Integrating Smart Manufacturing into Engineering Technology Courses

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Abstract

In xxxxxx university, the engineering technology programs aim to seamlessly integrate theoretical understanding with practical applications using smart manufacturing technologies. The xxxxxx Smart Learning Factory, featuring specialized laboratories dedicated to smart manufacturing, will create an environment conducive to learning, academic research, and industry partnerships. All programs within the School of Engineering Technology (SoET) will eventually engage with this facility. Currently, the smart manufacturing laboratory is in the planning stages, and there is a lack of relevant examples to guide faculty in incorporating these technologies into their courses, resulting in slow adoption. This project seeks to develop interdisciplinary examples to effectively incorporate smart manufacturing into existing courses and maximize the utilization of the Smart Labs across SoET.

To support this initiative, two faculty members have conducted several seminars in two consecutive semesters to help the faculties. Participants will receive innovative teaching materials aligned with various instructional modalities. They will also be guided in adapting lab modules to include smart manufacturing equipment. Additionally, participants will be supported in designing course projects that make use of the smart manufacturing facility. Ultimately, the series of seminar focuses on incorporating smart manufacturing technologies and applications into undergraduate education. Finally, this paper will present feedback and assess the effectiveness of the seminars from the participants' perspective.

Introduction

The rapid development of Artificial Intelligence (AI) continues to challenge and transform the traditional manufacturing industry [1]. However, current engineering technology curricula often struggle to keep pace with the needs of modern AI technologies [2, 3]. In order to bridge this gap and prepare students for the future of industrial innovation, the School of Engineering Technology (SoET) at xxxxxx University seeks to enhance the courses across all programs by integrating smart manufacturing concepts.

To achieve this goal, one of the most effective methods will to engage with the university's smart labs [4]. The xxxxxx Smart Facility includes the Smart Factory, Smart Foundry, Industrial IoT Lab, and Continuous Process Labs. These labs are designed to serve as incubators for innovation, allowing students to participate in hands-on, active problem-solving while exploring the full range of smart manufacturing technologies. The smart manufacturing laboratory is currently in its planning stage, creating two new challenges: the lack of relevant examples to guide faculty in incorporating these technologies into their courses effectively; the low utilization of the smart labs and the growing demand from students.

To support the SoET instructors in embedding smart manufacturing components into their courses and effectively engaging with the Smart Facility, two faculty members from SoET have conducted three seminars in two consecutive semesters. These seminars were designed to assist instructors prepare and refine their ideas for successful integration. This paper will present the design of the seminars, the implementation process, discussion questions, the feedback received, and the results of the surveys conducted before and after the seminars.

Designation

The activities designed to help instructors embed smart manufacturing components into their courses were two to three key sessions held over two semesters. A month before the first seminar, a survey was distributed to faculty members to gather insights on integrating smart manufacturing into SoET courses. To encourage more responses, the survey was sent again two weeks later.

In the first two seminars, participants received innovative lecture materials aligned with multiple modalities teaching approaches. They also received laboratory modules incorporating relevant smart manufacturing equipment. Additionally, the seminars emphasized designing course projects that utilize the smart manufacturing facility, focusing on integrating smart manufacturing technologies and applications into undergraduate education.

During the first seminar, one mechanical engineering technology (MET) course was used as an example. The session included a 20-minute presentation followed by a 40-minute discussion focused on innovating MET courses. In the second seminar, an electrical engineering technology (EET) was used to demonstrate and discuss the strategies for integrating smart manufacturing concepts into EET courses.

The two faculties co-leading this program, from mechanical engineering technology and electrical engineering technology, both planned to integrate smart manufacturing into one of their classes and presented their designs in the first two seminars. The second survey was be distributed to the SoET faculty after the second seminar.

The third seminar may be held in the following semester if any faculty members from the other engineering technology programs wish to share their experience. There will also be a 20-minute report on the progress of the two courses discussed in the previous semester, which have started implanting the integration.

Activities - Seminar 1

The invitation for Seminar 1 was sent out two weeks after the first survey. The seminar was hosted by a faculty member from the Mechanical Engineering Technology (MET) program. A MET course was used as an example to demonstrate the integration of smart manufacturing elements (SME) through a presentation and discussion. Nine faculty members attended the seminar in person, while six participated online.

