

Shaping Engineering Technology Students' Perceptions of Manufacturing Through Experiential Learning in a Flipped Classroom – A Case Study*

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This study examined how an introductory, survey-based manufacturing systems and processes course – which uniquely integrated a flipped classroom structure and multiple experiential learning elements – influenced engineering technology (ET) students' perceptions of careers, workforce expectations, workplace dynamics, and essential industry skills within manufacturing. Pooled qualitative data from 52 ET student's pre- and post-course reflection surveys, administered across four cohorts, were analyzed using topic modeling, sentiment analysis, comparative assessments, keyword frequency analysis, and/or impact assessment. The data offered valuable insights into students understanding of essential job skills, definitions of a good job, and perceptions of factory work. Before the course, students often associated factory environments with monotony and outdated stereotypes. However, post-course responses indicated a greater appreciation for modern, technology-driven manufacturing settings (i.e. Industry 4.0), workplace governance, and career growth opportunities. The results underscored the role of experiential learning in reshaping students' industry perceptions and improving workforce readiness. By integrating real-world observations and hands-on engagement, this case study highlighted the continued need for curriculum strategies that aligned ET education with evolving industry demands.

Keywords: flipped classroom; experimental learning; industry tours; engineering technology; manufacturing; qualitative research

1. Introduction

The rapid adoption of Industry 4.0 technologies is significantly transforming workforce skill requirements, emphasizing automation, technological proficiency, and digital literacy [1, 2]. These advancements are reshaping workforce expectations, emphasizing the need for professionals who possess both strong technical skills and essential competencies like problem-solving, teamwork, emotional intelligence, and the ability to adapt to evolving technologies [3]. As manufacturing systems and processes grow increasingly complex, educational practices must evolve to better prepare graduates for these emerging challenges. There is a need for continued innovation in instructional approaches that bridge the gap between theoretical knowledge and practical application, equipping students with the skills required for success in modern manufacturing environments [4].

In response, MET245000, Manufacturing Systems, a long-standing 16-week course at a large public R1 institution, was redesigned to incorporate a flipped classroom approach and experiential learning strategies, including industry tours and scaffolded lab activities. This redesign enhances Engineering Technology (ET) students' learning by integrating real-world industry engagement – through multiple site visits – with five challenging multiweek, team-based labs that build on funda-

mental manufacturing principles while also fostering professional skills such as teamwork, communication, and problem-solving. The flipped learning model is uniquely implemented by introducing pre-tour and pre-lab content before active learning activities. This approach allows students to engage with foundational concepts in advance, enabling them to make meaningful connections between theoretical knowledge, real-world observations, and collaborative lab experiences. As a result, students develop a deeper and more integrated understanding of manufacturing systems and processes.

Flipped classroom models have been extensively studied in engineering education [5, 6] and have been associated with improved learning outcomes, engagement, and student satisfaction [7, 8]. Similarly, experiential learning strategies, such as hands-on labs and industry exposure, have been shown to enhance engagement [9] and prepare students for professional careers [10]. For example, Yelamarthi and Drake [11] found that blending flipped instruction with experiential engineering projects significantly improved student performance, engagement, and self-efficacy in a first-year circuits course. While there is existing research on the implementation of flipped classrooms in manufacturing education [12], studies explicitly combining flipped instruction with multiple experiential learning strategies remain sparse and/or

undocumented. In this context, Gargac [13] explored the integration of a partially flipped classroom with hands-on manufacturing experiences and primarily virtual industry tours in a senior-level mechanical engineering course. Additionally, Durkin [14] examined how industry-partnered, project-based experiential learning enhances student engagement and technical competency in engineering technology education. However, further research is needed to explore the synergistic effects of integrating flipped classroom models with experiential learning strategies across diverse manufacturing education contexts.

The industry tours exposed students to a diverse range of manufacturing technologies, including high-speed automation, Computer-Numerical Control (CNC) machining, roll forming, precision tooling, robotics, and large-scale fabrication and assembly operations. These visits spanned various industry sectors, such as beverage and home appliance production, as well as metal forming and shaping. The labs reinforce these observations by immersing students in manufacturing tasks like reverse engineering, metrology, subtractive and additive manufacturing, statistical process control, and automation. This structured integration of theoretical learning, industrial observation, and applied practice provides a unique educational framework for an introductory, survey-based ET manufacturing course.

