Artificial Intelligence and Machine Learning Applications in Engineering Project Management: Developing A Course Module

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Dr. Eva Singleton is an Assistant Professor in the Department of Engineering Leadership and Program Management (ELPM) in the School of Engineering at The Citadel Military College in Charleston, SC. She is a certified Project Management Professional with over a decade of experience in various industries, including publishing, manufacturing, and government contracting. She enjoys teaching and serving in complex project management roles requiring adaptability and problem-solving, strategic planning, and leadership skills. Dr. Singleton is enthusiastic about educating professionals and students to advance their business and academic endeavors using project management competencies, tools, techniques, and leadership. Dr. Singleton's research interest includes interdisciplinary topics related to project management, such as leadership, entrepreneurship, artificial intelligence, process improvement, and burnout. The purpose of this paper, Artificial Intelligence and Machine Learning Applications in Engineering Project Management: Developing A Course Module, is for students to understand the basics of Artificial Intelligence and Machine Learning.

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Artificial Intelligence (AI) and Machine Learning (ML) are pivotal topics in today's education and have a significant impact on the future of engineering careers. AI and ML applications are gaining popularity in real-world engineering projects, making it essential for all engineering students to learn about the evolving tools and techniques. The objective of this paper was developing a specialized module within an Engineering Project Management and Planning course, offering students insights into the versatile applications of AI and ML in project management. The module focuses on four primary learning objectives. To achieve these objectives, we explored three key aspects of AI and ML in project management: 1) Enhancing decision-making through AI and ML predictive capabilities; 2) Optimizing resource allocation by automating report generation, virtual assistance, and automating communications; and 3) Mitigating project risks through early detection of positive, negative, or neutral data through using Natural Language Processing (NLP) as documents are reviewed. To ensure a comprehensive understanding for students, we integrated a few AI and ML tools currently utilized in industry projects into the module, summarizing their potential advantages and disadvantages. The module was designed for graduate-level students and spans one week of a three-credit-hour course. An in-class activity was included to engage students actively in the learning process. Students' attainment of the learning objectives will be assessed through a subsequent homework assignment, a quiz and one exam question in the form of matching statements. While primarily designed for graduate-level students, this module can be adapted with minor adjustments for inclusion in undergraduate-level engineering project management courses.

Introduction

Rapid advancements in Artificial Intelligence (AI) and Machine Learning (ML) in the past decade transform the practice of project management like most of the other disciplines. Research studies and current practices indicated that AI could assist project teams and project managers through automating repetitive tasks such as analysis for estimation and risk assessments, as well as project communications [1-6]. AI and ML could increase project productivity and free up project managers' time to focus on more strategic and complicated decisions [5].
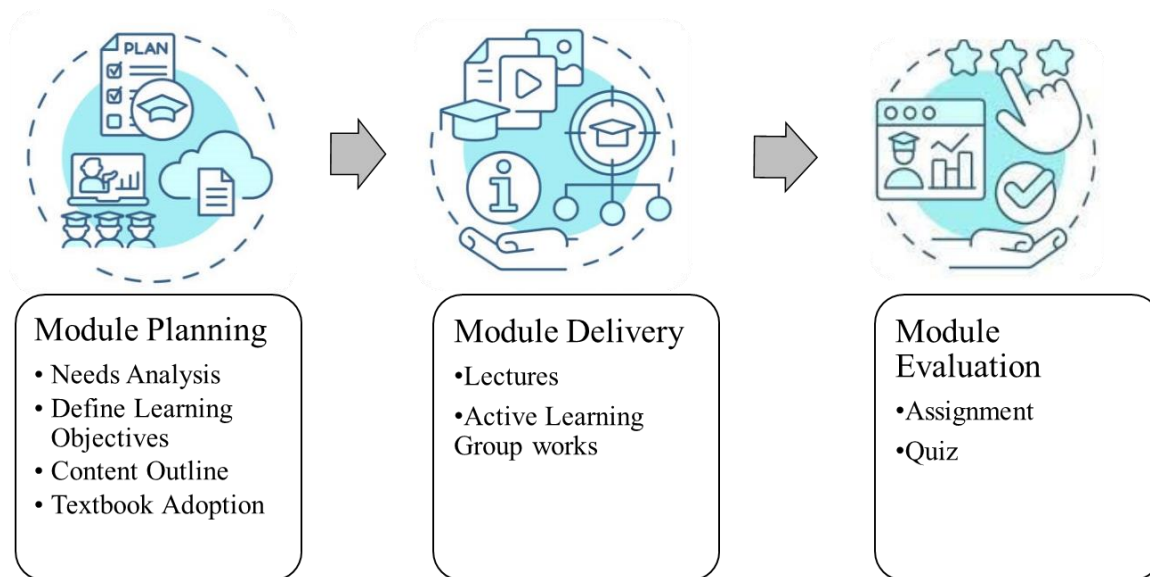
Students in the Engineering fields should prepare for tremendous changes in their future careers and should gain foundational knowledge and skills for AI integration in Engineering Project Management. As educators, we need to incorporate key aspects of AI and ML into the existing courses and develop new courses to keep up with the rapid changes. This paper aims to develop a course module to be added into the current Engineering Project Management and Planning course material and provided an overview of the course module. Figure 1 depicts the three steps to develop the new course module: Module Planning; Module Delivery; and Module Evaluation. Each of these steps are described extensively in the following sections:

Module Planning

The first step in the course development process, i.e., Module Planning, includes: Need Analysis, Define Learning Objectives, and Content Outline.

