The Evolution of Engineering Management Program Assessment: Lessons Learned in Digital Delivery

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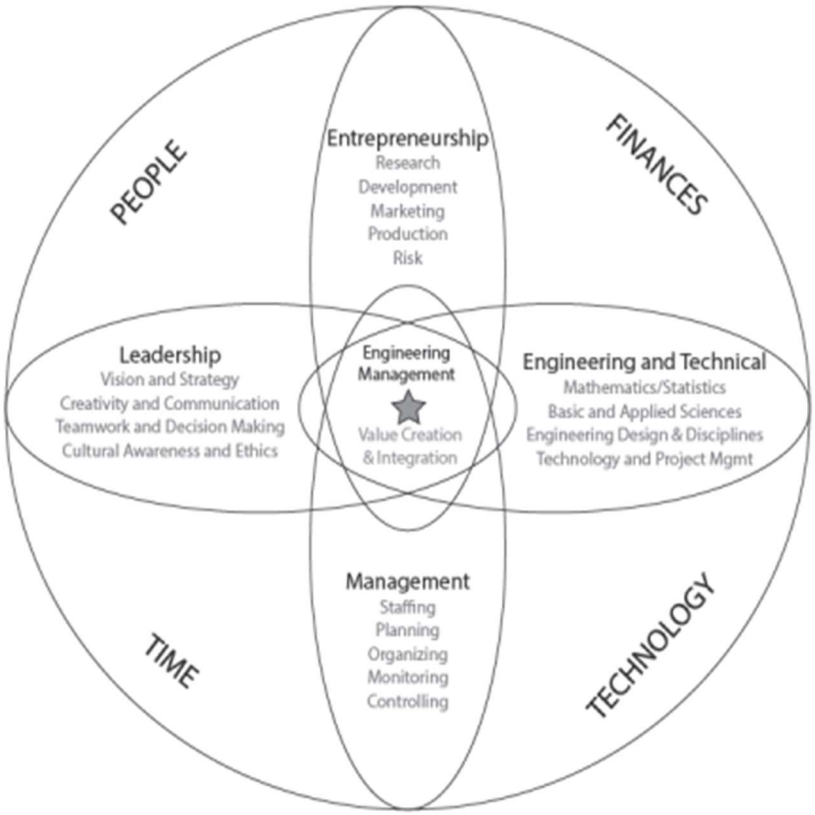
The Evolution of Engineering Management Program Assessment: Lessons Learned with Digital Delivery

Abstract

In the United States, the assessment of undergraduate Engineering Management (EM) undergraduate programs has significantly evolved as viewed through the lens of the Accreditation Board for Engineering and Technology (ABET). Initially, the assessment process primarily emphasized fundamental engineering skills and knowledge. However, with time, there has been a notable shift towards a more comprehensive approach encompassing broader competencies such as leadership, communication, and teamwork. This shift is in response to the interdisciplinary demands of modern engineering management. ABET has adapted to this changing landscape by emphasizing outcomes-based assessment more strongly. This shift encourages engineering management programs to define explicit learning objectives, assess student performance systematically, and commit to continuous improvement. This evolution ensures that undergraduate engineering management programs equip students with essential technical skills and nurture management and interpersonal abilities that are indispensable in the multifaceted world of contemporary engineering. At the United States Military Academy (USMA), an ABET-accredited institution, the transition towards this new paradigm is underway with the implementation of an innovative learning management system (LMS), Canvas. Focusing on a Project Management course as a case study, this paper will delve into the insights gained during the digital transformation. Specific lesson objectives within the Canvas system are intricately linked to various assessment methods, such as problem sets and quizzes. Furthermore, the paper explores the delivery of major exams, which have transitioned into a hybrid format combining digital and paper-based assessments, offering a balanced perspective on the advantages and drawbacks of embracing increased digitalization. During this exploration, we will thoroughly examine the lessons learned from successful implementations and the challenges faced in the digital transformation of the Project Management course at USMA. This endeavor contributes to the broader discourse on enhancing engineering management education, aligning it with the evolving demands of the field and the expectations set forth by ABET.