The purpose of this case study was to investigate how MET245000, Manufacturing Systems, influenced ET students' perceptions of careers, workforce expectations, workplace dynamics, and essential industry skills in the context of the manufacturing industry, by analyzing pooled qualitative data from pre- and post-course reflections over four cohorts. It contributes to ongoing discussions about designing ET curricula that more effectively addresses the evolving demands of the manufacturing industry (i.e. Industry 4.0, smart manufacturing) while also shifting ET students' perceptions of manufacturing away from outdated stereotypes of dirty, monotonous, and low-skilled work toward a more accurate understanding of modern manufacturing as clean, technology-driven, innovative, and integral to global competitiveness.

2. Methodology

2.1 Course Structure and Learning Components

The course under investigation was MET245000, Manufacturing Systems, at Purdue Polytechnic New Albany, one of nine statewide sites, distinguished by its close industry partnerships and focus on hands-on learning. The introductory, survey-based course is typically offered every fall semester

and consists of a 1-hour 50-minute lecture period and a 1-hour 50-minute lab per week over 15 weeks, plus a finals week. It is a required course for all mechanical engineering technology (MET) students and is often taken as a selective for students majoring in manufacturing engineering technology (MFET) and industrial engineering technology (IET) degree programs. The course integrates the following components:

- **Flipped Classroom Framework:** Assigned outside class content acquisition (i.e. assignments) provided students with foundational theoretical knowledge through readings (textbook and instructor-curated) and viewings (documentaries and online learning platform tutorials), enabling them to contextualize and critically analyze real-world observations during industry tours. This phase enhanced engagement during site visits and strengthened the application of learned concepts in hands-on lab activities, reinforcing the connection between theory and practice. Additionally, this framework created opportunities for in-depth group discussions, where students could collaboratively reflect on industry insights, share diverse perspectives, and engage in critical analysis, fostering deeper comprehension and knowledge application.
- **Team-Based Labs:** Five multiweek team-based labs reinforced fundamental manufacturing concepts, including reverse engineering, metrology, subtractive and additive manufacturing, statistical process control, and automation. Working in teams not only enhanced hands-on learning experiences but also helped students develop essential professional skills such as teamwork, communication, and collaborative problem-solving, preparing them for real-world industry environments. This parallels Monroe, et al. [15] findings, where a freshman engineering program emphasized experiential group projects to promote engagement and retention.
- **Industry Tours:** Visits to manufacturing facilities exposed students to advanced manufacturing technologies such as automation, robotics, CNC machining, roll forming, and large-scale assembly operations. These tours allowed students to observe real-world applications of manufacturing principles, gain insights into production efficiencies, and engage with industry professionals, fostering a deeper understanding of modern manufacturing environments and career opportunities.
- **Traditional Assessments:** To complement experiential learning activities, the course incorporated 11 quizzes (lower stake), and three exams (higher stake) designed to evaluate students' understand-

ing of foundational manufacturing terminology and concepts. These assessments reinforced theoretical knowledge gained through pre-class content acquisition, industry tours, and hands-on labs.

2.2 Data Collection

Study data comes from four cohorts of students enrolled in the course in the Fall of 2020, 2021, 2022, and 2024. The course was not offered in the Fall of 2023. The following are the two data sources:

1. **Primary:** The primary data consisted of online pre- and post-course surveys, assigned on the first day of class and during the final week of the semester. These reflection-based surveys were completed by students at both the beginning and end of the semester to assess changes in their perceptions of manufacturing careers, workplace dynamics, and essential industry skills.
2. **Supplementary:** In some analyses, anonymous written comments from end-of-semester course surveys, controlled and distributed by the university, were utilized to provide additional context and validation.

The pre- and post-course surveys included five open-ended questions, which were selected by the instructor and sourced from an open-source discussion guide for the documentary *American Factory* [16]:

1. What do you think are the most important skills for success in the job market?
2. How would you define a good job?
3. When you hear the term factory work, what comes to mind?
4. Who do you believe should have the most say in determining workplace conditions, wages, and benefits?
5. What qualities do you look for in a career?

