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Integration of Professional Publications in the Implementation of Industry 4.0 to Augment the Learning Experience in ETAC of ABET ET Programs

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Abstract:

In spring 2022, members of the Engineering Technology (ET) Industrial Advisory Board (IAB) discussed the importance of Industry 4.0 awareness in the region, and the department has been enduring its work in incorporating the various facets of this evolving technology in the ET curriculum. Integration of emerging technologies, such as Industry 4.0, technological skills to meet the demand of the regional workforce can be accomplished by few methods. One such method is integration of professional publications in the coursework. This paper will elucidate the results of successful implementation of Industry 4.0 concepts in ET curriculum through a pilot summer course, Control Systems. Additionally, the authors aim to present the opportunities for expansion to include other professional journals for continued implementation in the various concentrations of ET.

This paper aims to discuss and present the key findings in the following areas: (1) Explicate integration of student knowledge gained from reading publications from professional journals such as the International Society of Automation (ISA) - InTech Journal, in implementing Industry 4.0 in the ET curriculum. (2) Present the results along with a reflective analysis of the implementation in the pilot Summer III 2022, Control Systems course. (3) Present the process for integration of additional professional journals such as IEEE, Journal of Engineering Technology (ASEE), and Journal of Manufacturing Processes (SME), in the concentration-specific courses in the ET Program. (4) Deliberate the importance of integration of professional journals as a teaching strategy to augment the classroom learning experience in the department's ETAC (Engineering Technology Accreditation Commission) of ABET accredited ET programs in Austin Peay State University (APSU).

The full paper will elucidate the above areas (1- 4) in the efficacious integration of professional journals in the ET curriculum, description of assessment methods (class presentation and written report) used to evaluate the pilot project, statement of results, and a conclusion.

Introduction:

Over the years, we have seen a series of industrial revolutions which enabled the adoption of modern technologies in industries thereby increasing the productivity and utilization of resources. In the late 18th century in Britain, the first industrial revolution enabled mass production of finished goods by using water and steam power [1]. In the 19th century, the second industrial revolution launched assembly lines and use of oil, gas and electric power for production [2]. This improved the mass production and added some degree of automation to the manufacturing process. In the middle of the 20th century, the third industrial revolution supplemented computation, Programmable Logic Controllers (PLC) and telecommunications to the manufacturing process. PLCs were embedded into machines to support process automation in addition to collection and sharing of data [3]. We are now entering into the fourth industrial revolution, commonly known as Industry 4.0.

The term Industry 4.0 (I4.0) was first coined by the German government in 2011 as a part of their High-Tech Strategy for Germany [4][5]. Germany being one of the forefront countries during the second and third industrial revolutions, launched the fourth cycle to be competitive in the rapidly evolving industrial world. As a part of the I4.0 initiative, it supported the integration of Cyber Physical Systems (CPS) and Internet of Things and Services (IoTS) to further improve resource management, quality control, efficiency and productivity [6]. The CPS in the manufacturing environment includes intelligent equipment, storage systems, and production facilities capable of independently sharing information, networking, and controlling one another [7]. The goal behind launching this new strategy is to combat the challenges due to shortage of skilled work force, demographic changes, promoting work-life balance and global competition in the manufacturing sector [8]. Nevertheless, looking into the areas where I4.0 is focused, one cannot miss noticing that these challenges are addressed to attract and retain the next generation of work force, both Millennials and Generation Z.

We are now living in an era where automation, which is one of the facets of I4.0, is part of everyday life. From household appliances to smart phones that made a revolution world-wide in a short span of time, to transportation that we all use to commute on a daily basis, finished products that use automation have become an inevitability for human life. In the last century, automation drove the economy of the developed nations. However, the knowledge that comes with it stayed within the borders of these nations. In contrast to the past, the present day with the advent and widespread availability of the internet, the closed borders for knowledge have been open to everyone [9]. This enabled global prosperity and harmony [10]. Additionally, the COVID-19 pandemic showed how much every nation on planet earth is reliant on each other. This was evident when one nation was locked down to control the spread of coronavirus, there was chaos in the entire global economy [11]. This shows how much we are interdependent and reliant in the present-day globalized world. Technology and devices which once used to be a luxury are now being used widely by everyone to complete everyday tasks from ordering raw materials to launching new product into the market [12].

