social and economic developments. In the survey responses, students responded that they did not have significant experience or knowledge in Industry 4.0 technologies.

Introduction

As the industry goes through a significant transition, with the implementation of Industry 4.0 technologies, it is necessary for engineering and technology programs to develop new curricula around these new technologies. With these newly developed curricula, gaps form between expectations of students' previous experience and their true knowledge, where students have missed necessary formative information for Industry 4.0 topics, or even awareness of what constitutes Industry 4.0 technologies. Many engineering and engineering technology programs are focusing on how to implement Industry 4.0 technology training into the existing programs, especially with the restrictions of having to keep existing or preparatory materials in their curriculum.

In a previous discussion of educational requirements for Industry 4.0, Das et al. highlighted multiple new requirements for Industry 4.0 education including the addition of flexibility in learning and more interdisciplinary learning [1]. Yang et al. further discussed that students did not have confidence in their preparation in Industry 4.0 topics, specifically highlighting that formal experiences contributed to their confidence [2]. While these formal training opportunities do provide confidence boosts to students, many programs are looking beyond conventional course methods, by directing self-directed continuous learning through reviewing professional literature [3]. Other programs have focused on the development of new curricula in Industry 4.0 topics, as outlined by Sirinterlikci in his review of Industry 4.0 workforce development [4].

Further investigation into the barriers in industry for the acceptance of Industry 4.0 technologies, done by Müller, showed on the second largest concern about adopting Industry 4.0 technologies was the lack of competencies and knowledge [5]. In a further breakdown of this concern about the lack of competency, the largest amount of respondents stated that a lack of qualification in IT

related technologies, was the largest barrier [5]. In order to combat this lack of competency while potential workers in engineering and engineering technology programs should be exposed to Industry 4.0 technologies, even briefly, so that potential workers could have opportunities to develop these preparatory skills through their undergraduate or graduate education.

A key concern is the vast topics that make up Industry 4.0 technologies, requiring background and preparatory courses in multiple disciplines. As part of a graduate survey course in Industry 4.0 technologies, the following topics are covered;

- Cloud computing
- The industrial internet of things
- Virtual and augmented reality
- Cyber-physical systems
- Big data structures
- Additive manufacturing
- Artificial intelligence and machine learning
- Simulations and digital twin modeling,
- Industrial robotics
- Workers in Industry 4.0
- The emergence of Industry 5.0.

All of these topics can be discussed individually in specific disciplines, but as Industry 4.0 progresses, it is apparent that these technologies are consistently being implemented together, such as industrial robotics being controlled through a cloud system [6]. This study focuses on how well students taking this survey course were prepared for these topic areas or if they have even been exposed to Industry 4.0 topics.

Research Study Method

As part of the introduction to the graduate survey course (AET 675- Digital and Smart Manufacturing) , in the Master of Science in Technology Management program, students were asked to complete a survey of their existing experience in various Industry 4.0 technology topics. The Technology Management program has students with backgrounds in the engineering, sciences, technology, disciplines as well as students from management and business backgrounds. The course was delivered asynchronously, through the Blackboard Learning Management System, and students were asked to complete the survey in the first week of the course. The survey had a total of 17 respondents. The survey included questions on the familiarity of the students in Industry 4.0 technologies or asking for definitions of the major topics. The survey questions are shown below in Table 1.

Table 1. Survey questions for Industry 4.0 awareness.

Question Number	Question
1	What is your familiarity with smart manufacturing? (1 being not familiar at all and 5 being extremely familiar)
2	What is a digital twin?
3	How is "Big Data" used in industry?
4	What types of machine learning are familiar with?
5	What is a cyber physical system?
6	Have you ever used a 3d printer or additive manufacturing system?
7	Rate your familiarity with the following technologies/ concepts in order of most familiar to least
8	Describe the Internet of Things (IoT)

Of note, in the survey instructions, students were told that the assignment was being scored on completion, not on for correctness, but many students noted in some of their answers the sources they used to look up answers, and some students plagiarized their answers.

Results and Discussion

The first concern is how familiar do students feel with the course material and Industry 4.0 technologies. The results of the first question is shown below in Fig. 1, which shows most students with limited to no familiarity with Industry 4.0 technologies and the concepts of digital and smart manufacturing.