2.3 Data Analysis

Only data from students who completed the course and submitted both pre- and post-course surveys (i.e., the primary data source) were included in the analysis. Data from the four cohorts were pooled for an aggregated analysis. Aggregating qualitative data across multiple cohorts enabled the identification of overarching patterns and themes, enhancing the robustness and generalizability of findings while mitigating the influence of individual cohort variability.

A multi-method qualitative analysis was conducted to examine patterns and trends in students' pre- and post-course responses. By employing this

approach, the case study captured both thematic patterns and nuanced changes in student perceptions of manufacturing careers. The following analytical approaches were used:

1. **Topic Modeling (Latent Dirichlet Allocation – LDA):** LDA was used to identify dominant themes within student responses. Pre- and post-course reflections were analyzed separately to determine how perceptions evolved. Topics were extracted and compared to assess changes in key themes such as job skills, factory work perceptions, and career expectations. This approach was applied to all five questions.
2. **Comparative Analysis:** Pre- and post-course responses were systematically compared to evaluate shifts in student perspectives. This method helped identify emerging themes and areas where students refined or expanded their understanding of modern manufacturing careers. This approach was applied to all five questions.
3. **Sentiment Analysis:** A polarity-based sentiment analysis was conducted to measure changes in students' attitudes toward factory work. Pre- and post-course sentiment distributions were analyzed to assess whether students became more positive, negative, or developed more varied perspectives about manufacturing careers. This analysis was applied to question 3.
4. **Keyword Frequency Analysis:** A bigram and trigram frequency analysis was conducted to identify recurring phrases in pre- and post-course responses. This method helped highlight important terminology and conceptual shifts in how students described job skills, industry work, and career expectations. This approach was applied to questions 1 and 5.
5. **Impact Assessment:** Changes in student perceptions were mapped to specific course elements when possible, particularly industry tours and lab experiences, to determine which components contributed to shifts in understanding. This approach was applied to all five questions.

2.4 Limitations

This case study has several limitations. First, it focuses on a single course at one institution, which may limit the generalizability of the findings to other programs or educational settings. While the course structure, textbook, assignments (e.g., readings and viewings), quizzes, exams, and lab activities remained consistent across the four years of study, the primary variation occurred in the number and location of industry tours. These adjustments were based on industry availability

and logistical constraints, ensuring that experiential learning remained a core feature despite site changes.

Additionally, the researcher served as the sole instructor of record throughout the study, providing consistency in curriculum delivery and assessment methods. This standardization minimizes instructional variability, making it more likely that differences in student responses reflect individual factors or external influences rather than pedagogical changes.

Another limitation is the reliance on qualitative data, which, while valuable for capturing student perceptions and experiences, does not provide quantitative measures that could support statistical generalizability. The lack of numerical data makes it difficult to assess the magnitude of changes in student perceptions over time or to compare findings across broader populations.

Furthermore, the case study relies on self-reported data, which may introduce biases related to students' perceptions, memory, or willingness to provide accurate reflections. The sample also lacks demographic diversity, as it consists primarily of white males. This homogeneity may limit the applicability of the findings to a broader population, as it does not fully capture the perspectives of underrepresented groups in manufacturing.

3. Results and Discussion

This case study includes a total pooled sample of 52 students (52 males and 7 females) from the four cohorts: 9 from 2020 (90.00% response rate), 17 from 2021 (94.44% response rate), 10 from 2022

(76.92% response rate), and 16 from 2024 (94.12% response rate). These students were pursuing degrees primarily in MET ($n = 41$, 78.8%), with additional representation from MFET ($n = 7$, 13.5%), IET ($n = 3$, 5.8%), and ET ($n = 1$, 1.9%).

Academically, the sample includes students at different stages of their degree progress, with the majority classified as juniors ($n = 22$, 42.3%) and seniors ($n = 20$, 38.5%) based on their credit hours. The remaining students were sophomores ($n = 8$, 15.4%), and freshmen ($n = 2$, 3.8%). In terms of academic performance, most students earned a final grade of B ($n = 32$, 61.5%), followed by A ($n = 5$, 9.6%), C ($n = 12$, 23.1%), and D ($n = 3$, 5.8%). This grade distribution suggests a generally strong academic performance among the participants.