According to Pew research [13], the new generations, Millennials and Generation Z are racially and ethnically more diverse than the preceding generations. The rapid globalization also demanded the need for diversity and inclusion. Besides these factors, the new generations are expected to be more educated than their predecessors. Convergence of all these factors, one can argue the new generation of the workforce will be much more able to accept and integrate newer technologies into their work and everyday life. This not only reduces the workload but also improves the work-life balance, although further research is needed in this area. Looking at both I4.0 goals and adaptability skills of next generation workforce, we can deduce that integrating I4.0 skillset into the engineering and engineering technology curriculum is quintessential.

This paper will discuss and present the key findings in the areas (1-4) as deliberated in the abstract. It will elucidate the efficacious integration of professional journals in the ET curriculum, description of assessment methods (class presentation and written report) used to evaluate the I4.0 pilot project, statement of results, and a conclusion.

Engineering Technology Program:

The Department of Engineering Technology (ET) at APSU offers ETAC of ABET accredited degree programs at the four-year bachelor's degree level. Students can choose to major in one of the three concentrations – Electrical, Mechanical and Manufacturing. The coursework includes several lower, upper division, concentration specific courses and electives. In spring 2022, members of the ET Industrial Advisory Board (IAB) discussed the importance of I4.0 awareness in the region that includes Industrial Automation. In an effort to incorporate concepts related to Industrial Automation in the ET curriculum, the department unanimously voted to include Control Systems as an elective course in all three concentrations. The content covered in control systems provides a basis for the skill set as an Engineering Technologist in today's industry that incorporates advanced automation.

In Summer III 2022, ENGT 4210, Control Systems was offered as an elective course with a student enrollment of 14. Twelve students were from electrical concentration and two from Manufacturing. The course description, student outcomes, and grading criteria is below:

Course Description:

ENGT 4210 Control Systems (3.0 Cr.) Elective Course:

Introduction to Industrial Control Systems, Interfacing Devices, Process Control, and Instrumentation - Proportional (P), Integral (I), Derivative (D), PI and PID controls; tuning of closed-loop systems; Industrial Detection Sensors and Interfacing; Motion Control.

Student outcomes:

a) Students apply mathematics to solve equations in control electronics and mechanical systems.
b) Students will analyze process control systems, detection sensors, and motion control systems.
c) Students are introduced to Functional Industrial Systems currently used in the industry.
d) Students have the ability to communicate information in written, oral, and graphical forms as well as use technical literature.

Grading Criteria:

The numerical and letter grade for the course will be determined using the following method:

Tests, Quizzes, Oral Presentation, Homework, participation and attendance will be factored in determining the final grade according to the following percentage:

Tests (Test #1, Test # 2)	50%
Homework (15%); Attendance (2%)	17%
Quiz (Quiz #1, 2)	20%
Oral Presentation + Written Report	13%
Total	100%

The Oral Presentation (10%) and Written Report (3%) covers the student learning experience from Professional publications related to I4.0. The following section will discuss the (1) Integration of student knowledge gained from reading articles from the professional publication – InTech [14] from International Society of Automation (ISA) on a wide range of topics related to I4.0. (2) Present the results along with a reflective analysis of the faculty (instructor of record) as well as comments from the student course evaluation report.

Student learning from reading Professional Publications – Pilot Project Setup:

The course instructor, who is also the paper's main author researched InTech (ISA) magazine and prudently selected journal articles / publications covering a wide range of topics related to I4.0 and Industrial Automation Systems. They are IIOT, ISA 95, Digital Twin, Soft PLC, IIOT API, Digital Transformation, Smart Instruments, Cyber-Physical Protection Systems, Open PLC's, Automation Development, Digital Sustainability, Automating Automation and Augmented Reality. As a part of the pilot project, students were assigned the articles / publications (Table 1) and asked to comprehend, review, and summarize the contents of the publication from an I4.0 and Industrial Automation Systems viewpoint. There were two deliverables: (i) Submit a 2-page written report that summarizes the article / publication along with the key takeaways, and (ii) Deliver a Power Point presentation to the entire class and discuss the major takeaways. The key concepts and takeaways that affirm student learning related to I4.0 are presented in Table 1.

