Methodology to implement project-based learning (PBL) within the context of Operations Management.

Dr. Mahesh Kumar Pallikonda, Austin Peay State University

Dr. Mahesh Kumar Pallikonda is a faculty member in the Department of Engineering technology at Austin Peay State University (APSU). Prior to his academic career, he gained valuable industry experience in roles ranging from New Product Development to Process Control. He holds a Ph.D. and a Master's degree in Mechanical Engineering from Cleveland State University, as well as a Bachelor's degree in Manufacturing Engineering from the National Institute of Advanced Manufacturing Technology. Prior to joining APSU, he served as a faculty member at Ohio Northern University, where he taught courses on the fundamentals of electronics, including electrical circuits. At APSU, Dr. Pallikonda instructs courses specializing in Robotics and its applications, Engineering Economics, CAD and Manufacturing processes. Dr. Pallikonda is passionate about educating and inspiring the next generation of engineers, technologists, and innovators through his lectures. He is deeply committed to advancing the fields of robotics and manufacturing through interdisciplinary research in connected devices and Industrial Internet of Things (IIoT). His research interests span Manufacturing, Material Science, pedagogy, Lean Six Sigma, and Industry 4.0

Dr. Hossain Ahmed, Austin Peay State University

Hossain Ahmed earned an M.S. in mechanical engineering from Lamar University and a Ph.D. in mechanical and energy engineering from the University of North Texas. Dr. Ahmed is an assistant professor in the Department of Engineering Technology at Austin Peay State University, TN. His research interests are computational fluid dynamics (CFD), corrosion, and structural health monitoring (SHM). Dr. Ahmed has authored many journals, conference articles, and book chapters. He also serves as a reviewer for several international conferences and peer-reviewed journals.

Dr. Md. Ali Haider, Austin Peay State University

Dr. Md. Ali Haider is an Assistant Professor at Austin Peay State University, serving as the Electronics and Electrical Engineering Technology concentration coordinator. His research interests include Biomedical Signal Processing, Brain-computer interface, Image processing, Artificial Intelligence, Machine Learning, and the Internet of Things (IoT). Dr. Haider has authored multiple publications on signal and image processing and serves as a reviewer for several international conferences and peer-reviewed journals, including IEEE WF-IoT, IEEE EIT, IEEE Signal Processing Letters, Journal of Signal Processing Systems, and Remote Sensing of Environment.

Prof. Ravi C Manimaran, Austin Peay State University

Ravi C Manimaran is a Professor and Chair of the Department of Engineering Technology, Austin Peay State University, Clarksville, Tennessee. His education includes two Master of Science degrees in Electrical & Computer Engineering and Electronics and Control Engineering. He has been actively involved in higher education leadership in various capacities as a Dean, Department Chair, PI, Project Director, and a faculty member since 1997. He has served as the PI / Project Director for multiple agencies including NSF, DOL, DOD, and Perkin's Grant. His research interests include Industrial Automation Systems, VLSI, ASIC, and FPGA. Other areas of interest are Higher Education Leadership and Accreditation including ABET.

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Abstract

Operations Management represents a crucial discipline intersecting engineering and business, dedicated to refining processes, optimizing resources, and streamlining systems to elevate overall efficiency and productivity. Traditionally, this course has been delivered through lecture-based classes heavily grounded in mathematical models encompassing forecasting, inventory management, scheduling and operations planning, material requirements planning, and manufacturing resource planning. In pursuit of elevating the students' active learning and knowledge retention, we introduced PBL as an innovative pedagogical strategy. This paper begins with a review of the literature on PBL in engineering education and operations management, highlighting its benefits in fostering critical thinking, teamwork, and real-world problem-solving skills. It also addresses the challenges associated with implementing PBL in this context. In conclusion, the paper underscores the significance of PBL as an effective instructional method for Operations Management education, lessons learned, challenges of implementing PBL in operations management, and future recommendations for similar studies.