Introduction

The landscape of undergraduate engineering management programs in the United States has experienced an evolution captured by the Accreditation Board for Engineering and Technology's (ABET) recognition of the need for traditional engineering disciplines alongside a more comprehensive discipline that integrates leadership, communication, and teamwork competencies as seen in (Figure *1*. Engineering Managers manufacture fiscal and enterprise value in creating, designing, and implementing technical projects, products, or system solutions [1]. The West Point Engineering Management (EM) Program embodies this approach. It is housed in the Department of Systems Engineering at the United States Military Academy (USMA) as one of 28 ABET-accredited undergraduate EM programs globally and one of 17 in the United States [2]. This evolution in thinking responds to the interdisciplinary demands of modern engineering management, emphasizing outcomes-based assessment and continuous improvement.

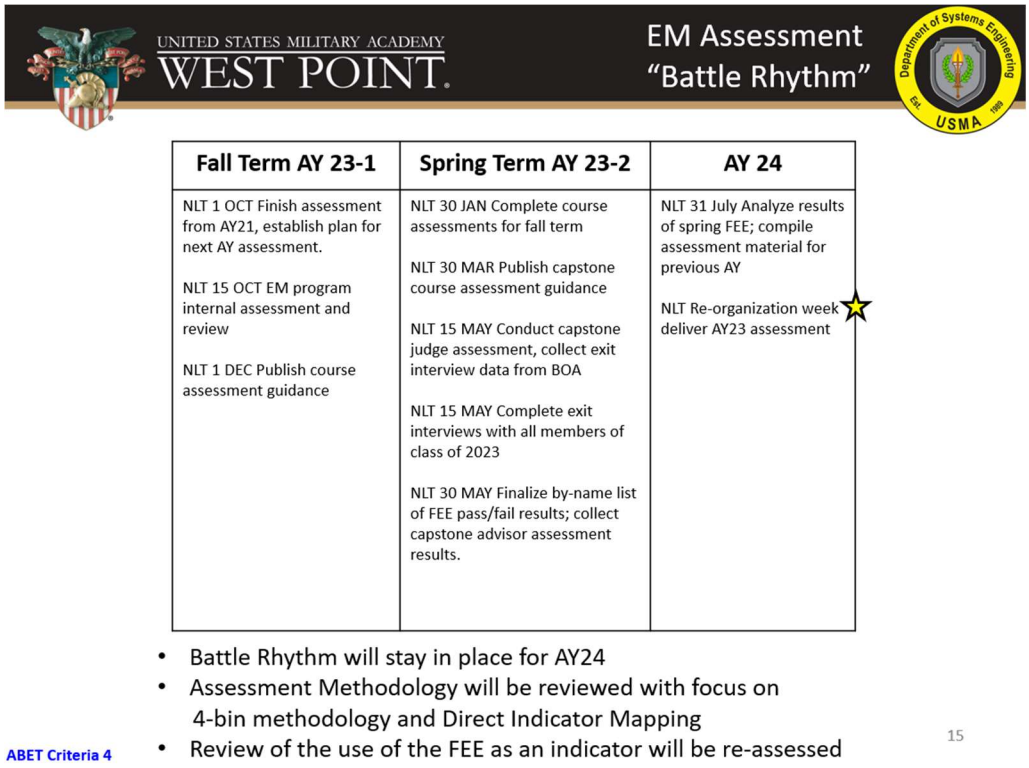


(Figure 1: The Engineering Management System and Value Model) [1]

USMA, with its ten total ABET-accredited programs, has recently gone through a digital evolution with the implementation of Canvas as its learning management system (LMS). There is a dearth of literature on LMSs and their employment in various academic settings. This paper centers on the USMA EM Program's EM411 Project Management course as a case study and, more broadly, delves into the insights gained during the digital transformation process at USMA. Examining the intricacies of lesson objectives tied to various assessment methods within the Canvas system, including problem sets and quizzes, the paper explores the transition of major exams into a hybrid format. This format combines digital and paper-based assessments, providing a balanced perspective on the advantages and drawbacks of increased digitalization. Through an in-depth exploration of successful implementations and challenges faced, this paper contributes to the discussion on advancing engineering management education to meet the demands of the field and align with ABET's expectations.

