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Integrating Soft Skill Development into a Manufacturing Systems Course

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Abstract

Today's labor market requires well-educated engineers with a variety of skills to effectively solve problems and improve processes. In addition to advanced technical skills, engineering work also demands effective teamwork and a range of soft skills. Despite such needs in the engineering workforce, academic engineering curricula tends to focus on developing the technical skills of the students, overlooking the soft skills or 21st century skills that are just as important. The 21st century skills include critical thinking, communication, teamwork collaboration, metacognitive awareness, and creativity. Developing such skills will enable future engineers to effectively engage in interdisciplinary endeavors and adapt to changes in national policies and emergent technologies. This paper presents a project that integrates 21st century skill development (i.e., metacognitive awareness, constructive thinking, and communication) into a manufacturing systems course. In this course, students learn about manufacturing systems through a series of teamwork-based manufacturing simulations. Workshops on developing metacognitive and teamwork skills were added to the course. At the conclusion of the semester, we examine the effectiveness of the skill integration into the manufacturing simulations.

Keywords

21st century skills, soft skills, metacognitive awareness, teamwork, communication, manufacturing simulation.

1. Introduction

The 21st century is characterized by rapid technological advancements that transform teaching and learning. Today's manufacturing industry is driven by information, knowledge, and innovation and it requires employees to have both technical and soft skills[1]. Reports show that there is sizeable skills gap in U.S. manufacturing and this gap is expected to result in a shortage of three million manufacturing jobs in the next decade[2]. To fill the skills gap in U.S. manufacturing, educators have been trying new instructional approaches in engineering education. Physical manufacturing simulation has been introduced to classrooms as it provides a research platform for science, engineering, and technology[3], and have demonstrated effectiveness in teaching students the technical aspects of manufacturing systems design and analysis[4]. However, literature indicates that most of these simulations do not teach students[6] how cognitive and metacognitive skills and group behaviors that may impact problem solving[7]. Educators should be able to align the education mission to today's job market that highly values good communication skills and metacognitive ability. This research intends to amend the current engineering curriculum by integrating the teaching of 21st century skills into manufacturing simulations. In doing so, soft skills are taught in a manufacturing systems course through two custom designed workshops. We examine the relationship between improved soft skills and problem-solving skills in student team activities.

2. Description of the Manufacturing Course

The Manufacturing Systems course discussed in this study is an undergraduate course in Industrial Engineering at Penn State University, the Behrend College. It introduces to students the modern manufacturing systems and discusses how the systems can be improved.

The course is offered during the seventh semester of the program. Students learn different tools and techniques employed by the design, analysis, development, implementation, and improvement of modern manufacturing systems. The general concepts provided in this course are also widely applicable to service industries. The course involves hands-on learning and exercises in laboratories as well as real world industry projects. Upon satisfactory completion of the course, students should be able to:

- Explain the key performance measures of manufacturing systems.
- Describe the different techniques and tools for manufacturing systems design and analysis.
- Compare key techniques used to improve manufacturing systems productivity and efficiency.
- Apply process improvement methods in real manufacturing or service environments.

The course covers the following topics:

- Introduction to modern manufacturing
- Basics of manufacturing systems
- Manufacturing strategies
- Demand planning and forecasting
- Material Requirements Planning (MRP)
- Factory dynamics and variability laws
- Lean manufacturing and Six Sigma methodology

Student learning is assessed through homework assignments, lab reports, a course project, and exams. Students work in groups for both the lab reports and the course project.

In order to investigate how learning soft skills impacts students on solving technical problems in manufacturing systems, we brought in the teaching of soft skills to the course as students went through the physical simulations. Student soft skills were measured before and after two workshops specifically designed to teach metacognitive awareness and teamwork. To put in a nutshell, the integration of soft skill development into manufacturing simulations consists the following steps: (1) students conducted a manufacturing simulation, (2) student soft skills were measured, (3) students attended soft skill development workshops, (4) students conducted more manufacturing simulations using what they learned from the workshop, (5) student soft skills were measured again, (6) student change in soft skills were compared and project evaluated, (7) researchers drew conclusions and reflect on the project. The following sections will discuss these steps in detail.

3. Course and Project Components

3.1. Manufacturing Simulation

Manufacturing simulation is an instructional method where students work in groups and follow a typical manufacturing process to make a product by mimicking the real-world industry. In this process, students are tasked to improve the efficiency of the manufacturing system. To achieve this goal, students need to identify problems arise from different phases of the process and provide solutions that benefit the entire system.