Introduction

Project-Based Learning (PBL) has emerged as a transformative educational approach that goes beyond conventional teaching methods, placing students at the epicenter of their learning journey [1][2]. PBL's roots can be traced back to the mid-20th century with the ideas of educational philosopher John Dewey. Dewey advocated for learning through experience and hands-on activities, emphasizing the importance of connecting classroom knowledge to real-world applications [3]. In the 21st century, PBL has become increasingly integrated into educational reform efforts globally. The emphasis on 21st-century skills such as critical thinking, communication, collaboration, and creativity has fueled the adoption of PBL as an effective methodology to develop these competencies [4]. The widespread availability and use of technology in education has further facilitated the implementation of [5]. Digital tools and online platforms provide new avenues for collaboration, research, and presentation. The continuous evolution of PBL reflects a response to the changing educational landscape and a recognition of its effectiveness in preparing students for the complexities of the modern world.

Project-based learning enables students to delve into real-world problems and wear the hat of a problem solver. In the context of operations management, Project-Based Learning in Operations Management is instrumental in preparing students for the industry's challenges and demands. It goes beyond traditional teaching methods, providing a holistic and immersive educational experience that equips students with practical skills, problem-solving abilities, and a deeper understanding of the complexities inherent in the field of Operations Management. Operations Management often involves solving complex problems related to production, logistics, and supply [6]. It uses techniques such as Total Quality Management (TQM), lean management, six sigma and others. On the other hand, Operations Research is field of study within the domain of

business operations where optimal solutions for the problems in scheduling, inventory management and others using mathematical modeling, game theory, optimization algorithms and simulations [7]. However, some techniques from Operations Research are universally used in Operations Management to optimize a process and informed decision-making. PBL encourages students to think critically, analyze situations, and develop effective problem-solving skills—essential competencies in the Science, Technology, Engineering and Mathematics (STEM) fields, see figure 1. PBL provides an environment where students can simulate decision-making scenarios that resemble real-world challenges in operations. This helps them develop decision-making abilities and understand the consequences of various choices [8]. Finally, PBL projects can be designed to align with students' interests, making the learning experience more engaging and motivating. When students see the direct application of their studies to real-world scenarios, it enhances their enthusiasm for the subject [9][10].