The course selected as the example was Materials and Processes 1, a first-year college course required for all MET students and also offered as an elective for other SoET programs. This course provides an overview of the structures, properties, processing, and applications of metals and ceramics. As a 3-credit course, it consists of a 2-hour lecture and a 2-hour lab each week, with an enrollment of around 150 students each semester. Table 1 presented the details of the methods integrating smart manufacturing elements in this MET course

Table 1. Incorporating Smart Manufacturing into a MET Course

	Smart Manufacturing Elements	**Implementation Methods**
Lecture Development	Introduce the updated smart manufacturing technologies related to the course topics	Add the most recent and relevant smart manufacturing applications into 1-2 course slides: i.e. additive manufacturing—updates of printing materials and efficiency
	Industry 4.0 - Generate new topic about the smart manufacturing	Let students choose their interested topic about smart manufacturing and present in class; 5-min length and once per week
Lab Design	AI application - New Hands-on labs adopted the smart manufacturing equipment	Casting lab - use the smart foundry to cast a student designed part
	Software - Introduce course related software which helps to operate the new equipment	Cast design software-Pro-Cast or Magma introduction
		Demonstration of a sample casting process (simulation)
Group Project	Industry 4.0 - Discuss real industrial cases related to the course that apply smart manufacturing technologies	Students research online and present in lab sessions

	AI application - Use the equipment in our smart manufacturing labs to complete the project	Design and build a mold for injection molding process by using the equipment the smart lab: i.e. 3-D printers
Course Assignments	Encourage students to research new technologies (online) related to course topics	Offer bonus points for submitting a short research paper
	Encourage students to attend the smart manufacturing related activities on campus	Offer bonus points for submitting an activity report
Others	Workshop and seminars	In-person or online
	Field trip	Tour the smart facilities; local factory plants
	Guest speaker	Invite an engineer/metallurgist from local industries or from job fair to the class

After the demonstration, there were 40-minutes discussion time. The key questions and topics discussed by the attendees are listed below:

- Scheduling a smart manufacturing lab for Non-Lab Courses: How should lab sessions be scheduled for courses that do not traditionally include them?

- Documentation: There is a need for clear documentation of the materials and equipment used in the labs.

- Faculty and Student Training: Faculty training is essential. Additionally, it was suggested to train undergraduate and graduate students to operate equipment in the smart labs, reducing the reliance on the lab supervisor. However, there is a need to define the specific type of training required.

- Coordinated Curriculum Innovation: There is a need for an overarching coordination effort to understand industry requirements and use this knowledge to drive curriculum innovation.

- Lab Structure Differences: The structure of labs in the School of Technology differs from that in the School of Engineering. For example, engineering programs often have standalone labs not tied to specific lectures, allowing students to spend more time in the lab. In contrast, SoET labs are limited to two-hour sessions linked to lectures.

Activities – Seminar 2

Seminar 2 was hosted by a faculty member from the Electrical Engineering Technology (EET) program. An EET course, ECET 27900 (Embedded Digital System), was used as an example to demonstrate the integration of smart manufacturing elements through a presentation and discussion. This course emphasizes applications of embedded digital systems, incorporating extensive programming to build students' logical thinking and troubleshooting capabilities in software and hardware. It caters primarily to sophomore and junior students from the various majors in the School of Engineering Technology, such as Electrical Engineering Technology, Mechatronics, and Robotics Engineering Technology. As a 3-credit course, it includes a 2-hour lecture and a 2-hour lab each week—enrollment averages around 100 students during the spring semester and 60 students in the fall semester. Currently, the laboratory exercise involves driving the stepper motor to a specific location on a clock face. In order to incorporate the Smart Manufacturing theme into the course, the stepper motor will be used to drive a conveyor belt's sorting mechanism.

Faculty were surveyed at the beginning of the semester on how they have or intended to include Smart Manufacturing elements in their courses. A summary interactive page, with all the courses that include Smart Manufacturing elements, was developed and shared during this seminar. Discussions on some of the courses were included in the seminar.

Table 2: Incorporating Smart Manufacturing into an EET Course

	Smart Manufacturing Elements	**Implementation Methods**
Lecture Development	Explore use of sorting mechanism in manufacturing facility	Use stepper motor as one of the sorting mechanism, introduce the various controlling methods on driving stepper motors by microcontrollers
Lab Design	Driving stepper motor to predefined locations	

Figure 1 below shows all the courses within SoET that include Smart Manufacturing topics: Smart Manufacturing-related topics are displayed at the bottom of the screen when the course is selected. The program is now in the process of identifying specific SM topics it aims to establish. Once defined, we can evaluate the breadth and depth of topics covered by the various courses. This effort will inform strategic enhancement and support the program's ongoing curriculum development.