3.2. Physical Simulations and Technical Skills Measurement

Students were divided into three groups for the simulation activities. Each group had six or seven students. The groups remained together throughout the semester and complete five simulation activities, each representing one manufacturing system covered in the course. Through these simulations, students learn the different types of manufacturing systems and how each system works. One simulation activity consists of the assembly and inspection of wood toy cars, shown in Figure 1 below. The car has four main components: the wheels, the brakes, the axles, and the body.

				
Wheels	Brakes	Axles	Car Body	Final Product

Figure 1. Main components of the car product

This simulation activity takes several phases to complete: kitting, subassembly, final assembly, inspection, transportation, and time study. For each manufacturing system simulation students worked on, the groups were given case-specific instructions to guide them through the different phases. Figure 2 shows pictures from the wood toy car simulation (left) and soft skill development workshop (right).

Figure 2. Simulation activity (left) and soft skills workshop (right)

Students' technical skill performance in the physical simulations was measured by the total profit the group made at the end of the simulation activity. The profit is defined as: *Profit = Sales – Cost of Goods Sold – Capital Charges*.

3.3. Soft Skill Assessment

The soft skills considered in this research are metacognitive awareness and team effectiveness. They were assessed before and after the soft skill workshops using survey instruments developed and validated by previous studies[5, 6]. Specifically, we used the Metacognitive Awareness Inventory (MAI)[5] designed to measure the metacognitive awareness of the students, and Group Style Inventory (GSI) developed by Human Synergistics® Company (www.humansynergistics.com) to measure teamwork and team behavior[6]. The total profit each group made at the end of a simulation was also used as the indicator from group effectiveness. In addition, the research team developed a specific survey to collect student feedback on the workshops.

3.4 Soft Skills Workshops

Soft skills workshops were designed to teach students the following skills: (1) metacognitive awareness, (2) groupthink and how to avoid it, (3) group effectiveness, and (4) communication skills. To make the workshops engaging and relevant, the research team included active learning activities and real engineering disaster videos to convey the messages. Some techniques to improve soft skills were immediately applied to subsequent simulation activities. For example, to reinforce metacognitive awareness, students were asked to use mind mapping to represent the process of maximizing the profit yield in the physical simulation activity.

4. Results and Analysis

4.1 Metacognitive Awareness

The metacognitive awareness scores of all the student groups also increased after the soft skills workshops were introduced. Figure 3 below displays the averages of the standardized MAI scores from all members in their groups. The picture on the left shows the mind mapping activity being applied to the physical simulation.

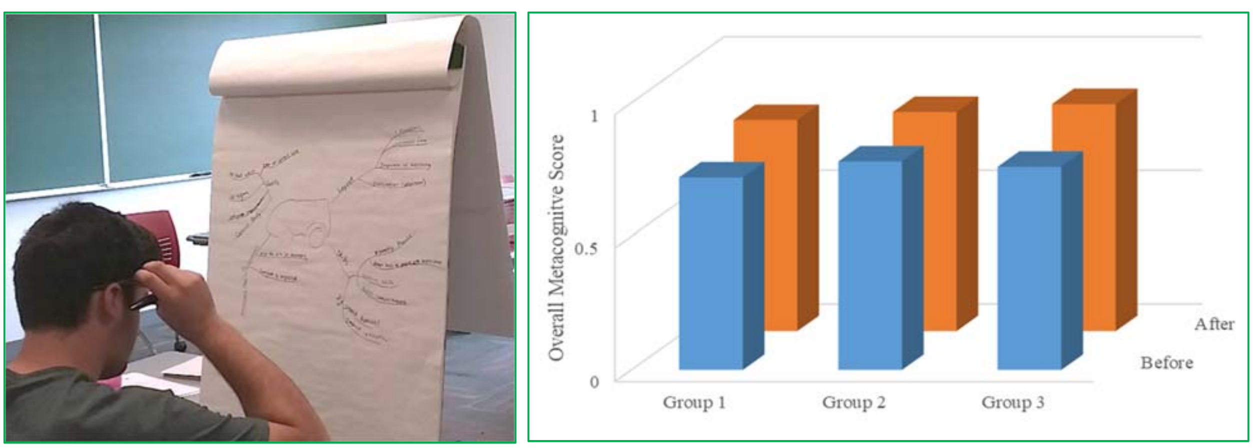
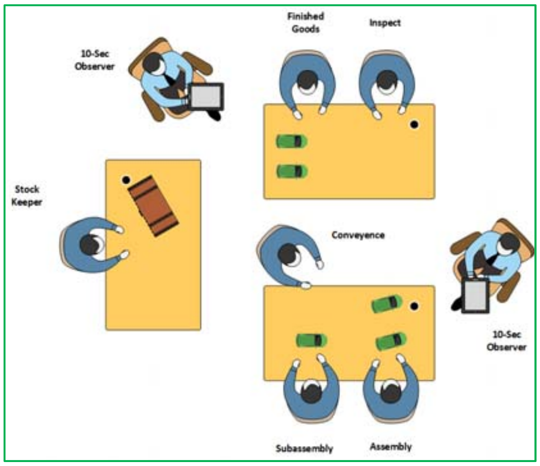