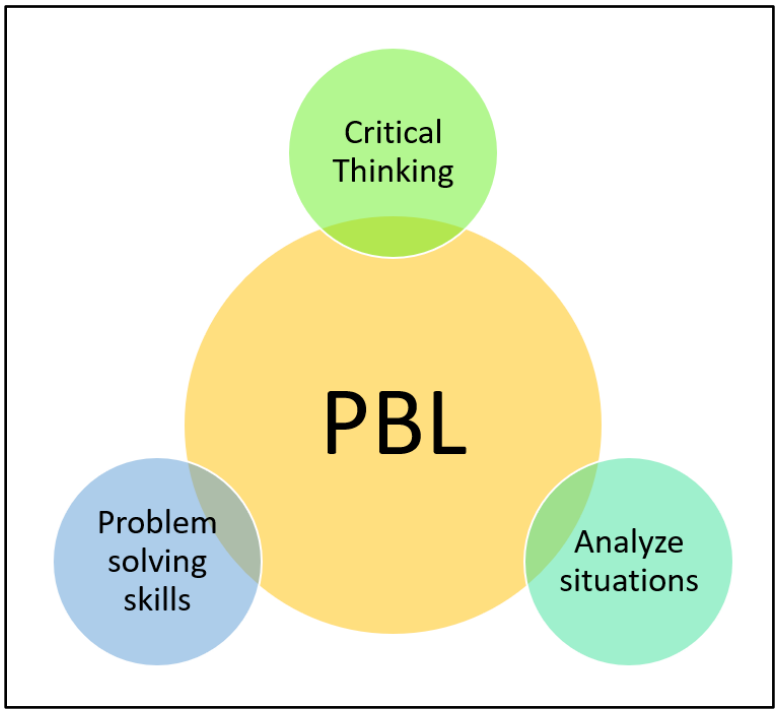

Figure 1: Key drivers for incorporating PBL

This paper is aimed at summarizing the results of implementing PBL in an operations management course. The cohort of students that participated in this study are either senior or junior majoring in Engineering technology (ET) with concentrations in Manufacturing and/or Mechanical. As a part of this study, students will conduct self-directed learning and investigate a case study in the domain of Production and Operations Management using real-world data. This study is part of a project aimed at developing project-based learning and continuous improvement strategies to align with ABET student outcomes. Finally, this paper will summarize the lessons learned, challenges of implementing PBL in operations management, and future recommendations for similar studies.

Data Set:

The pilot study of implementing PBL is conducted in the Production and Operations Management course. This is a required course in the Manufacturing ET Curriculum and a concentration guided elective for the Mechanical ET program. The cohort size is 8 students, and the coursework is spread over an eight-week schedule. The majority of the students are male (75%; 6 out of 8 students). Furthermore, the sample set consists of five Manufacturing ET students and three Mechanical ET students. Moreover, out of eight students, five are in senior class (62.5%) and the rest are classified as juniors (37.5%).

Project Description:

A complete submission of a project consists of three major components, i.e., Presentation, Participation, and a Reflective paper, as shown in figure 2. Students will research any topics within the domain of Production and Operations Management. Students are expected to bring real world scenarios as a case study. Project constitutes 30% of your total grade. Students can pick their partners (not more than 2 students) to work on the project.

Example topics:

- Forecasting the trend of influenza using historical data.
- Predicting stock prices of any stock using historical data.
- Role of alpha and Beta in forecasting and ways to manipulate them.
- Various organizational strategies with real world examples.
- Supply chain management with real world examples and case study.