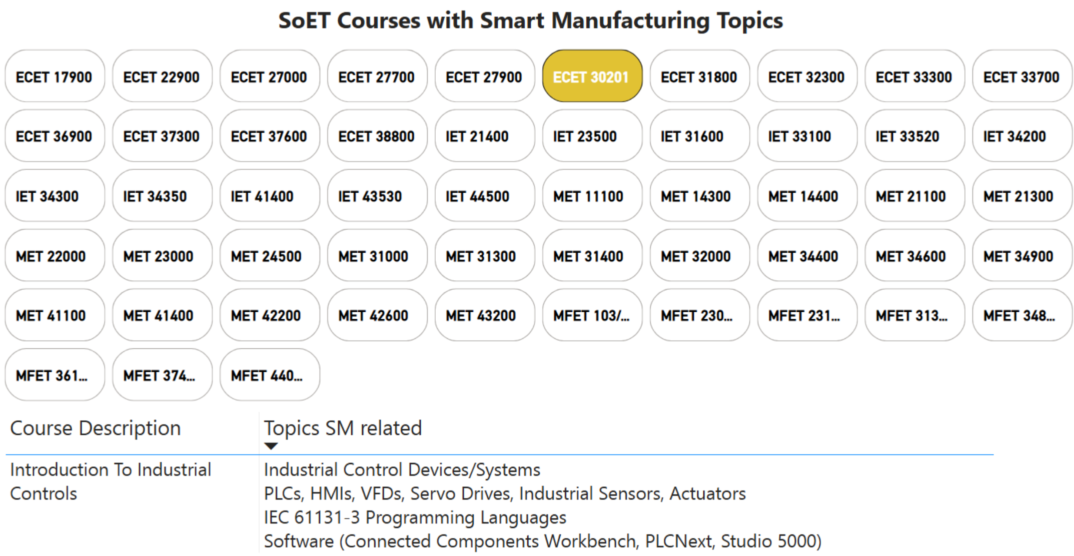

Figure 1: Webpage illustrating SoET courses that incorporate SM topics

Discussion of Survey Results

This activity involved two anonymous surveys. In Fall 2024, the first survey was distributed to all 85 SoET faculty members two weeks prior to the first seminar, with 55 responding. The survey consisted of three questions: two multiple-choice and one open-ended. Faculty members received the survey link without prior information about the seminars. For the multiple-choice questions, participants were allowed to select multiple options as applicable.

Figure 2 and 3 display the results of the two multiple-choice questions. In Figure 1, the majority of respondents indicated that they had incorporated smart manufacturing elements into their lectures. For both lab activities and project topics, 26 participants provided a positive response. Additionally, nine respondents were unsure whether their courses included any smart manufacturing elements, and no respondents indicated that their courses lacked smart manufacturing elements entirely.

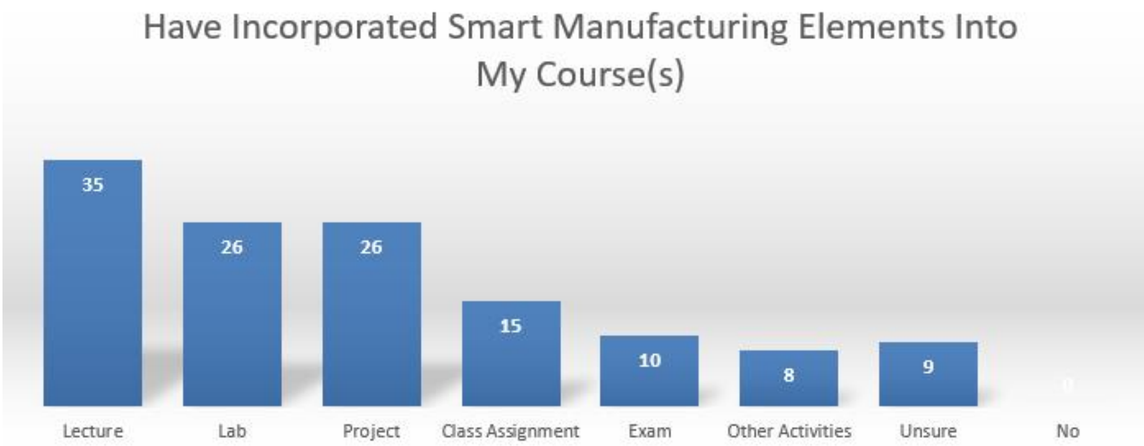

Figure 2. The result of the first survey (Fall 24), Question 1

Figure 2 shows the plan for incorporating smart manufacturing in the future. Two participants responded “no” to future plans, while five selected only “unsure”. Notably, 33 of the 38 participants who chose “unsure” also indicated that they see potential interest in adding smart manufacturing elements to their courses. Specifically, 28 participants indicated plans to add the topic to lectures, 27 to lab activities, and 15 to projects. These results closely align with the responses shown in Figure 1.