Evolution of Engineering Management Program Assessment

Assessment of the program links directly to Criterion 3: Student Outcomes and Criterion 4: Continuous Improvement for ABET. Seven student outcomes under Criterion 3 are annually assessed to ensure the program's educational objectives are supported, and graduates are ready to practice engineering. The 'regular use of appropriate, documented process for assessing and evaluating student outcome attainment' thus influences continuous improvement actions across the program or within individual courses [2]. The West Point EM program has evolved in the mix of direct and indirect, internal, and external assessment tools to evaluate outcome achievement, and the data feeding the assessment was assembled from multiple internal spreadsheets, USMA knowledge management survey platforms, and EM program-level feedback tools from external project partners and students alike. Aggregating and analyzing the different data indicators takes multiple weeks to capture fully. It includes inputs from the West Point Academy Management System, internal department operations Excel-based final grade artifacts, Blackboard, MS Forms, and an internal SharePoint system for the departments. While the assessment and continuous improvement process was validated without shortcomings in the 2019-2020 comprehensive review, and only strengths were identified, the time burden alone to pull from many assessment knowledge management data sources remained significant. The annual assessment rhythm for the West Point EM is illustrated in (Figure *2*.



(Figure 2: Assessment Process for Academic Year (AY) 24)

Direct Indicators of the assessment include multiple major graded events, including written, in-class evaluations, technical reports, and presentations. Surveys conducted by the capstone 'judges' during a project's day conference map directly to student outcomes 1-7. Data is also collected from the Industrial and Systems Engineering Fundamentals of Engineering (FE) Exam hosted by the National Council of Examiners for Engineering and Surveying (NCEES). The normalization of all the scores to a four-point scale is seen in(Figure 3 for ABET student Outcome 6. This is followed by statistical analysis conducted via multiple spreadsheets to determine if there might be slippage over time in achieving outcomes. Once compiled, each student outcome is assessed, and continuous improvement recommendations are considered.

6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

	Capstone Advisor	Direct Course Assessment	Projects Day Judging	FEE related content
Assessment:	3.10 29% Exemplary 20% Developing	3.26 (EM384 and SE375)	3.00	Probability & Statistics (3.5) – 1.02 PI

Discussion: Solid performance in AY23, but the left side of the distribution from capstone advisor assessment is concerning; 3 advisors accounted for majority '2' ratings.

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(Figure 3: Example of AY26 Assessment Crosswalk of ABET Student Outcome 6)

Reinforcing the direct and indirect assessments were student feedback surveys following each course (completed in Blackboard) and senior exit interviews (completed in MS Forms). (Figure 4 illustrates the generic question bank feedback and open-text deep dives. The robust and combined feedback has driven regular annual EM program improvements, including a new modeling and simulation track in recent years. Yet, the process of collecting, analyzing, and deciding remains arduous. Discussions about a revolution in knowledge management systems to guide assessment speed and accuracy were commonplace, and the onboarding of the Canvas LMS was happily received when announced by the Chief Information and Technology Office.

(Figure 4: Example of Indirect Data Tools for ABET Criterion 4 from Students)

Some background on the Canvas LMS is useful to understand before detailing the digital transformation at USMA. Canvas is currently the top-ranked educational LMS by market share, used by over one-third of higher education institutions in North America [3]. Blackboard, Moodle, and Brightspace are the next largest systems in respective order, used by higher ed in the United States. Previously, USMA leveraged a combination of Blackboard, MS Teams, and a free-for-teacher instance of Canvas to manage student learning.