Table 1: I4.0 Publications from InTech – ISA (International Society of Automation)

1.) Student 1 – Augmented Reality
https://www.isa.org/intech-home/2021/october-2021/columns/augmented-reality-becomes-authentic-reality
Augmented reality is the process of taking live video from the world around a user and converting it to a digital reality that can be easily modified to suit the user's needs. By the year 2025, 14 million employees are estimated to each have an Augmented reality headset increasing their productivity as well as displaying the necessary instructions and information in the same field of view as the machinery in question. Augmented reality is now appearing in many apps and games worldwide and has become steadily common over the past decade.
2.) Student 2 – Industry 4.0: A New Activity Model
https://www.isa.org/intech-home/2021/october-2021/features/beyond-the-pyramid-using-isa95-for-industry-4-0-an
In "Beyond the Pyramid: Using ISA95 for Industry 4.0 and Smart Manufacturing," the authors foresee the use of more intelligent products and smart production processes in combination with vertically and horizontally integrated manufacturing systems. The ISA95 functional model divides the activities in a manufacturing system into five levels that are strictly time dependent. The general ISA95 guidelines are simply a standard, where the tasks should be organized by the general time-related aspect and not by what is needed to complete the activities themselves. More companies and organizations are moving towards a new model that will be strengthened using the awareness of ISA95, certainly changing the way industry can and will operate.

3.) Student 3 – Open PLCs Enhance Automation

Open PLCs Enhance Building Automation (isa.org)

Use of open PLC enabled the user to make their own temperature-controlled system equipped with a weather reset functionality that lets the system adjust the interior temperature of the building based on the exterior temperature. The control results were better than what we had experienced with other common but dedicated off-the-shelf microcontrollers. The building staff can use remote access using google desktop, but if they were to add remote access directly to the platform it would've been easy to install as well.

Student's personal reflection: "What I have gathered while reading this article is that modern technology is the key to making everyone's job much easier. With the use of modern technology, the industry would save millions or even billions of dollars. This technology is also more flexible to where it won't be hard to connect to different systems, such as field devices."

4.) Student 4 – Smart Instruments

Smart Instrumentation for the Digital Present (isa.org)

The journal article "Smart instruments for the digital present" includes five case studies of industries that implemented smart instruments and have experienced improved results. It is evident that smart instruments are changing the industry for the better and are continuing to evolve on how industry process works. There is no doubt that digital data is going to become more prominent than analog as development continues to provide better performance in the industry in the years to come.

5.) Student 5 – Automation Development: Change the Industry, Not Just Your Company

Automation Development: Change the Industry, Not Just Your Company (isa.org)

In this article, there are a few approaches that are presented for the development of new automation technology specific to the oil and gas industry with a real-world example from ExxonMobil. There are many ways to develop new technologies and no one way is right for every situation. One thing to keep in mind is: can it benefit more than just my industry, and can I be the one to drive change and create a new standard that benefits multiple people?

6.) Student 6 – Cyber-Physical Protection Systems

Experience Centers Teach Cybersecurity Best Practices (isa.org)

Discussion on the importance of Cyber-Physical Protection Systems. "A 2018 study by Radware determined that the average cost of a cyber-attack can be $1.1 million." By having the PLC coding programmed to work with the detection systems on a network, it can

immediately isolate and separate individual parts of the system, or cells in the plant to protect them from the incursion.
7.) Student 7 – Automating Automation
[Improving Project Documentation and Change Management (isa.org)]
The article lists a few attributes required for a solution to automating the creation of automated processes. The solution should be scalable, consolidate data to lessen discrepancies, and be user-friendly. Finally, applicable company, sector, and country standards should be embedded to help users easily produce compliant documentation. **The student reflects:** With the author's thoughts in mind, a possible solution for this issue would be to implement a sort of cloud program suite akin to Adobe or Microsoft. It would be made up of the programs necessary to carry out the creation of these documents. The documents are to be uploaded to a storage cloud, which would allow it to be easily accessible to other members of the project team. This would also reduce the strain on desktop computers as they will not be fully responsible for storing the files and data. The applicable industry standards can be uploaded to the suite. The authors mention that instrumentation engineers are used to performing tasks utilizing manual methods, so the most difficult aspect of this would be giving them time to learn how to use this technology. It would come down to making the program user-friendly, as well as companies giving them time to play around with it.
8.) Student 8 – Digitalization Drives Sustainability
[Digitalization Drives Sustainability (isa.org)]
With the help of advanced analytical applications, companies gain the most essential component that brings their companies into the real time digital world. These applications help companies become experts in tracking performance, organization, and sustainability. It helps companies assess their weakest areas and helps to optimize environmental performance. In conclusion, when implemented correctly, the use of Advance analysis reports can help cut down on emissions used, optimize efficiency and help companies obtain a cleaner carbon footprint in general.
9.) Student 9 – Machine Health Moves Toward an Integrated Future
[Machinery Health Moves Toward an Integrated Future (isa.org)]
The article discusses the importance of "Integrating data from a variety of devices using a shared technology architecture". Industry plants are adopting machinery health software packages that can collect data from devices and carry out a lot of important roles in order to increase the speed of ROI. These software packages are made so that users can identify root causes and isolate problems before they become too bad or problematic; and to save users from sifting through enormous amounts of data, information is presented in a single location.
10.) Student 10 – OPC UA on IIoT Implementations

