

INTRODUCTION

This project integrates sustainability into Lean Six Sigma education using project-based learning (PBL), bridging theory with real-world impact at NCSU's Compost Facility.

- Undergraduate curriculum at the Fitts Industrial and Systems Engineering (ISE) Department is primarily delivered through traditional, lecture-based methods rather than more progressive teaching approaches, such as PBL.
- ISE department and its Industry Advisory Board identify sustainability as a strategic priority, but this focus has yet to be fully integrated into the curriculum.
 - On NCSU's strategic plan, Sustainability is one of the seven Values.

→ **Combine sustainability education with PBL to better prepare students for real-world challenges and for being agents of transformation.**

- At start of Fall semester, a project was defined with University Sustainability Office, focusing on capacity improvement of NCSU's Compost Facility.
- This project was used in a core ISE course, Lean Six Sigma. This is the first step toward expanding the use of PBL within the ISE curriculum, combining hands-on learning with a greater focus on sustainability.

METHODS

Lean Six Sigma course was assigned shortly before the start of semester. Therefore, syllabus grading components – quizzes and final exam – were inherited.

Previous course offerings:

- Employed a traditional, lecture-based format
- Discussed material in a traditional manufacturing context only; did not discuss Sustainability at all
- Evaluated grasp of knowledge abstractly; used multiple choice questions for quizzes (Figure 2a) and final exam (Figure 3a)

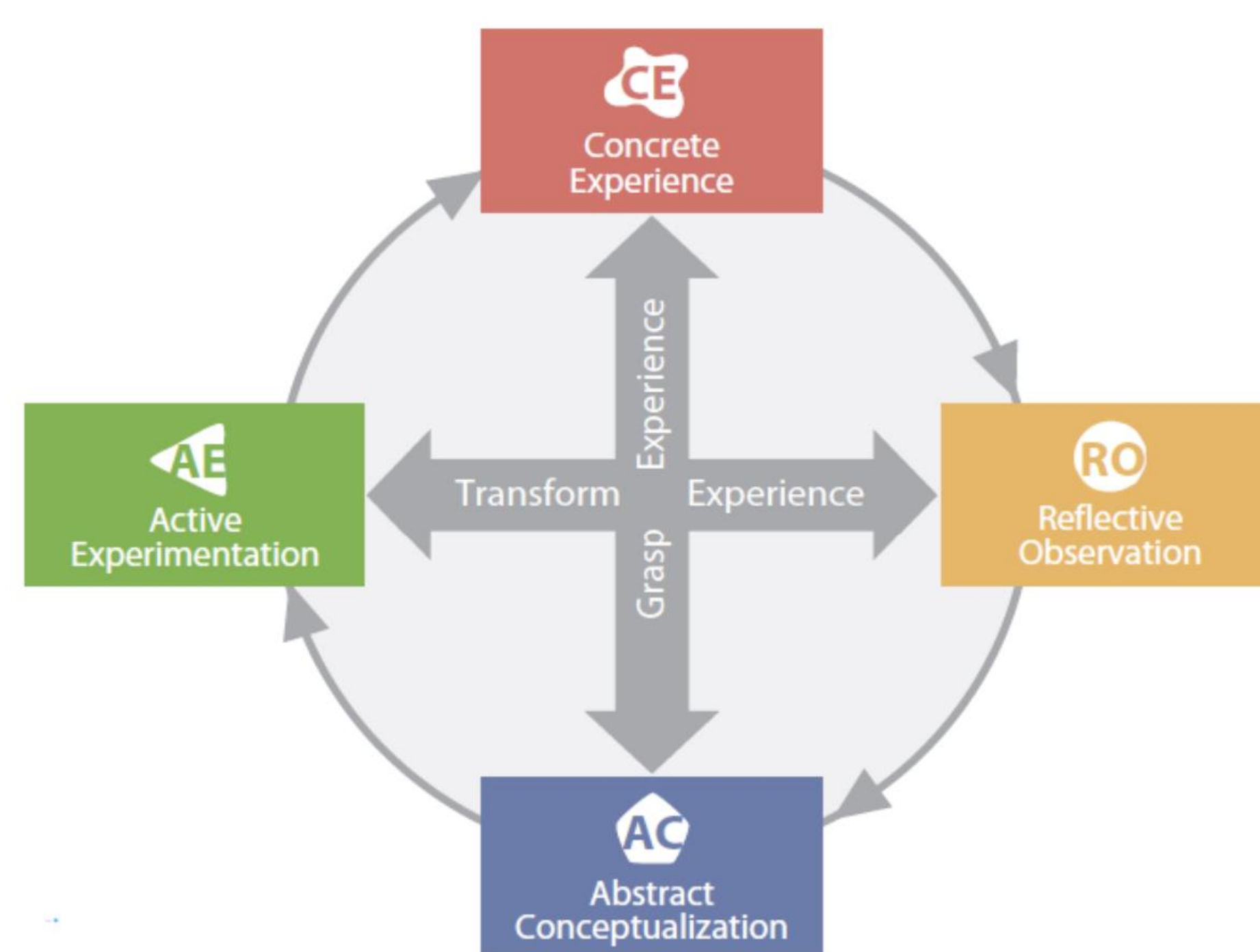
Current course offering:

- Used a PBL framework, integrating course project into topics, examples, and evaluations
 - This enhanced learning, according to Kolb and Kolb's (2013) model of learning (Figure 1)
- Focused on Lean Green to marry the concepts of Lean and Sustainability
- Evaluated grasp of knowledge – quizzes (Figure 2b) and final exam (Figure 3b) – based on project
 - Additional skills developed through literature review and presentation (Figure 4)
 - Additional skill developed through reflections (Figure 5)

Why PBL?