Table 1 provides a concise summary of the key themes identified before and after the course for each question, highlighting the most significant changes in student thinking and offering a high-level interpretation of how the course influenced their views on modern manufacturing careers. Subsections 3.1 through 3.5 present the detailed findings from the qualitative analysis of each individual reflection question. These sections incorporate direct student comments to illustrate key shifts in perception and provide contextual depth, capturing how students' understanding of job skills, good jobs, factory work, workplace governance, and career qualities evolved throughout the course.

3.1 Skills for the Job Market (Q1)

The topic modeling analysis of pre- and post-course responses revealed a shift from broad, theoretical discussions of job skills to a structured, applied

Table 1. Summary of Student Perception Shifts Across Five Reflection Questions

Questions	Pre-Course Themes	Post-Course Themes	Key Interpretation
Q1: Most important skills for success in the job market	General employability skills (e.g., adaptability, time management, integrity); soft skills emphasized	Balanced view of soft and technical skills (e.g., digital literacy, experience with automation); emphasis on real-world experience	Students developed a more structured, industry-aligned understanding of career readiness
Q2: Definition of a good job	Focus on financial compensation and job security	Broader perspective including workplace culture, respect, benefits, and long-term growth	Students shifted toward valuing job satisfaction, stability, and career advancement
Q3: Perceptions of factory work	Stereotypes: repetitive, dirty, monotonous, machine-heavy	More varied and nuanced: contrast between outdated and modern facilities; awareness of automation and structure	Course experiences expanded students' awareness of modern manufacturing environments
Q4: Who should have a say in workplace conditions	Broad agreement on shared input between employees and employers	More structured responses: consideration of negotiation, leadership roles, and fairness	Students demonstrated a deeper understanding of workplace governance and representation
Q5: Desired career qualities	Stability, pay, and a supportive environment	Emphasis on growth, learning opportunities, impact, and work-life balance	Students moved from short-term to long-term thinking about career success and fulfillment

understanding. Before taking MET245000, Manufacturing Systems, students emphasized general employability traits such as adaptability, time management, and accountability. One student stated, *"I think the most important skills, and even qualities, to have include adaptability, time-management, perseverance, integrity, and accountability (being able to take responsibility/admit when you made a mistake). People can obtain these skills by practicing them daily in their own lives and current workplaces."* Another highlighted, *"I think the two most important skills in today's job market would be soft skills or non-technical, interpersonal skills. This being the way we interact with others, and navigate our environment."*

Post-course responses reflected a more industry-aligned perspective, emphasizing structured skill development, technical knowledge, teamwork, and adaptability. One student stated, *"In today's job market, the most important skills are a combination of technical skills and soft skills. Technical skills, like digital literacy, the ability to work with new technologies, and specialized knowledge (such as coding or engineering), are crucial as industries continue to evolve superfast with automation and digital tools. Soft skills, which I personally find more important than technical skills, include strong communication, problem-solving, emotional intelligence, and adaptability."* Another reinforced the importance of experience, stating, *"People / social skills. I think one acquires and hones these skills by interacting with more and more people of different backgrounds. Learning about other cultures and how to best handle different situations can be a big help but it all requires real experience."*

Additionally, experience and task execution emerged post-course, indicating that industry exposure and hands-on learning reinforced real-world application. One student reflected, *"I feel like the most important skills in today's job market are communication and being able to be flexible in what the company wants you to do. If you show that you are willing to work with them then the company is more willing to want to give you a raise or a promotion."* This transformation suggests that the course helped students connect theoretical knowledge to practical career readiness, refining their job market perceptions.

3.2 Defining a Good Job (Q2)

The topic modeling analysis of pre- and post-course responses revealed a shift from broad, financial-focused definitions of a good job to a more comprehensive view incorporating stability, benefits, and job satisfaction. Before taking MET245000, Manufacturing Systems, students primarily defined a good job in terms of pay and financial security.

One student stated, *"To me, a 'good job' means one that pays well for the work performed and provides enough to live comfortably without struggling."* Another noted, *"A good job offers a balance of work, opportunities for advancement, and financial stability."* While some responses included elements like career growth, work-life balance, or fulfillment, most remained centered on compensation and job security.