Need Analysis: Engineering Project Management is a comprehensive and interdisciplinary field covering multiple engineering disciplines. It encompasses project management principles, processes, and basic tools and techniques, aiming to prepare the students for success and equip them with the tools to work efficiently in project teams to accomplish project objectives.

However, the content in this course at The Citadel Graduate College was developed more than eight years ago and revised after *A Guide to the Project Management Body of Knowledge Seventh Edition* (PMBOK) was released. The need for an AI and ML module to introduce the rapid growth and adoption of AI tools in the industry projects was identified by the instructors. This module development was motivated to provide the students with the most updated and available tools to improve the project management processes and increase the success rate. The tools include but not limited to AI-powered project management software such as Trello, Asana, Monday.com and Smartsheet. These tools leverage AI to offer features such as task automation, predictive analytics, and resource allocation optimization to improve project management efficiency and effectiveness.

Module Planning
- Needs Analysis
- Define Learning Objectives
- Content Outline
- Textbook Adoption

Module Delivery
- Lectures
- Active Learning Group works

Module Evaluation
- Assignment
- Quiz

Figure 1-Course Module Development Process

Define Learning Objectives: To respond the need mentioned above, the four module learning outcomes were identified and defined as follows:
1. Discuss the Basics of AI and Machine Learning:
   - Define and explain fundamental concepts related to artificial intelligence and machine learning.
2. Identify Opportunities for AI Integration in Project Management:

- Identify areas within project management where AI can be effectively applied to enhance efficiency and decision-making.
- Evaluate the potential benefits and challenges of integrating AI into project management processes.
3. Examine Real-world AI Applications in Project Management:
   - Explore and analyze case studies and examples of successful AI implementations in project management across various industries.
   - Assess the impact of AI on project outcomes and organizational performance.
4. Evaluate AI Tools and Technologies:
   - Familiarize with different AI tools and technologies used in project management.
   - Evaluate the capabilities and limitations of specific AI tools for various project management scenarios.

Content outline: The third part of the planning phase focused on the content of the course. To accomplish the learning objectives, the course should include an overview of the fundamental AI and ML concepts and major components to discuss how they will be helpful in assisting project managers. It will also help the students to recognize the prediction capabilities of AI and ML. The concepts include, but are not limited to: Introduction to main terminologies such as AI, ML, Deep Learning and Data Science and their differences; Data preparation (Cleaning and Wrangling); Data representation; Supervised, unsupervised, and reinforced learnings; Neural Networks; Natural Language Processing (NLP); and Predictive analytics. In this part of the course content students will learn about AI which is an overarching field focused on creating machines or systems that can perform tasks that typically require human intelligence. Then they will be introduced to ML that is a component of AI that employs algorithms and statistical models to empower computers to acquire knowledge and formulate predictions or choices based on data. Then the distinct subfield of ML, Deep Learning, that focuses on artificial neural networks will be introduced to students. The distinctions of Data Science field as well as its overlap with AI will be also explained to assist students comprehending the next part of the content. Figure 2 depicts the relationship among AI, ML, Deep Learning and Data Science.
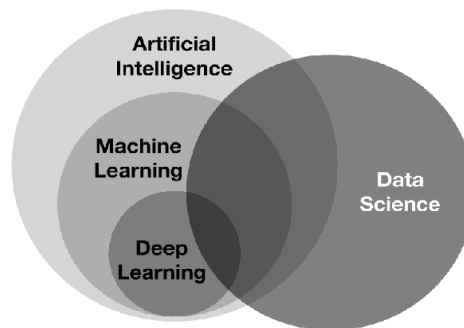

Image credit: https://lotuslabs.medium.com/

Figure 2- Venn Diagram to Clarify AI, ML, Deep Learning and Data Science overlaps.

After introducing AI and ML, the module will cover the major possible integration of AI and ML into project management. Three key aspects of AI and ML in project management were

explored after extensive review of the existing books and journal articles and based on the recent advancements in the project management tools: 1) Enhancing decision-making through AI and ML predictive capabilities; 2) Optimizing resource allocation; and 3) Mitigating project risks.

- Enhancing decision-making through AI and ML predictive capabilities: A major impact of the integration of AI and ML in project management is improving the accuracy of decisions based on predictive analytics of the models. AI systems provide decision support by analyzing vast amounts of data to recommend optimal decisions. This is particularly valuable in situations where multiple variables need to be considered, helping project managers make more informed choices. Additionally, AI algorithms analyze historical project data to identify patterns and trends. This enables predictive analytics for estimating project durations and activity costs, and resource requirements which will be insightful for project managers.