Figure 3. Mind mapping (left) and metacognitive scores from the student groups (right)

4.2. Group Performance

Student performance data was collected on both technical and soft skills before and after the workshops. Figure 4 below shows the layout of one simulation activity, known as batch-and-queue system (left) and the total profit achieved by the three groups before and after the soft skills workshops (right). In all the simulations, group performance, which is a strong indicator of group effectiveness represented by total profit, was measured before and after the soft skills workshops. We found that the total profits achieved by the student groups from all simulation activities increased after they attended the soft skills workshops.



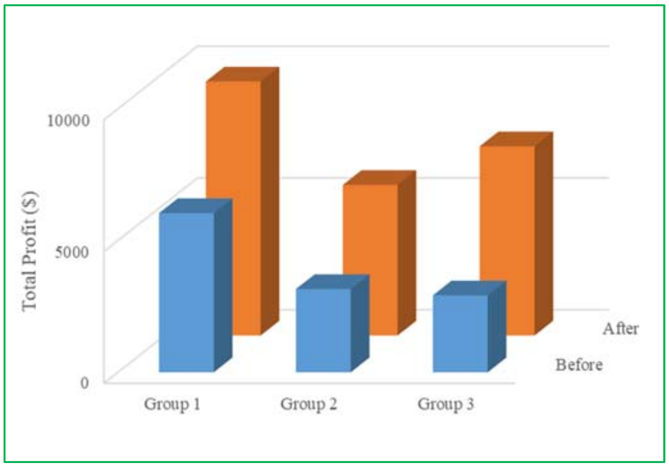


Figure 4. Manufacturing simulation layout (left) and total profits obtained by the student groups (right) in one simulation activity

The group effectiveness results for one student group are shown in Figure 5. The GSI Circumplex shows three types of group styles: constructive, passive/defensive, and aggressive/defensive. Effective teams should have higher score – ideally exceeding the bolded middle ring – in constructive style (blue) and lower scores in both passive/defensive (green) and aggressive/defensive styles (red). The GSI scores for all the student groups have improved after the soft skills workshops.

The manufacturing simulations and soft skills assessment were also implemented in another manufacturing systems course in the Spring semester. A group of five students implemented two manufacturing simulations but this time without introducing the soft skill development workshops. It was found that the group effectiveness scores for the student group have decreased (i.e., became worse). This shows the effectiveness of the workshops and how they can improve students soft skills. More data will also be collected in the future to further validate the findings.