Post-course responses reflected a broader and more structured perspective, incorporating workplace culture, sustainability, and long-term career growth. One student stated, *"A good job is one that provides stability, whether financially or in job security, and allows for future career growth."* Another emphasized workplace environment, saying, *"A good job means to me that the company I work for values me, treats its employees with respect, and provides opportunities for growth."* A third student highlighted workplace well-being and benefits, stating, *"A good job, to me, means a position that provides stability, fair compensation, and benefits that support a balanced life."* This evolution in responses suggests that course activities and industry exposure helped students develop a more nuanced view of job quality, shifting beyond financial compensation to consider long-term career growth, workplace well-being, and company culture.

3.3 Perceptions of Factory Work (Q3)

The topic modeling analysis of pre- and post-course responses revealed a shift from a broad, stereotypical view of factory work to a more detailed, experience-based perspective. Before taking MET245000, Manufacturing Systems, students generally pictured factory work as machine-heavy, repetitive, and labor-intensive. One student described it as, *"What comes to mind is typically a lot of machinery, assembly lines, and workers performing the same task repeatedly."* Another student stated, *"What comes to mind for me when picturing factory work is long hours, repetitive tasks, and minimal interaction beyond the work being done."* While some responses referenced modernization and automation, many still viewed factory work as physically demanding and monotonous.

Post-course responses reflected a more nuanced and varied understanding of factory environments. One student noted, *"What comes to mind are two different images: one of old-school, dirty manufacturing floors and another of modern, highly automated, clean facilities."* Another student highlighted negative aspects, stating, *"Dirty, assembly line, a lot of employees, unsafe conditions, and long hours."* Meanwhile, another response indicated a shift in understanding of scale and organization, saying,

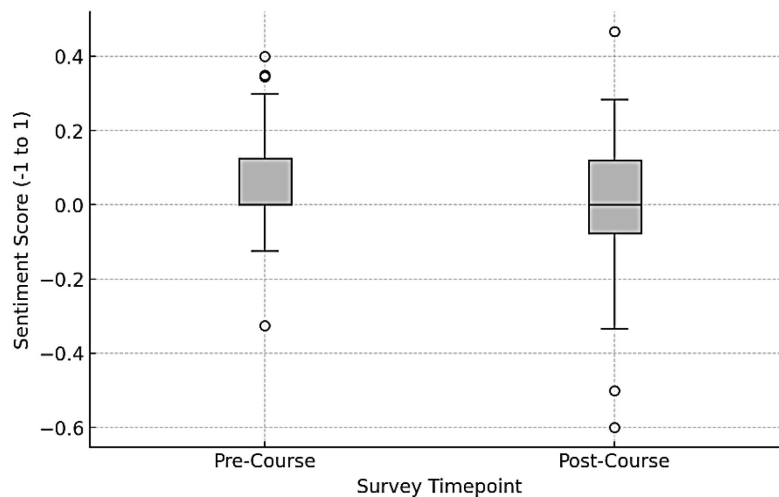


Fig. 1. Sentiment Distribution: Perceptions of Factory Work.

“When I picture factory work, I think of a big, structured process with different teams working in sync to keep production moving.” This evolution in responses suggests that course activities and industry tours exposed students to a broader range of manufacturing environments, reinforcing the reality that factory work is not uniform. While some students maintained negative or neutral views, others recognized the contrast between traditional factories and modern, technology-driven manufacturing facilities.

The sentiment analysis (see Fig. 1) of student perceptions before and after the course revealed a shift toward more varied opinions rather than a uniformly positive change. While pre-course responses were mostly neutral to slightly positive, post-course responses showed greater variability, with some students becoming more positive and others more negative. This suggests that industry tours and course experiences provided a more nuanced understanding of modern manufacturing, challenging preconceived notions rather than reinforcing a single perspective. The course exposed students to real-world complexities, leading to a broader range of opinions rather than an overall increase in positivity.

