Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #47331

The Integration of Emerging Technologies into University Education

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The Integration of Emerging Technologies into University Education

Abstract:

Use of emerging technologies such as the Internet of Things (IoT), Machine-Learning (ML), and Artificial Intelligence (AI) is becoming more commonplace in industry. Academia provides some level of education and training in these new fields, however, it is not always understood if the curriculum taught in higher education aligns with the needs of manufacturing industries. Companies were found to be faster in the adoption of new technologies compared to academia. A survey of manufacturing and industrial professionals sought to determine what emerging technologies are in use by their respective companies, and what emerging technologies professionals thought should be addressed in higher education. It was found that cybersecurity, 3D printing, and the use of sensors were most readily in use in manufacturing. It was also discovered that professionals believed AI, MI, 3D-printing, and sensor applications are the most important topics to be covered by educators.

Introduction:

The Industry 4.0 moniker has been around since the early 2010's and has grown to represent the next evolution of human machine interfacing. It has been permeating into our everyday lives to where we can find practical examples of it in our everyday personal routines, our workplaces, and our leisure times. Many people are accustomed to autocorrect on our phones or in our word processing software. This software streamlines simple tasks for many. As more complex applications become available, the user interfaces and knowledge required to implement and operate these software also become more complex. These applications are becoming more common place and companies are more interested in employees that can operate these technologies.

University students in the STEM fields expect to gain technical knowledge and critical thinking skills that will make them more attractive to hiring managers upon graduation. Though there are typically discussions and feedback into the universities and colleges through industry partners, there continues to be a strong need for students to posess critical thinking skills and technical knowledge. Companies expect graduates to be up to date on the latest concepts and technologies that are currently used and will be used soon in their careers.

For graduates, being able to hone their critical thinking skills and technical knowledge should be a factor in the value of their education. For employers, there should be an expectation that the graduates that they are hiring posess these skills. The payback on hiring the graduate and the graduate's ability to quickly provide value to the company can be dictated by how well they can incorporate their knowledge to solve problems they encounter.

This paper focuses on the emerging technologies that are used in the manufacturing and industrial production fields. Specifically, the authors surveyed companies in Texas to determine what emerging technologies are currently relevant in industry in order to determine which of these technologies should be focused on for integration into the university's curriculum.The paper expects to show what company's in the state are expecting students to learn in their university education.

Background:

The background discusses the emerging technologies that the paper considers, what the literature says about student and industry perception of education, and discusses other similar work that has been previously performed.

Emerging Technology

Emerging technologies are everchanging but will have a constant presence in education. This is not only from the academic standpoint but also from the utilization and implementation perspectives in industry. In some contexts, emerging technologies "refer to resources, artifacts, tools, concepts and innovations associated with digital, that have a disruptive potential to transform or generate changes in the processes where they are used, regardless of whether these are new or old technologies" [1]. In short, these are the newer digital technologies that will help industry operate more efficiently and productively now and in the future. In the context of this paper, the following technologies are considered emerging technologies: machine learning, artificial intelligence, cybersecurity, augmented reality, internet of things, virtual reality, sensors, robotics, machine vision, RFID, virtual reality, and drones. These technologies and others are common to Industry 4.0 and the push for cyber-physical systems [2].

Perceptions of Students

One measure to help determine an engineering graduate's perception of their education is how prepared they felt after graduating. Previous research evaluated how students perceived their knowledge of some of the more prevalent emerging technologies, such as virtual reality, rapid prototyping, and Industry 4.0. A study in Italy by Motyl et al showed a very low, specific knowledge on many of the emerging technologies by first and second year engineering students. The students questioned in this study were aware of some of these technologies, but researchers attributed this awareness to the technologies' likely presence in video games [3]. In a separate survey by Sahu et al, 47.5% of Indian students surveyed showed very little knowledge of the Industry 4.0 technologies [4]. These studies help provide insight on students' awareness of the Industry 4.0 technologies. Though the studies do not necessarily discuss graduates' understanding of these technologies, they do point to the students' in process understanding of the technologies and an opportunity to introduce these technologies in their education.