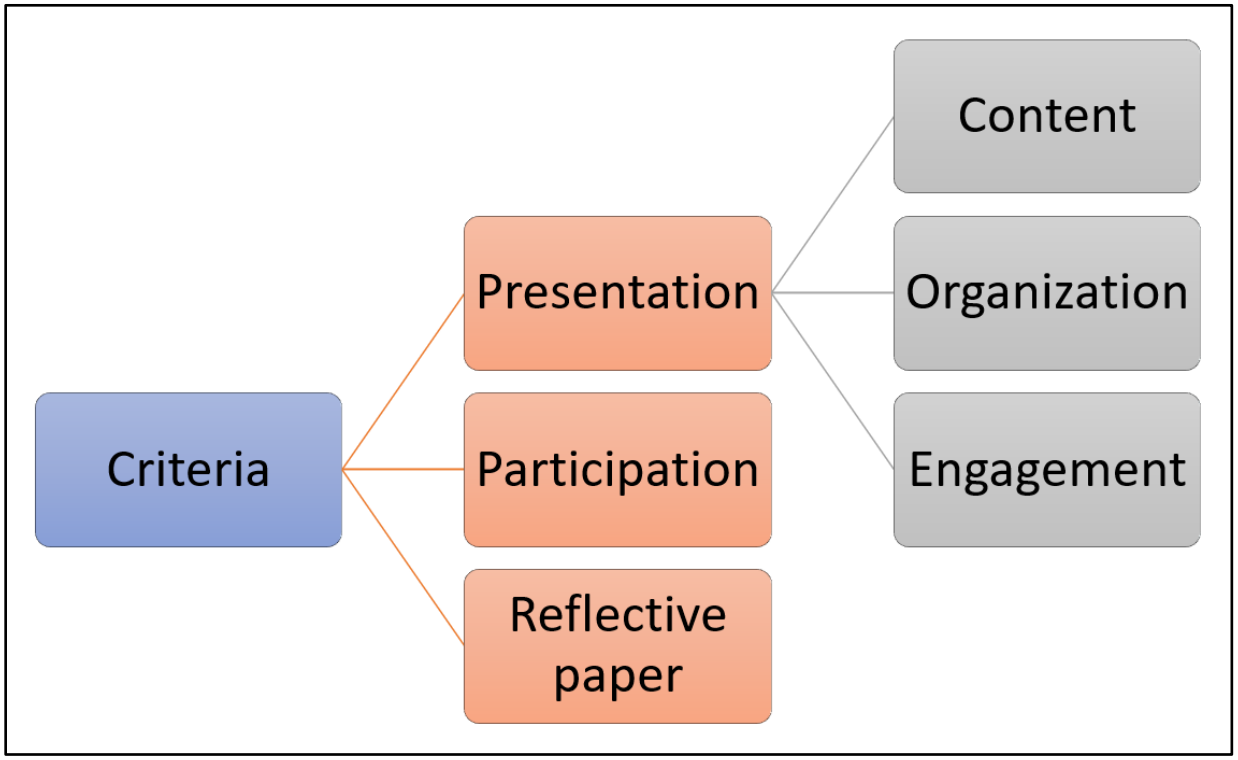

Figure 2: Components considered for evaluating projects

Presentation: Presentation is an oral Communication where a prepared, purposeful, presentation is designed to increase knowledge, to foster understanding, or to promote change in the listeners' attitude. To promote purposefulness and foster understanding, students are given the flexibility of the presentation time. However, they were informed not to exceed 25 minutes. This enables them to focus on the content dissemination rather than filler material. Presentation assimilates students' work, be it a forecasting analysis or a factory's POM strategy. Grading is divided into three components, i.e., content, organization, and engagement. All three components are rated from 1 to 5. 1 being poor and 5 being excellent. Table 1 provides the rubric used for grading the presentation. Presenting their projects in class not only allows students to share their experiences with their peers but also fosters higher-order learning and thinking. By articulating their methodologies, analyzing their findings, and answering questions from their classmates, students engage in critical reflection and synthesis of their learning. Moreover, the act of presenting addresses important ABET student outcomes for oral communication, as students must effectively convey their ideas and findings in a clear and coherent manner. As students gain experience in presenting, their confidence grows, enabling them to communicate more effectively and persuasively. This process of presenting and receiving feedback also encourages students to reflect on their work, identify areas for improvement, and engage in continuous learning and improvement. Overall, presenting their findings in class serves as a catalyst for enhancing students' critical thinking skills, oral communication abilities, and commitment to continuous improvement in their academic and professional endeavors

Table 1: Rubric used for grading Student Presentations

Criteria	Excellent	Good	Satisfactory	Needs Improvement	Poor
Content	The information included is accurate and completely addresses each component of the assigned topic or research question.	The information included adequately addresses each component of the assigned topic or research question.	The information included inadequately addresses the assigned topic or research question. The information included is sometimes inaccurate.	The information included does not address the assigned topic or research.	There is no evidence of accurate content information.
Organization	The presentation content has been organized using a logical sequence. The presentation is	The presentation content has been mostly organized using a logical sequence, but some flaws	The presentation content has been organized using a somewhat logical	The presentation content is disorganized, unclear, or confusing. The presentation	The presentation does not include evidence of organization .

	engaging and effective.	exist. The presentation is adequate.	sequence. The presentation is sometimes confusing.	is not adequate.	
Engagement	The presenter effectively and creatively delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are effectively used.	The presenter adequately delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are mostly appropriate.	The presenter delivers the information but does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter omits important information and does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter does not effectively deliver the necessary information.