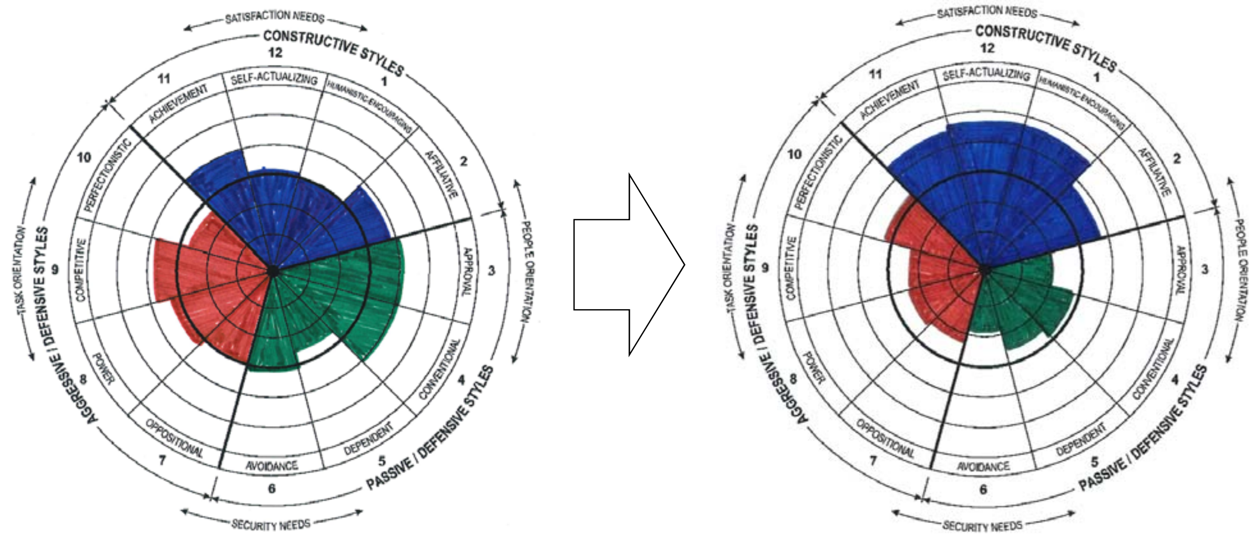


Figure 5. Group effectiveness results (BEFORE, left and AFTER, right) for students who participated in soft skill development workshops

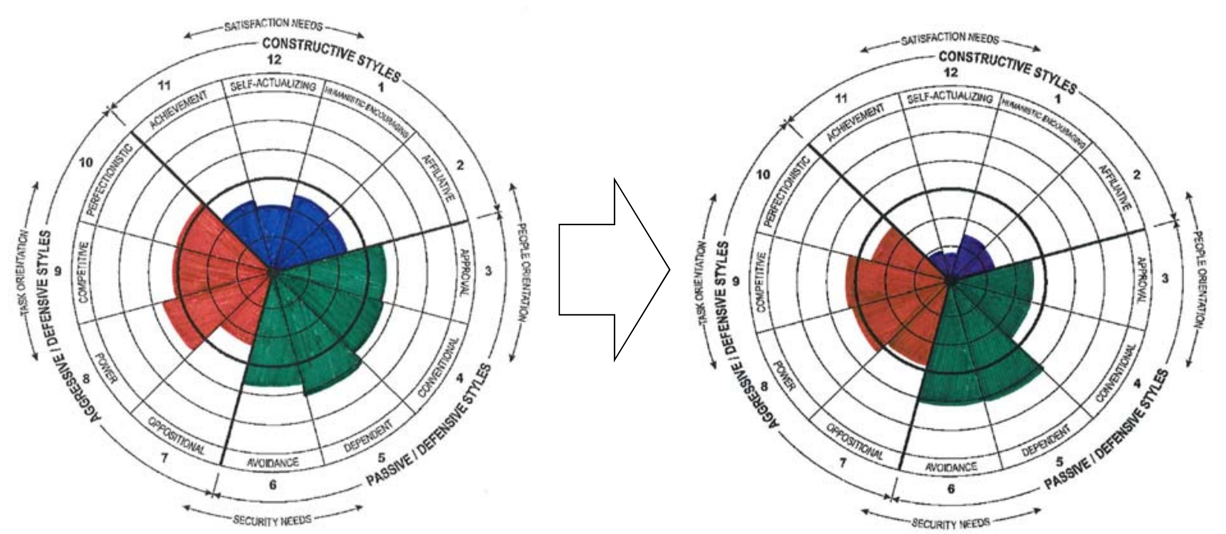


Figure 5. Group effectiveness results (BEFORE, left and AFTER, right) from students who were not exposed to the soft skill workshops

4.3 Student Feedback to Soft Skills Workshops

We also surveyed students in the manufacturing system course to collect their feedback to the soft skill workshops. The survey has three sets of questions. The questions from the first set are shown in Table 1 and the results are shown in Figure 6. Overall, students overwhelmingly agreed or strongly agreed that the workshops integrated into manufacturing simulations helped them learn about soft skills and their importance. A few students thought they should be provided with detailed instructions on how to perform the different steps of the final physical simulation activity. The reason the research team did not provide pre-determined instructions for all the simulation activities was to encourage creative thinking among students. For the final simulation activity, students were asked to develop the simulations by themselves and create a novel layout that can improve the performance of the system.