3.4 Governance of Workplace Conditions and Benefits (Q4)

The topic modeling analysis of pre- and post-course responses revealed a shift from general, principle-based perspectives to a more structured view of labor relations and workplace decision-making. Before taking MET245000, Manufacturing Systems, students largely agreed that both employees and employers should have a say in wages, benefits, and working conditions. One student stated, *“The employer and the employee should both have a say. If*

only one side makes decisions, it will be unfair.” Another emphasized a collaborative approach, noting, *“When it comes to working conditions, wages, and benefits, I believe both the employees and management should be involved in these decisions to ensure fairness.”* A third student simply stated, *“The employees and the employer should have a say together.”*

Post-course responses reflected a more refined and industry-aware perspective, highlighting structured negotiation processes and workplace policies. One student reinforced a balanced approach, stating, *“I think that both employees and employers should work together in determining these factors because it affects both sides.”* Another response emphasized the role of company leadership, saying, *“The employee in conjunction with the company they work for should decide on working conditions, wages, and benefits to ensure fairness and productivity.”* A third student expressed a stronger stance on employee representation, stating, *“Ideally the people who do the work, like the employees, should have a larger say because they are the ones directly impacted by these policies.”* This evolution in responses suggests that course discussions and industry exposure helped students develop a more structured understanding of workplace decision-making, moving beyond broad fairness arguments to consideration of formal negotiation, leadership roles, and the importance of balancing employer and employee interests. This aligns with Chen, et al. [17] findings that experiential settings shape professional identity and understanding of workplace roles.

3.5 Desired Career Qualities (Q5)

The topic modeling analysis of pre- and post-course responses revealed a shift from broad expectations of job satisfaction and stability to a more structured

view incorporating long-term career growth, benefits, and work-life balance. Before taking MET245000, Manufacturing Systems, students generally prioritized job stability, salary, and workplace culture. One student stated, *“I believe the qualities of my future job that will be most important are good pay, good benefits, and an environment where I feel valued.”* Another emphasized the balance between work and well-being, saying, *“For my future job, the most important qualities are financial stability, job security, and a work environment that values personal and professional growth.”* A third response highlighted fair compensation and ethical work culture, stating, *“An important and crucial quality of my future job is fair treatment, benefits, and a work environment where I feel comfortable growing in my career.”*

Post-course responses reflected a refined and industry-aware understanding of job expectations, focusing more on skill development, career progression, and work-life integration. One student shifted emphasis toward continuous learning, stating, *“I think the skill level that will be most important in my future job is the ability to continue learning and growing in my field.”* Another reinforced the need for job fulfillment beyond salary, saying, *“After graduating, the most important qualities of a job for me will be a workplace that values both skill and personal well-being, with clear opportunities for advancement.”* A third response placed stronger emphasis on long-term career viability, stating, *“After graduating, I believe the most important qualities of a job are not just financial but also the ability to grow, maintain work-life balance, and feel that I am making an impact.”* This evolution in responses suggests that course discussions and industry exposure helped students develop a more structured and practical understanding of job quality, shifting from a focus on immediate stability and salary to long-term career growth, learning opportunities, and workplace culture.

4. Conclusion

This multi-method qualitative research case study highlights how the integration of flipped classroom instruction and experiential learning strategies – specifically industry tours and team-based labs – can significantly influence students’ perceptions of manufacturing careers and industry expectations. An innovative aspect of this work is its instructional design, which strategically combines these pedagogical approaches within an introductory ET course. While flipped learning and experiential activities have been explored separately in engineering education, this study is among the first to intentionally merge them to enhance student engagement, deepen contextual understanding, and challenge outdated perceptions of manufacturing. By delivering pre-tour and pre-lab content in advance, the course enabled students to actively apply theoretical knowledge during real-world observations and hands-on activities. Additionally, the use of multi-method qualitative analysis – spanning topic modeling, sentiment analysis, and keyword frequency – offered a novel, data-driven approach to assessing the impact of this design on workforce-aligned learning outcomes.

Findings indicate that students shifted from broad, theoretical views on job skills to more structured, industry-relevant perspectives. Their understanding of factory work evolved from stereotypical views to a more nuanced recognition of modern manufacturing environments. Additionally, students demonstrated more thoughtful perspectives on workplace governance, job quality, and long-term career development. Overall, MET245000, Manufacturing Systems, effectively reshaped student perceptions by connecting classroom learning to real-world industry practices, reinforcing the value of experiential, context-rich curriculum design in ET education.

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