- Effective teaching methods should mirror practices of professionals in the field.
- Engineering educators should complement theoretical topics with real-world pedagogical components. An effective and common method is PBL.

Figure 1: Experiential Learning Cycle



Kolb and Kolb (2013) provide the basis for a model of learning that recognizes how learning occurs.



METHODS

Why Lean Green?

- Lean is based on Toyota Production System. It is a philosophy of continuous improvement, focusing on reducing waste and creating customer value.
- Lean Green supports economic, environmental, and social pillars of a production system by emphasizing waste reduction and efficient use of resources.
 - Environmental and operational goals are simultaneously pursued.**

Figure 2: Sample Quiz Questions

Poka-Yoke:
Select one:
a. Mistake-proofs a process
b. Uses the Theory of Constraints to smooth production
c. Makes material handling easier.
d. Enables data sharing of key processes.

- Develop a project charter for the Compost Center project. (60 points)
- If the Center's Coordinator were to collect VoC data, what would be some attributes that we might see? (10 points)
- Develop a SIPOC diagram for the process. (30 points)

(a) Quiz questions in previous offering of the course (blue box) were abstract in nature, and multiple choice in format. (b) Quiz questions in current course offering (green box) were applied, project-based, and short-answer in format.

Figure 3: Sample Final Exam Questions

Which statement about Standard Operating Procedures (SOP's) is incorrect:
a. It is a step-by-step procedure of all tasks.
b. All statements are correct.
c. Does not reinforce standardization and consistency.
d. It is a living document and must be updated as necessary.

NC State Compost Facility has hired you as a consultant to improve its operations. The client has identified the decontamination process as a primary area of concern. Use all the knowledge and skills gained in ISE 398 to address the problem and develop a well-supported recommendation for the client. Your final deliverable should be a concise consultant report that includes:

- A comprehensive Project Charter
- A detailed application of relevant tools and methodologies covered in ISE 398
- Final justified recommendation(s) based on your analysis

(a) Exam questions in previous offering of the course (blue box) were abstract in nature, and multiple choice in format. (b) The only technical exam question in current offering (green box) of the course was applied, project-based, and in a consultant report format.

Figure 4: Quiz 3

Students are asked to select an article, 2010-present, from either of two journals: "Cleaner Production" and "Sustainability" and create a 4-minute, recorded presentation. The presentation should focus on the following:

- A high-level summary of the article and its findings. (20%)
- What Lean Six Sigma techniques did the authors use to improve sustainability-related metrics in the project tackled? (70%)
- Drawing parallels with the Compost Center project. (10%)

Activity requires students to perform literature review and to present their findings.

Figure 5: Reflection Questions on Final Exam

- From your understanding of Lean Six Sigma and its focus on eliminating waste, how do you see Industrial Engineers playing a key role in advancing environmental sustainability? (10 points)
- Reflect on how/if working on the Compost Facility project has impacted your understanding of the role of Industrial Engineers in sustainability-focused process improvement. Did this project influence your perspective on your future career path or your sense of professional purpose? (10 points)

Questions contribute to students' critical thinking, asking them to reflect on the big picture and their sense of purpose.

STUDENT IMPACT

- Student response was very positive to PBL nature of course and sustainability focus. Sample comments from student evaluations and sample responses from Final Exam, are displayed in Figure 6, a and b, respectively.

Figure 6: Sample Comments from Student Evaluations

The course outlined the principles of lean and Six Sigma very well. All assignments were useful aids. Quizzes and assignments aligned with course goals. It is evident that Dr. Kiassat is passionate about Lean Six Sigma and sustainability. He did a great job of teaching us the concepts of Lean Six Sigma whilst making it relevant to outside scenarios and projects. This course definitely improved my understanding of Lean Six Sigma and how to implement it. All the lecture material was appropriate for the course. The term project was a great application of what we learned. I walk out of the class knowing more about lean than I had before. I could definitely apply the course material to many different aspects, outside and inside of school.

(a) Direct student quotes, showing appreciation of course format and practical approach.

In my few years of experience with LEAN and Six Sigma, I have only seen it utilized by manufacturing systems. These seem like the most likely candidates for the cultural and systematic implementation on these concepts. But, the compost center project has opened my eyes to new ways to apply these concepts. As for my professional purpose, the compost center project was a source of inspiration. I had always thought of LEAN Six Sigma as tools for more efficient manufacturing, but, I now see them as necessary tools for a sustainable planet. The goals of LEAN and Six Sigma are not make immediate change, but rather continuous improvement. Establishing a sustainable system is not an instant change and never will be. It is making small improvements towards a much larger goal, you can see the similarities between this and LEAN Six Sigma. This is where Industrial Engineers come into play. Through concepts such as lean six sigma, we can focus on reducing material use in manufacturing, and limiting energy consumption through eliminating wasteful activities and processes that are only in a company because "it has always been that way". Throughout this course I gained a deeper understanding of what Lean Six Sigma was and how to apply it to real-world scenarios. As someone that learns best through examples, this was immensely helpful. Whilst analyzing the Compost Facility I was able to pinpoint a few aspects that were not Lean Six Sigma friendly and was able to come up with ideas based off the course material.

(b) Direct student quotes, responding to Reflection questions displayed in Figure 5

PLANS

- Establish a strong presence as a faculty member actively engaged in sustainability initiatives
- Pursue additional grants to develop and implement pedagogical innovations centered on sustainability
- Strengthen collaborations with fellow EOP Cohort III scholars to enhance interdisciplinary efforts
- Apply PBL and EOP framework with a focus on sustainability in future courses
- Use courses where sustainability has been successfully integrated as a proof of concept to encourage adoption among ISE faculty.
- Develop and implement sustainability modules across multiple courses in the undergraduate ISE curriculum, leading to the creation of a micro-credential in sustainability.

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