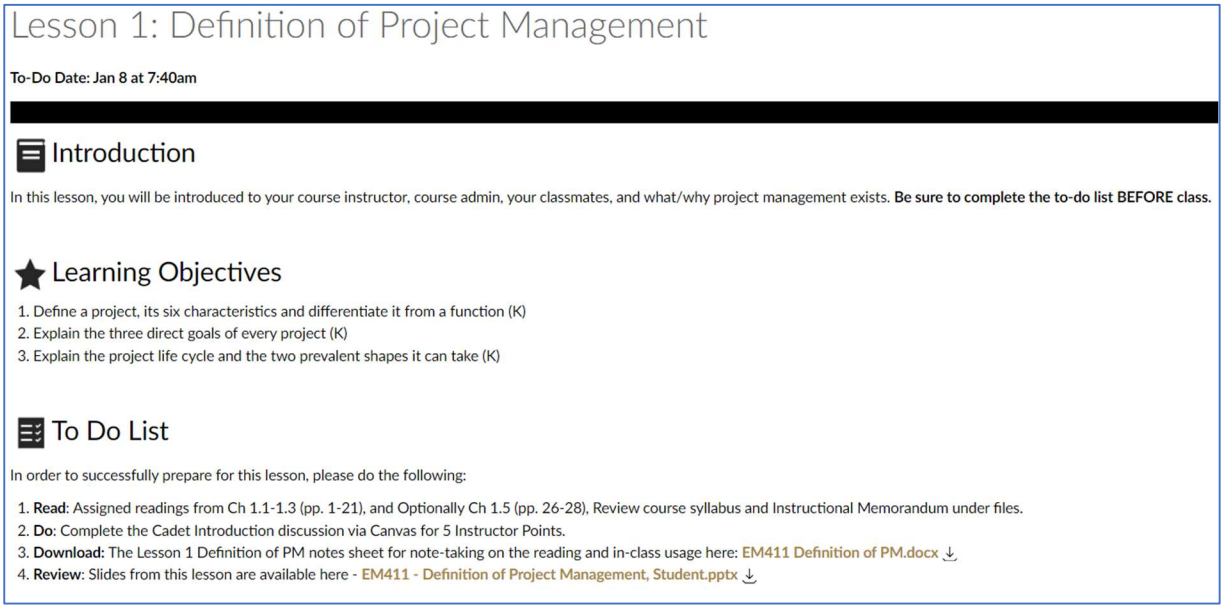
Case Study: Project Management Course

At USMA, EM411 Project Management, is an undergraduate-level course that all Students majoring within the Department of Systems Engineering (DSE) complete. Students learn to initiate, plan, execute, monitor, and control a project. Topics include project selection, project manager roles and responsibilities, organizational structure, project planning, budgeting, scheduling, resource allocation, monitoring and controlling, risk assessment and response management, and evaluation and termination. The end state is that each student understands the application of project management and the complex interrelated tasks associated with completing projects on time, within budget, and to specification.

The authors served as course directors, responsible for the class's design, content, and delivery in the first year that Canvas was implemented as the primary LMS at West Point. In recent years, within the Department of Systems Engineering, MS Teams delivered content outside of in-class lectures (posting lesson material, uploading assignments, etc.). The experience of digitally transforming the EM411 course provides an excellent case study of the advantages and disadvantages of delivering an engineering education. A study conducted by a college in southern California details a similar transition to the Canvas LMS and found that both students and faculty preferred Canvas over other LMSs due to its intuitive interface, flexible customization, dynamic cloud-based control, ability to engage with media, system support, and efficiency of grading [4]. The following discussion will highlight more specific examples of related advantages and some perceived disadvantages.

The transition to Canvas for EM411 offered significant advantages to students and faculty. Foremost for students, they would not require disparate LMSs across their diverse curriculum. For example, a student taking a social science course may have been directed to utilize the Blackboard LMS, while a student taking an engineering course may have utilized the MS Teams LMS. With Canvas, students now have a single integration point for their curriculum across every department at USMA, which neatly displays each of their respective courses via cards in an online dashboard. Second, the ability to create a living Syllabus for the engineering course via ‘Pages’ and ‘Modules’ helps organize the preparation and delivery of lesson material. Previously, students would have to reference the Syllabus file to understand what was required for pre-class reading and assignments. While students could still manually reference a cursory Syllabus file, Canvas provides the ability to create a separate ‘Page’ for each lesson, and respective ‘Pages’ can be organized into ‘Modules’ or blocks of learning. (Figure *5* below shows how each lesson in EM411 is set up as a ‘Page’ that clearly outlines the learning objectives and to-do list for each class. Within the to-do list are clear instructions for each student, including links to relevant course documents embedded in one location. Establishing individual lesson ‘Pages’ ensures

instructions, tasks, and end goals are clear to students before each class. The simple organizational structure that Canvas offers is an enormous benefit. Furthermore, instructors can export/copy their course design and content to a digital 'Commons', which allows other faculty members from the institution to download any material they desire. Shareability enables smooth course content and delivery continuity as a new term begins or enables others to gain ideas and perspective.



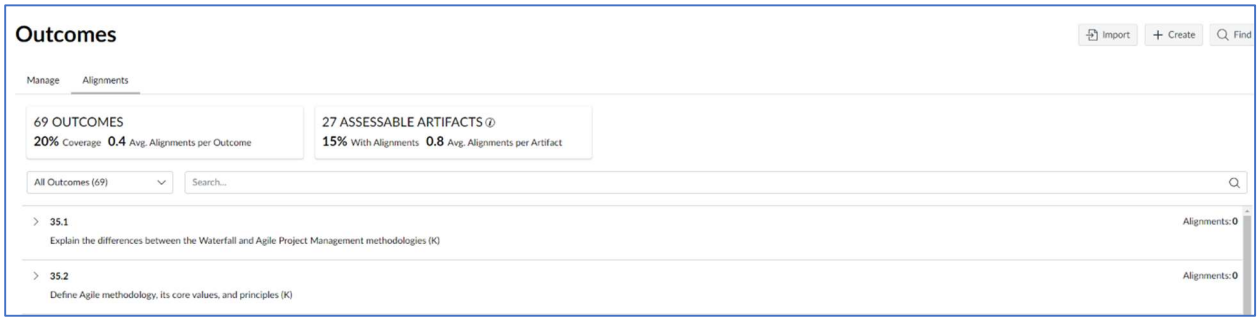
(Figure 5: EM411 Lesson 1 Page in Canvas LMS)