A recent survey from the Cengage Group showed that many graduating students do not feel prepared for using AI technologies in their careers. This survey showed that a majority (70%) of students felt that basic generative AI should have been taught to them in class while the majority (55%) believe that their programs did not adequately prepare them to use these new technology tools in the work place [5]. Another 39% of students believe that AI will replace them or the jobs that they have been training for through their college education [5]. This flies in the face of many students. Ingleby reported that, "students view higher education as a means to equip them with the right skills for employment" [6], [7]. Students also expect their education to not only cover specific skills for employment but to also be trained to develop the skills necessary for life-long learning [7]. Though not specific to emerging technologies or Industry 4.0, there is evidence that engineering graduates do feel that they are prepared as they graduate and grow into their

industrial engineering positions. Deters, Paretti, and Ott found that as US-based graduates from Mechanical Engineering and Engineering Science programs surveyed spent more time in their professional positions in their first three months of employment, the level of preparedness they felt they gained in their education increased [8].

Perceptions of Industry

Industrial adoption and use of emerging technologies tend to be vastly different than the implementation of these same technologies into higher education curriculum. Industry in general, tends to adopt technologies quicker than academia [5]. This may be due to the competitive advantage the technologies provide or to the solutions that these technologies provide. There does seem to be that academia needs to partner with industry in order to become more agile with the technologies that they teach [5].

Additionally, Cheng et al. write that, "… employers hold a view that responsibility for graduate employability needs to be shared between students, HEIs (higher education institutions) and employers …" and "… for this to function effectively employers will need to increase collaboration with HEIs to make their needs known, to increase student internship opportunities and to provide employees with professional on-the-job learning" [7]. One of the conclusions from this study was the partnerships that must exist between industry, the colleges and universities, and the students to ensure a prepared and functional work force.

One of the major challenges encountered by most companies implementing Industry 4.0 is having a work force with the requisite skills in emerging technologies [4]. The expectation for many employees is to develop advanced skills in many of the technological domains including AI, IT, data analytics, and robotics. Additionally, employers are expecting the work force to possess skills and traits such as cognitive abilities, analytical thinking, decision-making abilities, organizational skills, social intelligence, system and technical expertise, logical reasoning, troubleshooting, etc., that can be associated with Industry 4.0 [19]. Accordingly, to develop essential skills, intelligence, and expertise, and to prepare the workforce for Industry 4.0, industry is looking to the higher education system and the universities to adapt their curriculum and training [2].

What Others are Doing

Though this paper focuses on bringing emerging technologies into the classroom that industry partners believe are relevant for their employees, there have been other works that have highlighted similar efforts. Not all efforts have focused on engineering programs but have evaluated higher education as an entity. Sosa, Salinas, and Crosetti developed a model for integration of emerging technologies in the classroom. This study was not specific to engineering but included disciplines from several areas. They state that the purpose of their model was to get others to incorporate emerging technologies using a systematic methodology [1]. Oke and Fernandes looked at how Industry 4.0 was being accepted and the consequences of Industry 4.0 in education. They utilized face to face interviews to determine that education is unprepared for Industry 4.0. They state that, "the use of technology has been predominantly limited to a didactic approach of teaching and learning, whereby teaching is facilitated with the use of a personal computer and the provision of electronic teaching materials" [9]. Mian, Salah, Ameen, Moiduddin, and Alhalefah evaluated how universities could determine what technologies their

faculty should be involved with in order to teach Industry 4.0 and for universities to be equipped for these technologies. The study determined the technologies and organized them using a SWOT analysis. They followed this up with a survey sent to experts in the field who have been active in publishing content regarding the use and application of Industry 4.0 technologies. Of interest, these authors noted many of the weaknesses of and threats to a university that affect their ability to support integration and implementation of the Industry 4.0 technologies into their curriculum [2].