[OPC UA Makes IIoT Implementations Possible (isa.org)]
With high demand in production globally, industries need to have a capability of fast production and delivery. To accomplish that, industries need a platform that will help communication not only machine to machine but also one factory to another. OPC UA is short for “Open Platform Communications United Architecture” in other words is a data exchange standard for industrial communication which allows machine to machine or PC to machine to communicate. OPC UA provides that standard for the way servers represent data to clients using an object-oriented model. OPC UA specifies how information in industrial systems is exchanged. IIoT and Industry 4.0 are a few of the key requirements for industrial organizations to compete globally and to establish secure, scalable products and processes faster.
11.) Student 11 – Top Industrial Companies Find Pathways to Transform.
[Top Industrial Companies Find Pathways to Transform (isa.org)]
Discussed a journal article titled, Top Industrial Companies Find Pathways to Transform, discussed case studies of twenty-five companies that excelled at industrial digital transformation. The top five companies in order are: Tesla, Intel, BMW, Johnson & Johnson, and 3M. The top companies stand out for showing substantial progress in transforming their cultures, adopting technologies, and embracing digital transformation to enable business outcomes. The scoring comprises three main components: financial indicators, transformation indicators, and collective intelligence. Most of the successful companies have stated their revenue growth and profitability would suffer in the future if they did not digitally transform quickly enough.”
12.) Student 12 – Soft PLCs
[What You May Not Know About SoftPLCs (isa.org)]
What can be inferred from the research that was done is that Soft PLCs may be the future. They offer more modularity and capability than their predecessors (Hard PLCs). However, they are still not in a place where they can be relied upon more than Hard PLCs due to security issues. When you network your entire system to one operating system, then the damage that can be done is a lot more significant than if you just had a Hard PLC. With malware such as Ransomware wreaking havoc on the current manufacturing companies, they fear making fundamental changes to their network that could potentially make them more vulnerable. However, Soft PLCs could create new opportunities for companies. It will be interesting to see how, or if, the industry uses Soft PLCs in the future.
13.) Student 13 – Digital Twins: Enabling the Autonomous Paper Mill
[Digital Twins Enable the Autonomous Paper Mill (isa.org)]

Since 2018, Palantir Technologies has made extensive hours of research and followed growth of the digital twin technology. "They build software that empowers organizations to effectively integrate their data, decisions, and operations." (3) **Student reflects:** With the digital twin and the process model, coupled with the DCS and the control model, the behavior of the autonomous mill can be analyzed over a range of production rates, operational settings, and constraints. Key process design assumptions and decisions could be made clear, and the autonomous mill can be optimized.
14.) Student 14 – Understanding IIoT Application Programming Interfaces (API)
Understanding IIoT Application Programming Interfaces (isa.org) As technology moves into the "fourth industrial revolution" it will be vital for manufacturing systems to have the latest applications and software to keep up production with increasing demand of today's society. API is one of the key factors that will make that possible by adding an extra communicative layer into the industry. With it, companies are able to combine old applications with new updated applications which will in turn increase development and efficiency and decrease downtime. Also, for any future updates to the system, API will allow these to be upgradeable without having to rewrite code for the whole system.

Assessment and Evaluation of the Pilot Project:

The pilot project used both direct and indirect assessment methods to evaluate the effectiveness of the implementation. The direct measure was based on student scores from oral presentation and written report. The indirect measure was achieved by a combination of student responses from a course evaluation survey and faculty refection of the student learning related to I4.0. They are presented below.