Table 1. Survey questions for student feedback on soft skills workshops
4 = Strongly Agree 3= Agree 2 = Disagree 1= Strongly Disagree NA: Not Applicable

No.	Question	Answer Choices
Q1	The workshops helped me understand soft skills and their importance.	4 3 2 1 NA
Q2	The information and/or skills presented were relevant and useful.	4 3 2 1 NA
Q3	The material provided was useful.	4 3 2 1 NA
Q4	I can now apply what I have learned to real life situations.	4 3 2 1 NA
Q5	The hands-on activities were useful and effectively taught.	4 3 2 1 NA
Q6	The videos were helpful and informative.	4 3 2 1 NA

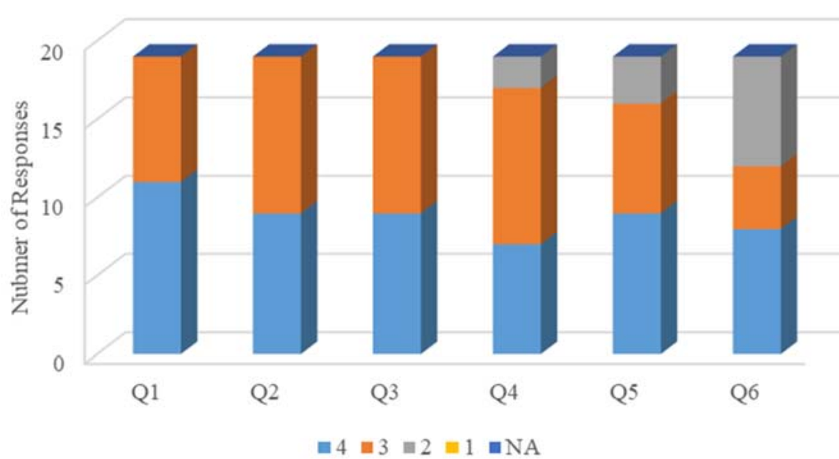


Figure 6. Tabulation of student responses to the workshop survey

In the second set of the survey questions, students were asked to comment on the workshops with regard to (1) what skills they learned, (2) what they think about the workshops. Student responses were put into word cloud as shown in Figure 7. For question 1, student responses center around teamwork, communication, and how to avoid groupthink. For question 2, students indicated that they liked the workshops and the workshops helped them understand manufacturing systems and associated skills.

What skills did you learn?	What do you think about the workshops?

Figure 7. Word cloud from student comments

In the third set of questions, students were asked about their future career interest: (1) Do you have a job offer? (2) Do you prefer to work in manufacturing? (3) Do you think soft skills are as important as technical skills? and (4) Do you think soft skills impact employee performance and productivity? The results of these four questions are shown in Figure 8. The vast majority of the students perceive that soft skills are just as important as technical skills. All students agree that soft skills can impact employee performance and productivity.

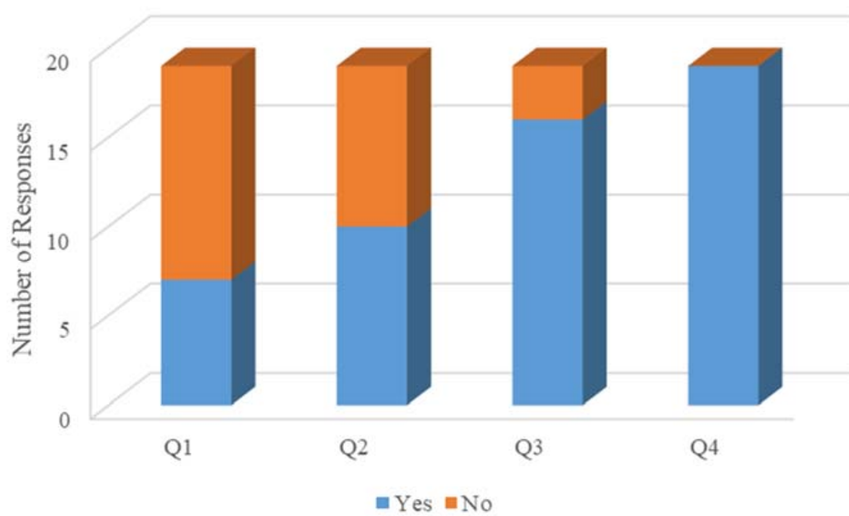


Figure 8. Student responses to manufacturing career questions.

5. Conclusions and Recommendations

Research studies show that today's job market considers soft skills just as important as technical skills. However, most academic curricula focus on the side of technical skills and have not yet paid enough attention to improving the soft skills of their students. In this research, we integrated soft skills development into manufacturing simulations in an undergraduate manufacturing systems course. We developed and delivered soft skills workshops to students. The results suggest that the benefit of teaching students soft skills extends beyond soft skill growth to improved team performance. Future work should investigate in the expansion of soft skill development in large enrollment classes and at the curricular level. The teaching of additional soft skills, such as creative thinking, should also be considered.

Acknowledgment

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