Some researchers have looked more specifically how engineering programs and the STEM fields have incorporated emerging technologies. Kumar, Carberry, Beenfeldt, Andersson, Mansouri, and Gallucci utilized virtual reality to help with chemical and biochemical engineering education and training. In addition to the case study, the authors introduced the need for assessment methodologies to evaluate how virtual reality impacts the student's learning [10]. Miranda, Navarrete, Noguez, Molina-Espinosa, Ramírez-Montoya, Navarro-Tuch, … & Molina, evaluated Education 4.0 and developed models for implementing the technologies of Industry 4.0. They recognized that the modalities and information used for learning have changed and that there needs to be a method for developing and integrating new technologies [11].

From the research, it appears that most academic research only evaluates the emerging technologies as a method to teach materials to students or the incorporation of emerging technologies into an industrial setting, not as an incorporation into the curriculum so that students are better prepared for industry jobs. Work by Miranda, etc. supports this as they state, "that these initiatives and projects must align with the needs and requirements of educational institutions to respond to current social contexts, considering technological megatrends as drivers to achieve innovative solutions…" [11].

Methodology:

The research aims to identify the extent to which emerging technologies are utilized in the manufacturing and industrial industries. It also evaluates which of the emerging technologies that industry partners believe should be integrated into engineering curriculum. The study uses a quantitative approach, through online survey dissemination to collect data using Qualtrics. The study was funded by the President's Excellence in Research Scholars (PERS) FY 2024 and approved by the Institutional Review Board (IRB) #22012621. To achieve a comprehensive result, the descriptive survey combined both quantitative and qualitative methods. The survey was divided into two sections, the first on technologies used in the industry and can be adopted into higher education while the second on demographics. Features that define a questionnaire method are how participants are identified and data captured from the recipients [12]. Companies surveyed were limited to those in the state of Texas and included companies considered as manufacturing or industrial. Participants were identified from publicly available information sets and email listservs such as the Thomas Register, the Centralized Master Bidders List from the Texas Comptroller, school industry advisory board lists, and former students. The instrument used various question types for data capture that included; multiple-choice, Likert scale, ranking, and short essay-type questions. The survey instrument was validated for reliability through pilot testing. In turn, the pilot tested instrument was emailed to almost 100 practitioners returning only seven completed responses straight-line removal, and incomplete questions. Also, research using top-level management (CEO, CFO, Managers, Owner, etc.) always draws a smaller size of participants [13].

In the portion of the survey this study represents, respondents were provided with a list of technologies considered to be emerging technologies. This list includes: 3D Printing, Artificial Intelligence, Augmented Reality, Blockchain, Building Information Modeling, Cybersecurity, Digital Twins, Drones, Internet of Things, Machine Learning, Machine Vision, RFID, Robotics, Sensors, and Virtual Reality. Respondents were provided free response entries where they could identify other technologies that they are using that are not included in the survey.

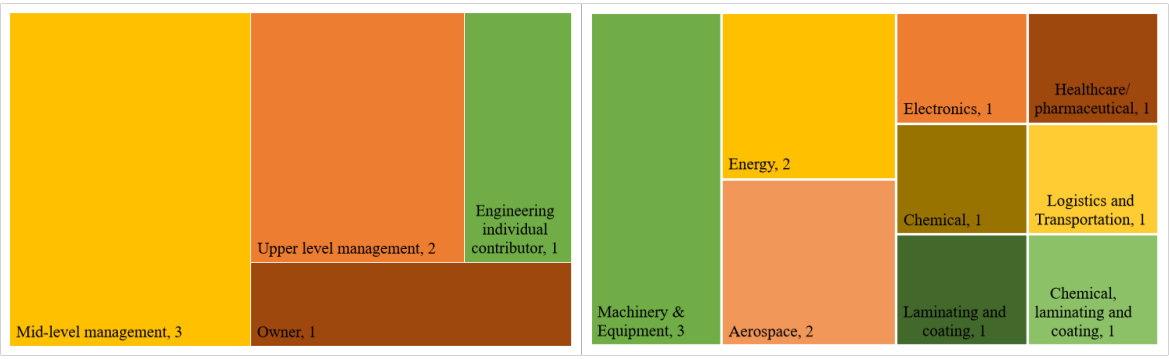
The study utilized MS Excel and Power BI to analyze the data obtained from the survey. An open-source word cloud generator was used to generate the figures in the paper.