Participation: Participation is intended to improve the listener's attitude. Students are required to ask questions and have an intellectual discussion. Participation during presentations is a pivotal aspect of the learning process, as it allows students to actively engage with the material being presented and contribute to the collective understanding of the topic. By listening attentively to the presenter and asking relevant questions, students not only demonstrate their interest and investment in the subject matter but also enhance their comprehension and critical thinking skills. The incorporation of participation points incentivizes students to actively participate in the learning process and fosters a positive attitude towards engaging with their peers' presentations. Grading is more of a qualitative nature rather than quantitative approach for this section. Unlike quantitative grading approaches, which may prioritize quantity over quality, the qualitative assessment of participation encourages meaningful interactions and thoughtful contributions. This qualitative approach enables instructors to assess the depth of students' engagement, their ability to pose insightful questions, and their capacity to engage in constructive dialogue with their peers. By emphasizing participation as a key component of the learning experience, instructors promote a student-centered approach to education, where active engagement and collaboration are valued and encouraged. Ultimately, participation points serve as a catalyst for promoting immersive, student-driven learning environments where knowledge is co-constructed through meaningful dialogue and interaction.

Reflective Paper: As a part of reflective paper students submitted a concise 2–3-page reflection. Our program is Engineering technology where we emphasis hands on learning and the student

body is mix of traditional and non-traditional students. Over 75% of the student body taking this class are working either full-time or part-time. Therefore, encouraging students to approach their reflective paper informally fosters a conducive environment for expressing their own perspectives and insights, rather than conforming to a rigid academic structure. This approach minimizes the burden of formatting and styling, enabling students to channel their focus towards synthesizing their thoughts and reflections on the chosen topic. Through this reflective process, students are prompted to delve deeper into their thought processes, articulating their rationale for selecting a specific topic and elucidating their comprehension of the subject matter. By articulating their own interpretations and insights, students engage in critical self-reflection, evaluating their learning journey and identifying areas for further exploration and growth.

Moreover, the informal nature of the reflective paper encourages students to adopt a more personal and introspective approach, facilitating creative thinking and problem-solving. This emphasis on individual expression and creativity cultivates a culture of intellectual curiosity and exploration, where students are encouraged to challenge conventional wisdom and think creatively. Overall, reflective paper serves as a valuable tool for promoting critical thinking and analytical skills. By providing a platform for students to express their thoughts and reflections in their own words, instructors nurture a learning environment where diversity of thought is celebrated, and students are empowered to become active agents in their own learning journey.

Finally, students are given the option of forming teams of two students. Although students work in teams on studying and preparing for the presentation, the reflective papers are meant to be individual artifacts. Reflective papers are not tied to teamwork and are aimed at gathering each student’s personal thoughts and reflections on the topic chosen by the team.

Embodying Core PBL Principles:

In alignment with Dewey’s principles PBL is deeply rooted in hands on learning and connecting classroom knowledge to real-world applications there by fostering student-centered learning and active learning. Incorporating PBL into the curriculum bridges the gap between theoretical knowledge and practical application, fostering an immersive learning experience for students. By engaging with real-world data sets, students actively apply classroom concepts to authentic scenarios, promoting hands-on learning and critical thinking. Through the freedom to choose topics within the realm of Production and Operations Management, students take ownership of their learning journey, driving motivation and engagement. The project's inquiry-based approach encourages students to explore, analyze, and solve complex problems, cultivating essential skills for success in their field. Through this project, students worked on real world data sets and enjoyed working with mathematical models for forecasting the prices or economic activity in a region. Furthermore, by examining operational strategies of established firms, students gain insights into industry practices, enhancing their understanding of Operations Management principles. Overall, the project embodies the core principles of PBL by empowering students, promoting active learning, and fostering practical skills development within the context of Operations Management education.

Project Outcome:

Students were successful in completing the projects in time. Despite being given the option to work in teams, out of total cohort of eight students, four students decided to work independently. The remaining four paired to form two teams consists of a team with two students. This resulted in a total of six projects. Table 2 provides the list of projects with the number of students working on each project. Column 1 shows the team number, column two indicates the number of students in a particular team and column three indicates the project title as provided by the student. It is noticed at least a few teams came with descriptive titles and others are cryptic. Nevertheless, the title alone is not a criterion to grade the student performance and used as an informational piece of their project.