- Optimizing resource allocation: Using AI could help optimize human resources by automating report generation or virtual assistance. Furthermore, communication management, which is one of the crucial responsibilities of the project manager could be automated by utilizing appropriate AI systems. Moreover, AI helps optimize resource allocation by considering factors like team members' skills, availability, and workload. This ensures that the right people are assigned to the right tasks at the right time, improving overall project efficiency.

- Mitigating project risks: Improving project risk management could happen by predictive analytics of the historic data as well as sentiment analysis of project documents and early issue detection from textual data. Analysis of the data from past similar projects will be useful in identification of the risks, and calculating the probability and level of impacts of the risks if they occur. Also, the risk responses of past projects could be evaluated, and more reliable action plans could be created by project managers.

Textbook adoption: Four different books were reviewed as potential adopted textbooks for this module. The review results are summarized in Table 1.

According to the reviews, the first book listed in Table 1 was selected as the required textbook due to coverage of the module content and affordability. The second book was included as recommended textbook for the interested students to extend their knowledge and learn the step by step modeling process. In addition to the textbooks, some of the articles referred to in this study were also used for students' class activity or case study reviews.

Table 1-Summary of Reviewed Textbooks

Book Title	Author/ Year Published	Comments
Applying Artificial Intelligence to Project Management	Paul Boudreau/ 2019	It started with an introduction of AI/ML and importance of data in the current world of decision making and then overviewed some sample AI tools to be used in project management. It also discussed how to acquire the best AI tool for any particular project. It appeared as a good beginner book for students with no background in AI and ML. It is only 160 pages and easy to read. The price is also reasonable ($11.95) to be included as required textbook for the students.
Artificial Intelligence in Project Management and Making Decisions	Pedro Y. Pinero Perez; Rafael E. Bello Perez; Janusz Kacprzyk/ 2022	This book compiled 23 technical articles and categorized them into 4 parts: Linguistic data summarization for decision-making in project management; Planning and sustainability of projects assisted by AI; Knowledge and human resource management assisted by AI; and BIM and other emerging technologies in project management. It includes deep discussions and details on how each model was evolved and could be incorporated into the decision-making process. It included step by step modeling processes such as inputting data and required algorithms, which makes it difficult for beginners. It could be a great reference for those students who are interested to peruse more information and implement it in their career. The price is high to be the reference for only. one module ($167.40)
Artificial Intelligence and Machine Learning in Project Management: A New Era of Transformation	Lukasz Dziewiecki/ 2023	It provided an overview on transformation of the project management processes from traditional to AI-driven methods. It also discussed the applications of AI and ML in several aspects of the project management and its impact on the productivity of the projects. It included a discussion on legal and regulatory landscape for AI and ML in project management and shared a few AI-ML models along with the detailed use cases to guide the project managers how to benefit from these capabilities. This book's language is less technical and is at the introductory level. Its price is low and suitable to be included as a textbook ($11.67).
Project Management in the Age of Artificial Intelligence: Strategies for the Future	J Red/ 2023	This book only provided a very general overview on the AI applications but lacks detailed information to understand how it could be implemented. The price is high ($53.00).

Module Delivery

As pointed out in figure 1, the next step was delivering the module. This course is offered to graduate students in both online and face-to-face sections. The module is worth three hours of class content, required for one week. The lecture slides were prepared based on the targeted students and included all the content discussed in the previous section. Besides all the potential and benefits that AI and ML could offer, the challenges and considerations were also planned to be discussed during the lecture. At least one case study from the referenced articles would be discussed in the class. And finally, a class group activity was designed to engage students effectively. The students will be asked to discuss ethical consideration of the AI and ML integration in project management in their assigned group and summarize their opinions for the class. They will be encouraged to search online and provide examples of real-world projects that faced ethical issues. In the online delivery modality, the students will be assigned to complete a discussion board assignment with the same topic to replace this class activity.

Module Evaluation/Assessment

After finishing the module, the students are required to complete a homework assignment. Each student should explore their own work environment and find how integrating one of the introduced AI/ML tools could improve their performance and work productivity. Since the majority of the graduate students are working, they are expected to come up with real scenarios. But in case their work is irrelevant to projects, they should create a fictional scenario and answer this question. If they are already implementing any AI/ML tool, they could explain it and find another opportunity for improvement.

An end-of-module quiz was also designed to evaluate the students' learning outcome and will be one of the ten quizzes of the course. The quiz was created on Canvas and could be included in both face to face and online modalities. The final examination will also include at least one question from this module to ensure students attained the learning objectives.

Conclusion and Future Works

The current transformation in the project management field in the presence of Artificial Intelligence and Machine Learning is inevitable. Educators should prepare the next generation to face these changes and provide them with the required knowledge and skills. This paper designed a course module for graduate level students enrolled in Engineering Project Management course to introduce the opportunities of integrating AI and ML into project management processes. Although it is originally designed for graduate level, the module could be simplified to be included in the undergraduate Engineering Management courses too. The next step would be developing a full course on this topic for graduate level. The ultimate goal is to offer other in-depth courses for AI and ML applications and eventually offering a graduate certificate for students who will take all four courses.

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