Results/Discussion:

Though the survey had partial information on approximately 100 participants, only seven completed the whole survey. The results from the completed surveys are discussed.

Demographics

As depicted in Fig. 1.a., the seven participants who completed the survey have a distribution of one owner and engineering individual respectively, other role distributions are three (3) mid-level management, two (2) upper-level management, and one (1) owner. This implies that almost 90% of the participants are in a management position or higher roles that are considered as those who make major strategic decisions and oversee directions in the organization. The survey question that guided this response is "What is your current role within your organization". In Fig. 1.b., the survey question was "What is your company's specialty". As seen below the response represents that multiple specialties exist within a single organization, and the data result are Machinery & Equipment (3), Energy and Aerospace (2) respectively, and one (1) for the rest of the company specialty. These responses will help point to similarities in the quest for technologies used in the industry and advice should be integrated into university education.



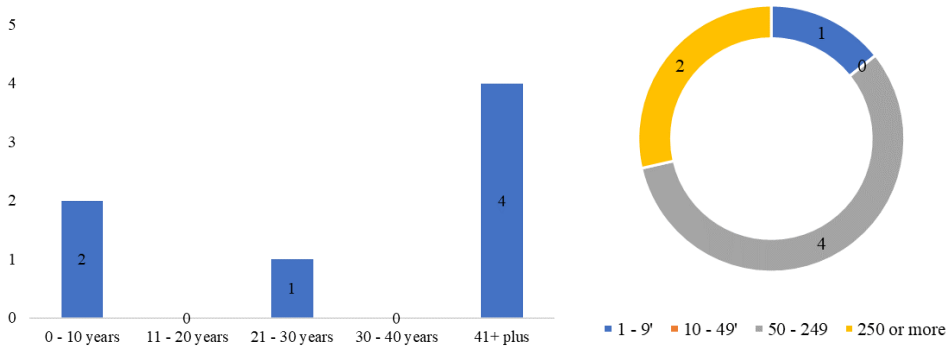
a. Roles b. Specialty

Fig. 1.

Industrial and manufacturing organizational roles and specialty

Participants distribution is shown in Fig. 2. For the survey question on organization years of experience, there were four (4) responses for 41+ years, two (2) for 0 – 10 years, one (1) for 21 – 30 years, and none or zero (0) for 11 – 20 years and 30 – 40 years. The organizational size shows that the employee size with 50 – 249 has the most responses (4), next was 10 – 49 with two (2)

responses followed by only one (1) response from an employee size organization with 1 – 9 employees. There was no response for 250 or more organization size. This indicates a wide range of organization years of experience and size as it relates to the need for emerging technology in industrial and manufacturing organizations likewise the need for integrating the same into university education.



a. Years of Experience b. Size

Fig. 2.

Organizational years of experience and size.

When asked, "What type of ownership classification is your organization?" More than half (57%) of the participants, representing four (4), responded to be a 'Limited Liability Company'. The remaining 43%, which is three (3) of the participants, responded to be a 'Corporation'. No responses from sole proprietorships, government, or employee-owned corporations see Fig. 3.

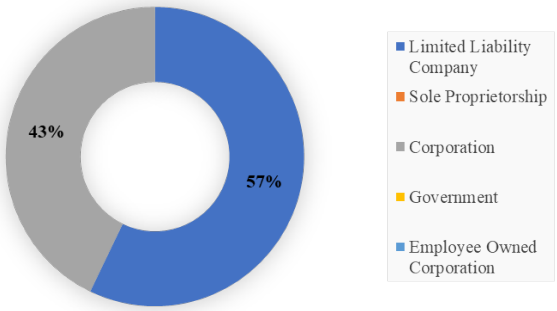


Fig. 3.

Organizational ownership classification.