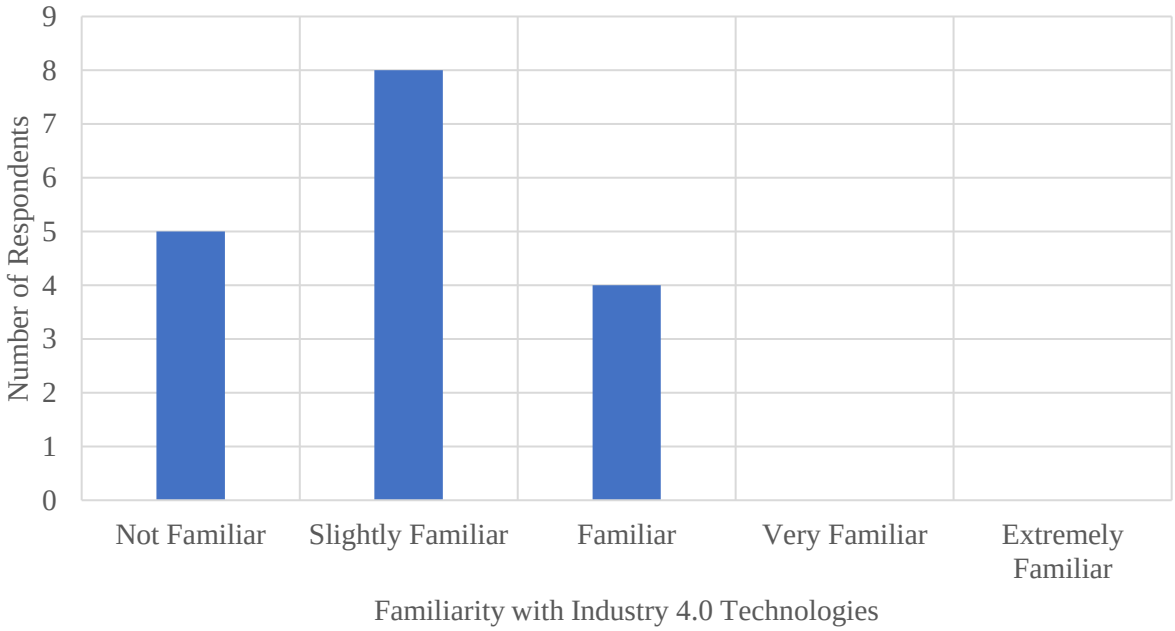

Fig. 1. Results from Question 1 (student familiarity of Industrtry 4.0 technologies).

The concern from this question is that students in a graduate program in a technology discipline are stating they are not familiar with these technologies, with limited exposure in their respective undergraduate programs.

While the students indicated they have little familiarity with Industry 4.0 technologies, it was necessary to gauge what the students' true level of understanding is. It has been showed that learners have difficulty assessing their own skill level by investigations by Caputo and Dunning, Pazicni and Bauer, Pavel et al., and Kribs [7–10]. For this reason, students were also asked as series of assessment questions to show basic understanding of Industry 4.0 concepts. The results of these assessments are shown below in Fig. 2.