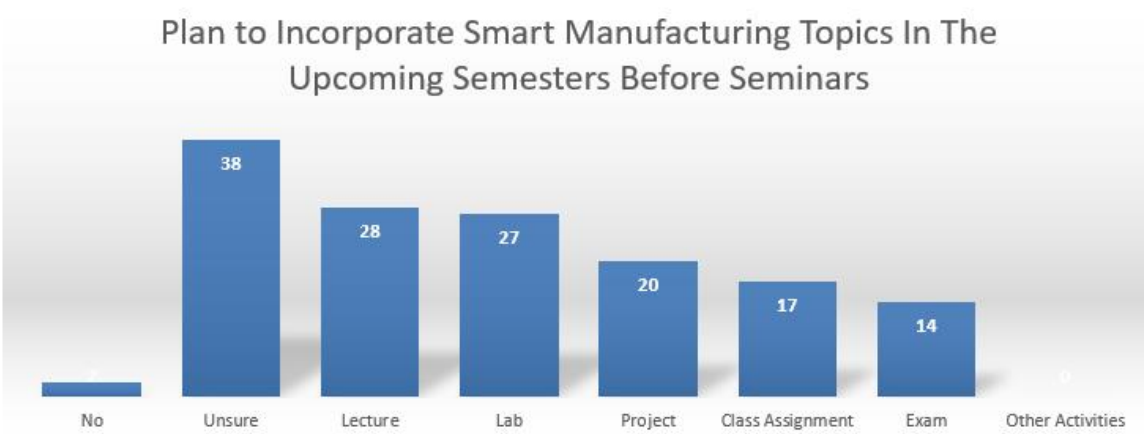

Figure 3. The result of the first survey (Fall 24), Question 2

Out of the 55 participants, 24 left comments on integrating smart manufacturing elements into their courses. A summary of their opinions is presented in Table 3. The survey link was distributed to all SoET faculty members across eight statewide campuses.

Table 3. Personal Comments on Integrating SME in Courses in Survey 1

First Survey Comments	#
My course/lab is taught in the Smart Factory.	1
My course includes industry 4.0 topics.	4
I think my course can add SME next semester.	3
“Smart” does not means “New”	2
Expect to see a common theme / an example demonstration	6
Identify which course requires integration	2
Get references from other universities	1
Introductory of smart manufacturing (e.g. Industry 4.0) can be helpful	2
Students in statewide campuses cannot access the smart labs	2
My course doesn’t fall into this category (no need to integrate)	2

Among the comments, the most frequently mentioned suggestion was the need to review a sample course that incorporates smart manufacturing elements, indicating that the planned seminars will have an audience.

The second survey, using the similar questionnaire as the first, was conducted in Spring 2025 after the second seminar and received 59 responses out of 85. Figure 4 shows the number of faculty who incorporated SME into their courses this semester. Compared to the previous semester, six more faculty members added SME content to their lectures, while four respondents reported no application of SME this time.