Technologies Used in Industrial and Manufacturing Organizations

For the survey, responses were collected from seven participants representing various organizations, ensuring a diverse range of perspectives. The technologies identified by

respondents are illustrated in the word cloud in Fig. 4. Participants were asked to indicate which emerging technologies are adopted and used in their organizations.

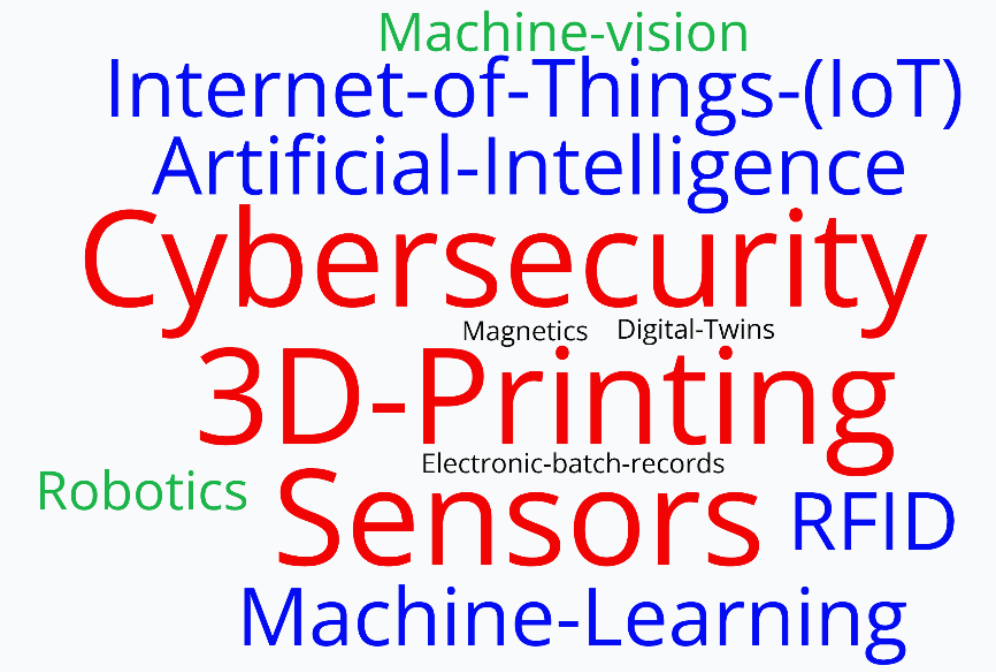


Fig. 4.

Word cloud of technologies used in the organizations.

In the first tier, which had the highest selection of technologies, sensors, cybersecurity, and 3D printing were the most prominent, each identified by five participants, indicating a 70% adoption rate. This highlights the critical role these technologies play in advancing Industry 4.0. According to [14] and [15], safeguarding industrial and manufacturing control systems is paramount as organizations transition to Industry 4.0. Implementing robust cyber-physical systems is essential to mitigate production line attacks, particularly in environments where humans and robots cohabit, thereby protecting production lines and preventing data breaches.

3D printing significantly enhances additive manufacturing by producing objects layer by layer, aligning with the smart factory concept of Industry 4.0 [16], [17]. This technology minimizes waste, reduces material usage, simplifies manufacturing processes, and decreases human involvement, contributing to energy efficiency and sustainability. Similarly, the integration of sensors plays a pivotal role in factory automation, making systems more intelligent and supporting the evolution of intelligent manufacturing within Industry 4.0.

The second tier technologies, adopted by three participants (approximately 43%), included Artificial Intelligence (AI), Internet of Things (IoT), Machine Learning (ML), and RFID. While the application of AI in manufacturing is still emerging, it holds immense potential for transforming modeling, analysis, and automation processes [18], [19]. AI applications generate vast amounts of data, necessitating efficient management tools like IoT, which helps manage

system complexity, enhance information transfer, and improve productivity, in line with Industry 4.0 objectives [20], [21]. However, challenges such as resistance to change, talent shortages, and difficulties in investment justification hinder seamless IoT adoption.