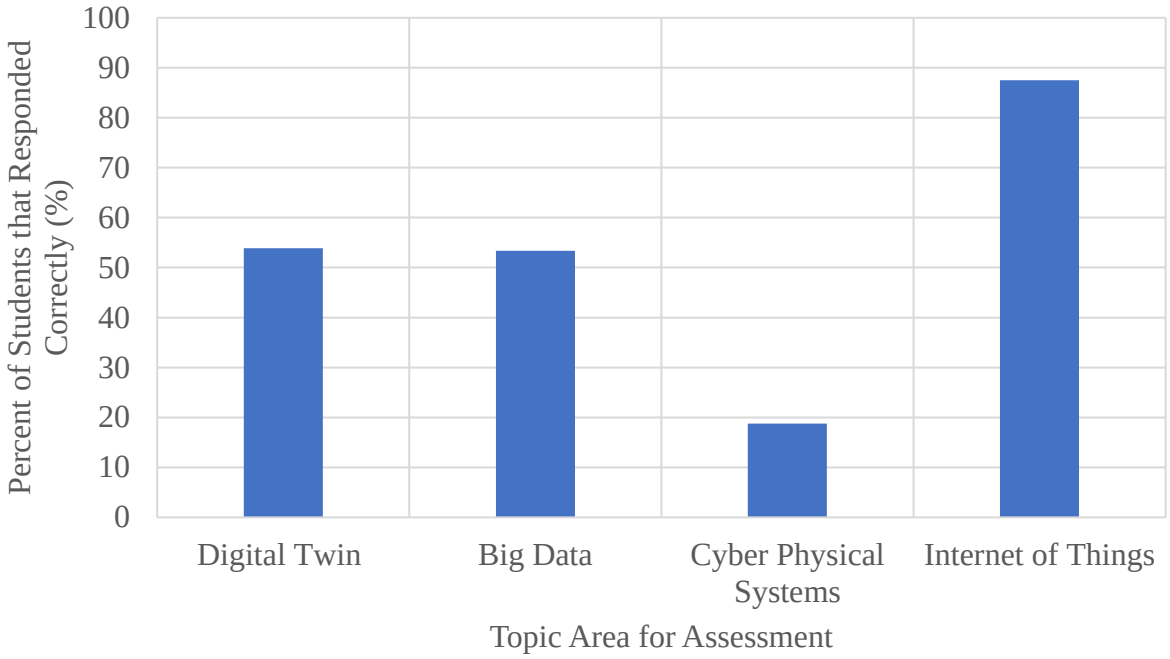

Fig. 2. Student scores on Industry 4.0 assessment questions (Questions 2, 3, 5, and 8).

As shown in Fig. 2, for the questions on topics in some IT fields (big data and the Internet of Things) students scored above 50%, as well as for the digital twin assessment question. For the assessment question on cyber-physical systems, students only correctly identified CPS 19% of the time, with most students gave responses that involved virtual reality devices, cloud computing, or that it was the same as the internet of things.

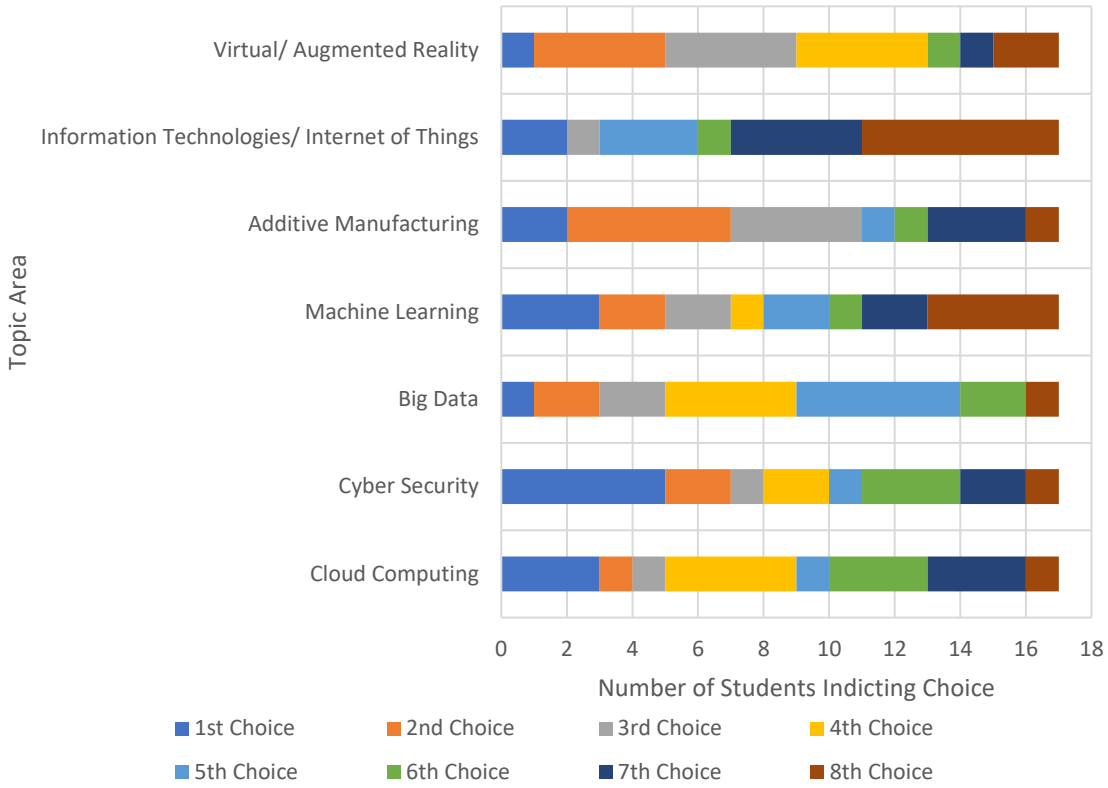

Fig. 3. Topics that students indicated the most familiarity with.

In question 7, the students ordered the technologies listed in Fig. 3, by order of familiarity with the topic area. From Fig. 3, it is apparent that students were more familiar with computer-based fields, specifically cybersecurity, cloud computing, and machine learning being the first choice for most students. Of note, many students indicated that their second most familiar choice was additive manufacturing, but the result of question 6 showed that only 5 students in the course had used a 3d printer or additive manufacturing system. Of note, the largest "8th choice" topics were information technologies and machine learning. Many of these students are in a certificate program in data analytics, which has a significant machine-learning coursework component. Also of note, many of these students are international students with undergraduate degrees from non-US undergraduate programs.