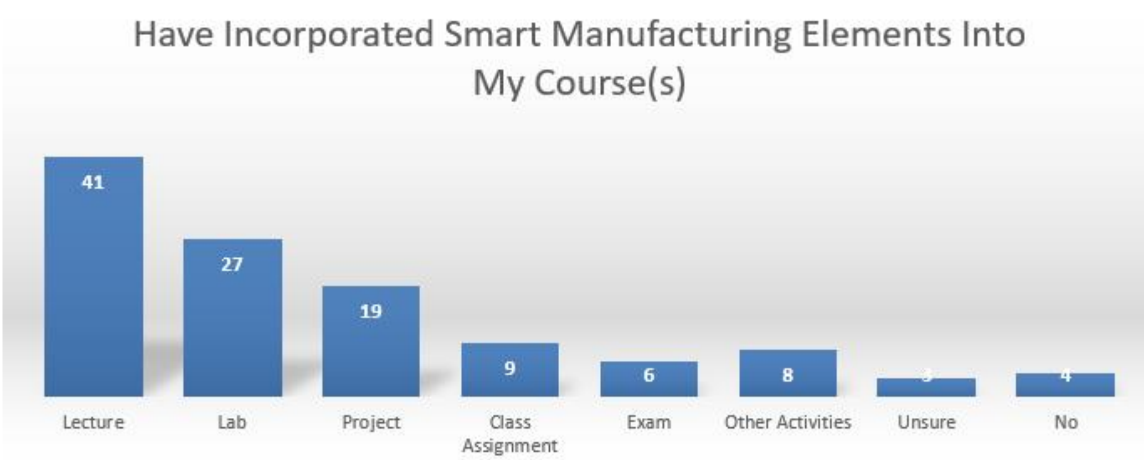

Figure 4. The result of the first survey (Spring 25), Question 1

Figure 5 shows a significant change: the number of respondents who were uncertain about incorporating smart manufacturing topics dropped from 38 to 6. Additionally, 11 faculty members planned to integrate SME into other course activities—a number that was zero in the first survey. This suggests that, following the two seminars, participants began actively considering course redesign to include SME content. This time, 25 respondents provided comments, which are summarized in Table 4. Compared to the first survey, more individuals strongly support incorporating smart manufacturing elements into courses. However, some remain uncertain and prefer to evaluate the effectiveness of student learning before making changes.

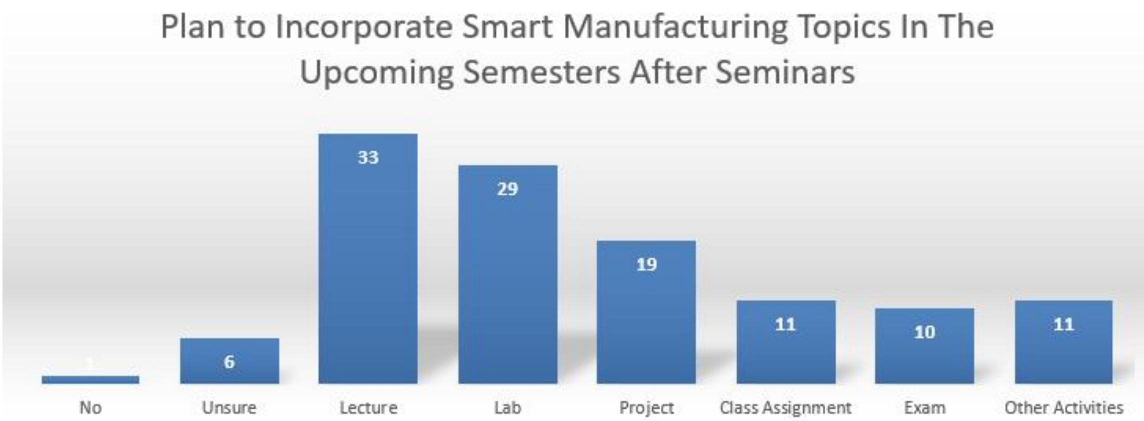

Figure 5. The result of the first survey (Spring 25), Question 2

Table 4. Personal Comments on Integrating SME in Courses in Survey 2

Second Survey Comments	#
Smart manufacturing elements have been embedded into my course.	7
Manufacturing means different approach to each faculty, so having a common theme would provide helpful alignment.	2
I have planned to incorporating SME into my course(s) in future semesters.	3
Incorporating SME into our courses should be a requirement.	3
Unclear if SME should be added to all courses. Evaluation of each course first.	3
I'm interested in seeing examples and learning about the effectiveness of how others have incorporated SME in courses.	2
Request the arrangement of Smart lab field trips for statewide students.	1
Request access to the remote courses on Smart labs application offered to statewide students.	2
I want to examine if 3D printing could be integrated to my course.	2

Conclusions

The survey results reveal a positive shift in faculty engagement with smart manufacturing content following the seminars. While the initial survey reflected strong interest with some uncertainty, the follow-up survey showed a clear reduction in uncertainty and an increase in active planning to incorporate smart manufacturing elements into lectures, labs, and projects. Faculty comments also highlighted the importance of practical examples and peer sharing, reinforcing the value of continued support. These outcomes suggest that structured faculty development activities—like the seminars—are effective in promoting curricular innovation and preparing instructors to align with evolving industry needs. Continued investment in faculty development and curriculum adjustment will be vital to maintaining this momentum and enhancing the impact of smart manufacturing integration in the School of Engineering Technology.

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