Machine learning, a subset of AI, offers predictive insights, enabling predictive maintenance, quality improvement, process optimization, task scheduling, and supply chain management [22], [23], [24]. RFID technology enhances material and product tracking throughout production and logistics, serving as a crucial IoT enabler that optimizes operational capacity [20].

The third tier technologies, identified by two participants (30%), were machine vision and robotics. Industrial robots are increasingly used in modern manufacturing to perform complex tasks efficiently. Machine vision tools enhance robot performance by enabling online programming tests and simulations, reducing downtime [25], [26].

The fourth and final tier included Digital Twins, Magnetics, and Electronic Batch Records, each identified by one participant (10%). Digital twins provide life cycle simulations, enabling the detection of physical issues and accurate outcome predictions, which are vital for continuous Industry 4.0 implementation [27], [28]. Magnetics technology improves efficiency in applications such as sensors and motors [29], [30], while electronic batch records streamline documentation to ensure compliance with industry standards [31].

In summary, the adoption and integration of these emerging technologies are essential for achieving greater automation, improved efficiency, and enhanced flexibility. Leveraging these technologies will drive innovation and competitiveness, enabling industrial and manufacturing organizations to thrive in the era of Industry 4.0.

Technologies Integration into University Education

The integration of emerging technologies into industrial and manufacturing university education is visually depicted through the word cloud illustrated in Fig. 5. The responses are categorized into five tiers, reflecting the technologies participants consider most important for inclusion in educational curricula. This classification extends one tier beyond the organizational breakout classification, indicating a broader scope of technological prioritization in education.

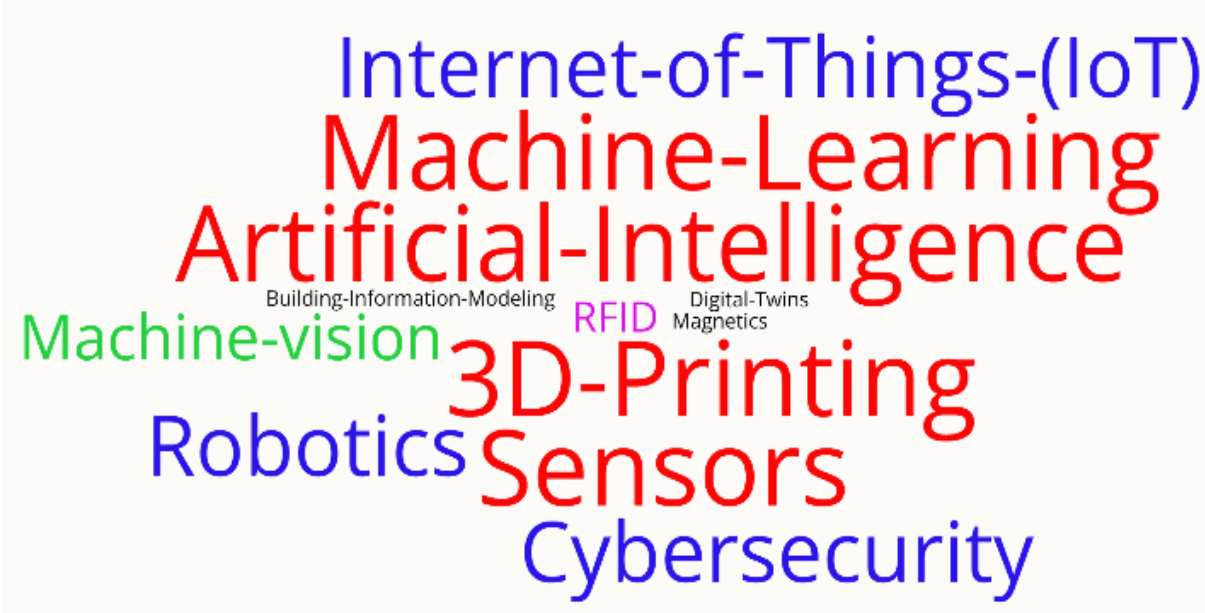


Fig. 5.

Word cloud of technologies integration into university education.