Table 2: List of student project titles

Team Identifier	Number of students	Project Title
1	1	Forecast for the Shell Chicken Eggs Price in the USA Market
2	2	Ikea's Warehouse Layout
3	1	Process Strategies
4	2	Forecasting Montgomery Visitor Spending
5	1	The Several Factors that Determine a Firm's Location
6	1	A Structural Products Industry's Effective use of POM

Lessons Learned:

The instructor of this course is a tenure track faculty and teaching this class for the first time. The instructor's teaching philosophy is deeply rooted in Socrates questioning and project-based learning. These qualities of the instructor religiously motivate him to instill critical thinking and project-based learning into his curriculum. Overall, this project was a wonderful experience for him since he had never taught this course before. Ideally, the instructor expected all students will find data from internet sources to build seasonally adjusted time series such as Team #1 and #2. However, project work was announced to students at the start of the semester, and this led to a broad spectrum within operations management for the topics to be chosen. The instructor is confident in the next offering he will be able to improve the quality of the projects by narrowing the project focus.

Furthermore, students shared after the presentations were completed that they felt they learned a lot working on the projects and improved their learning. In the course evaluations one student commented as below:

"The class presentation allowed us to showcase our understanding of concepts with the use of current and relevant data."

Moreover, assisting students with data collection, explaining them the outliers in the data, and explaining the multiple reasons why a company has to changes their strategies and others had significant impact which translated in students improved confidence on instructor. Below are testimonials of students from the course evaluations.

"Very useful information was given when compared the course material to real world applications and emphasized concepts widely used in industry."

"I really liked the fact that Dr. Pallikonda has the necessary background in industry and in the concentration to teach the course."

Challenges:

This course was offered on an 8-week schedule. The accelerated course offering negatively impacted the student's performance. Students said they had little time from the completion of coursework to work on projects. This demotivated students to work on time consuming projects involving associative models or MRP (which is covered during the last two weeks of classes). Additionally, the instructor anticipated the students will work in teams which is directly linked to the ABET student outcome 4 that states "Students have the ability to work as a team to deliver results in a timely manner". However, a plethora of factors negatively affected it, not limiting to accelerated coursework.

Moreover, small cohort size resulted in few projects. This did not give the opportunity to the students to learn from peers. The more the projects, the more approaches students get to witness. A bigger cohort and higher number of projects would have directly impacted the positive student learning. The majority of the students are non-traditional students. This is another reason for the courses to be offered in the evenings. Most of the students work in the mornings and attend classes in the evening. Therefore, most students felt the coursework was overwhelming and also did not give them the opportunity to work in teams.

Future Recommendations:

- Discuss the project's expectations more elaboratively, including the necessities for descriptive titles and the scope of the project.
- Encourage teamwork, if time permits, give students time to work on the projects during the scheduled class meeting times
- Emphasis the importance of the reflective paper, it was noticed at least two students did not do a comprehensive work and submitted a half-written report.
- Give a format with questions in place of reflective paper. This will enable all the reports to be consistent and serve as an indirect assessment tool.
- Add a type of direct assessment in the form of quiz or exam question to understand student learning.

Conclusion:

This study is another clear indication that students enjoy project-based learning and show interest in learning the concepts. Students indicated a distaste for the course initially, especially when

time series and data analytics were introduced. However, students' engagement with the course material and understanding of the content improved dramatically when the students started to engage with the project work. Their mundane attitude to operations management transformed into excitement while working with the project work. Nevertheless, with improved student learning, there are also a handful of challenges that need to be addressed. A few challenges are easy to address and the instructor is working on the continuous improvement of the student learning and engagement. However, there are few inherent challenges such as non-traditional students lack time or find mutually agreeable time to work on projects. Short term (8-week terms) has limited time to absorb the course content and reflect it on the projects. Overall, it achieved a satisfactory improvement in student learning and with the future recommendations, we can offset the challenges to an extent.

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