Direct Measure:

As evident from the Table 2, the overall results of the direct measure are very good and encouraging. Column 2 is the cumulative score (oral presentation & written report) and column 3 is the final letter grade for the Control Systems course. The scores in Column 2 is worth 13 % of the final grade. Except students 1 and 7, the rest of the class cohort scored 80 % and above in the pilot project. In other words, 86% of the class scored 80 % and above. Due to an extenuating circumstance, student 7 chose not to do the class presentation but only submitted the power point presentation and the written report. Student 1 scored 75 % because certain parts were incomplete in the oral presentation and written report.

Table 2: Total Scores on Oral Presentation & Written Report

ENGT 4210 – Oral Presentation & Written Report – I4.0			
Name	**Oral Presentation & Report (%)**	**Course Letter Grade**	**Course Grade Summary**
Student 1	75	B	A = 3 B = 10 C = 1
Student 2	88	B	
Student 3	89	B	
Student 4	90	B	
Student 5	94	B	
Student 6	90	B	
Student 7	54	C	
Student 8	92	A	
Student 9	94	B	
Student 10	93	A	
Student 11	94	B	
Student 12	91	B	
Student 13	80	B	
Student 14	95	A	

Indirect Measure:

(a) The course evaluation student survey had positive feedback with students being appreciative of the real-world exposure to current trends in the industry provided as part of the course material.

In response to a question, "What did you like best about this course**"**, the student responses were:

- Student #1 response: “The information is current and had real life situation. I learned things that are really needed in work situation.”

- Student #2 response: “I enjoyed the applications aspect of the course because it showed me where I can actually use this information. It also gave me a broad understanding of many instruments and techniques used in industry today, which only expands my knowledge that I can use in future employment.”

(b) Faculty reflection of Student Learning related to I4.0:

The main author, who was also the course instructor, reports that the students were very enthusiastic during the class presentation which was evident in the interaction of their peers' asking questions on the wide range of I4.0 topics covered. For example, during the presentation student 13 indicated that his company has been working on “Digital Twins” since 2018. Students 5 and 6 stated that they have been working in the Automation Industry for the past few years and have seen digital transformation happening. Student 11 talked about how top industrial companies from Tesla to BMW are embracing digital transformation to enable business outcomes. In addition to presenting the key concepts and takeaways, the students were encouraged to reflect and provide a solution to the industry problem discussed in the InTech journal article, as applicable. Student 7 (Automating Automation) reflected and presented a solution for “automating the creation of automated processes”. In summary, the course instructor reflects that in doing this pilot project with his undergraduates, he learned a few new concepts of I4.0 and also shared with the department colleagues in ET.

Conclusion:

One of the goals of the ET program at APSU is to offer the graduates valuable, marketable skills that give them a head start on career opportunities in emerging technologies, such as the I4.0. In summer III 2022, the pilot project was implemented successfully in the elective course that is part of the three ETAC of ABET programs BS Electrical ET, Manufacturing ET, and Mechanical ET. The pilot project covers areas 1 and 2 of this paper. The course ENGT 3280, Communication Systems I, offered in spring I 2023 is one of the required concentration courses in the BS Electrical ET program. The course instructor has implemented a rubric that involves class presentation on the key takeaways from a peer reviewed publication / conference paper, or an article on Electronic Telecommunications. There are plans to incorporate analogous strategies by including articles / publications from the Journal of Manufacturing Processes (SME) in ENGT 3850, Manufacturing processes II, when it is offered in Fall II 2023. ENGT 3850 is a required course in the Manufacturing ET program. Finally, articles / publications from the American Society of Mechanical Engineers (ASME) or the Journal of Engineering Technology (ASEE) will be incorporated in ENGT 4800, Machine Design which is a concentration-specific course in the Mechanical ET Program. This covers area 3, the process of integration of publications / articles from other professional societies. All ETAC of ABET programs are associated with a lead professional society that provides input with regards to skill set and career preparation in the development of the respective program outcomes. The pilot project implementation demonstrates student engagement with the journals published by one of the professional societies and affirms the importance of knowledge acquired from reviewing the publications. The authors believe that integration of publications from the professional societies affiliated with ABET, as a teaching strategy will also bolster the attainment of program outcomes in the department's ETAC of ABET accredited ET programs. This covers area 4 of the paper.

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