Participants were asked to indicate which technologies they deemed most crucial for integration into the education curriculum. The first tier, comprising 3D printing, Artificial Intelligence (AI), Sensors, and Machine Learning (ML), was identified as the most important, with each technology receiving five endorsements, representing 70% of the participants. Notably, while 3D printing and Sensors are already widely adopted in industry, AI and ML emerge as critical additions for educational integration. This underscores the industry's recognition of a skills gap, particularly in AI and ML, which must be addressed to ensure students are adequately prepared for future industrial roles.

According to [32], integrating 3D printing into industrial and manufacturing education would significantly enhance teaching and learning, particularly in improving CAD drawing skills, fostering lifelong learning, and increasing students' awareness of workplace environments. Similarly, [33] highlights that AI's continuous innovation aligns with the demand for diverse, multi-level intelligent manufacturing processes. The incorporation of sensors and ML, subsets of AI, into education curricula will facilitate the global advancement of industrial and manufacturing sectors by equipping students with essential skills for success.

The second tier technologies, identified by 57% of participants with four counts each, include Cybersecurity, Internet of Things (IoT), and Robotics. Cybersecurity's integration into the curriculum is vital for equipping the future workforce with skills to understand and mitigate the risks of cyberattacks on industrial control systems, thereby enhancing organizational processes [34]. The role of IoT and Robotics in the digital age is transformative, enhancing curriculum design, educator knowledge transfer, and research activities, which, according to [35], are crucial for transitioning from Industry 4.0 to Industry 5.0. The inclusion of IoT in the second tier also reflects its established adoption in industry, highlighting its foundational role in smart manufacturing.

In the third tier, Machine Vision was the sole technology highlighted by three participants (43%), emphasizing its importance in improving production accuracy and precision. This positions Machine Vision as an essential component of industrial automation education, preparing students to meet the precision demands of Industry 4.0.

RFID was categorized in the fourth tier, with two counts (28%), indicating moderate importance. Despite its established role in tracking and logistics within industry, its educational integration appears less prioritized. However, RFID's capabilities in enhancing material tracking and process optimization make it a critical IoT enabler that should not be overlooked in curricula development.

The fifth tier, with one count each (10%), included Magnetics, Building Information Modeling (BIM), and Digital Twins. Surprisingly, BIM, a significant enabler of Industry 4.0, is listed among the least important technologies despite its capacity to enhance work processes, increase efficiency, and improve productivity [36], [37]. BIM's integration into education can foster student engagement and employability, making it an essential component of a comprehensive Industry 4.0 education strategy. Digital Twins, which model complex processes and facilitate lifecycle simulations, offer valuable insights for students in predictive maintenance and operational efficiency, essential for modern industrial settings.

While electronic batch records were not considered essential for educational integration, their role in streamlining documentation and ensuring compliance with industry standards highlights their potential utility in specialized training.

Machine Learning's role in fostering interdisciplinary learning by merging computer science, statistics, and engineering is well-documented [38], [39]. Its inclusion in education curricula will prepare students for the multifaceted challenges of Industry 4.0, promoting innovation and enhancing competitiveness in the global manufacturing landscape. The overarching need for these emerging technologies in education curricula can not be overemphasized as the benefits surpass the challenges in the long run.

Conclusion:

This paper provided insight into which emerging technologies are increasingly used in industry and should be focused on in university curricula. Through the use of a survey instrument and literature review, the critical need for higher education institutions to adapt their curricula to better align with the demands of Industry was underscored, given educational institutions are typically slow to react to the adoption of new technologies. Sensors, cybersecurity, and 3D printing were found to be adopted and used by 70 percent of the organizations surveyed while AI, IoT, ML, and RFID, are used by 43 percent of respondents. The findings highlight the importance of integrating these technologies into university training programs to ensure that students are well-prepared for the evolving landscape of modern industry. The study has limitations that future study will need to expand. The sample size is small because it focused only on top and senior managers, therefore it limits generalizability and may not represent a broader industry. The next step is to introduce the survey during the industrial advisory board meeting for the department to obtain participants' thoughts on emerging technologies.

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