The concern from this data is that most students list familiarity with various Industry 4.0 technologies, without true experience with this technology and these students have already completed an undergraduate degree. Based upon this data, either students have very limited experience with most Industry 4.0 technologies, or students are overestimating their knowledge base with these technologies. Either of these results necessitates a change in undergraduate teaching of Industry 4.0 technologies, and future planning for Industry 4.0 technologies.

Conclusions

For a graduate course in Industry 4.0 technologies, students were asked a series of both perception and knowledge-based questions. Student responses showed that,

- Students reported some familiarity with Industry 4.0 technologies, though most mentioned having limited familiarity with Industry 4.0;
- Based upon knowledge based questions, students showed decent awareness of the internet of things, digital twins, and big data structures, but limited knowledge of cyber physical systems, and students also reported limited experience with additive manufacturing equipment;
- Students reported more familiarity with cybersecurity, machine learning, and cloud computing technologies compared to other Industry 4.0 technologies;

Based upon these results, it is necessary to review how much of these topics are being introduced in undergraduate programs.

Acknowledgments

The research reported in this paper has been supported by the National Science Foundation (NSF) Excellence in Research Grant (Award 2100850) and the author would like to acknowledge the support of Dr. Salil Desai and the Center for Excellence in Product Design and Advanced Manufacturing (CEPDAM) at North Carolina A&T State University.

References

[1] S. Das, D. K. Kleinke, and D. Pistrui, "Reimagining Engineering Education: Does Industry 4.0 Need Education 4.0?," *ASEE Annu. Conf. Expo. Conf. Proc.*, 2021, doi: 10.18260/1-2--35136.

[2] X. Yang, A. C. Floyd, L. A. Smith, and B. Morkos, "Analysis of Engineering Undergraduates' Confidence with Hands-on Tasks – Preparation for Collaborative Manufacturing Environments in the Era of Industry 4.0," 2023.

[3] R. C. Manimaran and M. K. Pallikonda, "Integration of Professional Publications in the Implementation of Industry 4 . 0 to Augment the Learning Experience in ETAC of ABET ET Programs," in *2023 ASEE Annual Conference & Exposition*, 2023, pp. 0–12.

[4] A. Sirinterlikci, "Developing the industry 4.0 workforce," *ASEE Annu. Conf. Expo. Conf. Proc.*, vol. 2020-June, 2020, doi: 10.18260/1-2--34437.

[5] J. M. Müller, "Assessing the barriers to Industry 4.0 implementation from a workers' perspective," *IFAC-PapersOnLine*, vol. 52, no. 13, pp. 2189–2194, 2019, doi: 10.1016/j.ifacol.2019.11.530.

[6] R. Rahimi *et al.*, "An industrial robotics application with cloud computing and high-speed networking," *Proc. - 2017 1st IEEE Int. Conf. Robot. Comput. IRC 2017*, no. i, pp. 44–51, 2017, doi: 10.1109/IRC.2017.39.

[7] D. Caputo and D. Dunning, "What you don't know: The role played by errors of omission in imperfect self-assessments," *J. Exp. Soc. Psychol.*, vol. 41, no. 5, pp. 488–505, 2005, doi: 10.1016/j.jesp.2004.09.006.

[8] S. Pazicni and C. F. Bauer, "Characterizing illusions of competence in introductory chemistry students," *Chem. Educ. Res. Pract.*, vol. 15, no. 1, pp. 24–34, 2014, doi: 10.1039/c3rp00106g.

[9] S. Pavel, M. Robertson, and B. Harrison, "The Dunning-Kruger Effect and SIUC University's Aviation Students," *J. Aviat. Technol. Eng.*, vol. 2, no. 1, pp. 125–129, 2012, doi: 10.5703/1288284314864.

[10] J. D. Kribs, "Observing Student Confidence Levels in Undergradate Engineering Labs: When Student Confidence Does Not Match Student Knowledge," *J. Eng. Technol.*, vol. 39, no. 2, pp. 40–51, 2022.

Biography

JAMES KRIBS is an assistant professor in the Applied Engineering Technology Department at North Carolina A&T State University, where he teaches courses in automotive engineering technology, manufacturing, and technology management. He received his PhD in Mechanical Engineering from North Carolina State University in 2013. He is a member of the American Society of Engineering Education, the American Society of Mechanical Engineers, and the Combustion Institute. His current research interests are in electrohydrodynamics, combustion, composite materials, and engineering education.