One of the most prominent advantages of assessing learning in the EM411 course is directly aligning 'Outcomes' (what Canvas calls learning objectives) with assignments and quizzes. (Figure *6* below shows an example of this alignment embedded within the rubric for the first major assignment within EM411. Each Outcome is coded based on the lesson number and the number of objectives within that lesson (e.g., the second objective in Lesson 2 is tracked as Outcome 2.2). Note that any course can choose to create whichever naming or numbering convention is best suited for the content. Instructors grade students utilizing the highly efficient 'SpeedGrader' functionality, allowing them to select the appropriate rating scale to score and assign their assessment of a student's mastery of a learning objective. As the course progresses and new opportunities to demonstrate mastery occur, Canvas will leverage a weighted average. The 65/35 default weighted average calculation method will count the most recent result as 65% of the mastery weight and average all other results as 35% (mastery levels shown in Figure 6). Thoughtful features such as evaluating outcomes through weighted averages make a difference in assessing student understanding over time, rather than from a singular point in the course's execution, or a more basic flat average across multiple assessments. The automated calculation and reporting features of Canvas on these outcomes is another major advantage, which requires only the knowledge of how to navigate the system to benefit fully.

3.1 Apply numeric project selection models (weighted scoring model). (S) threshold: 3 pts	4 pts Exceeds Mastery	3 pts Mastery	2 pts Near Mastery	1 pts Below Mastery	0 pts No Evidence
2.2 Apply numeric project selection models (payback period, discounted cash flow) (S) threshold: 3 pts	4 pts Exceeds Mastery	3 pts Mastery	2 pts Near Mastery	1 pts Below Mastery	0 pts No Evidence
5.1 Apply Stakeholder Identification and Analysis Techniques (Power-Interest Grid and Commitment Assessment Matrix) (S) threshold: 3 pts	4 pts Exceeds Mastery	3 pts Mastery	2 pts Near Mastery	1 pts Below Mastery	0 pts No Evidence
9.1 Analyze project risk to include Risk Identification, Risk Analysis, and Response to Risk. (S) threshold: 3 pts	4 pts Exceeds Mastery	3 pts Mastery	2 pts Near Mastery	1 pts Below Mastery	0 pts No Evidence
9.2 Create a Risk Assessment for a Project (S) threshold: 3 pts	4 pts Exceeds Mastery	3 pts Mastery	2 pts Near Mastery	1 pts Below Mastery	0 pts No Evidence

(Figure 6: EM411 Outcome Alignment within Assignment Rubric)

Like assignments, quiz questions within Canvas can each be aligned with their respective outcomes. Within Canvas's 'Outcomes' feature, instructors can see how many course outcomes have been aligned to assessable artifacts such as problem sets, graded discussions, or quizzes, and better understand which course outcomes require more thoughtful incorporation within the course. (Figure *7* below shows an overview of the total number of 'Outcomes' and assessable artifacts currently designed within EM411 and how many are currently aligned with assessments (either through inclusion on an assignment rubric or alignment of an outcome with a quiz question). As the course director, one could instantly see how only 15% of outcomes have been aligned to assessments and which outcomes still require alignment to assess student learning holistically, for example, Outcome 35.1 in (Figure *7*.



(Figure 7: EM411 'Outcomes' Overview)

One aspect of the digital transformation for EM411 that occurred outside of Canvas included using the freely available TEAMMATES peer evaluation tool. TEAMMATES is a cloud-based system that is easy to use and will facilitate optionally anonymous feedback between students within teams [5]. EM411 involves two major group-graded assignments that build off one another. Learning how to work with and manage other students successfully is related to key course objectives that are often difficult to evaluate within the classroom. The TEAMMATES tool provides objective feedback to students and faculty on individual teamwork and, more importantly, helps them develop self-awareness through feedback [6]. Students were asked the following four questions:

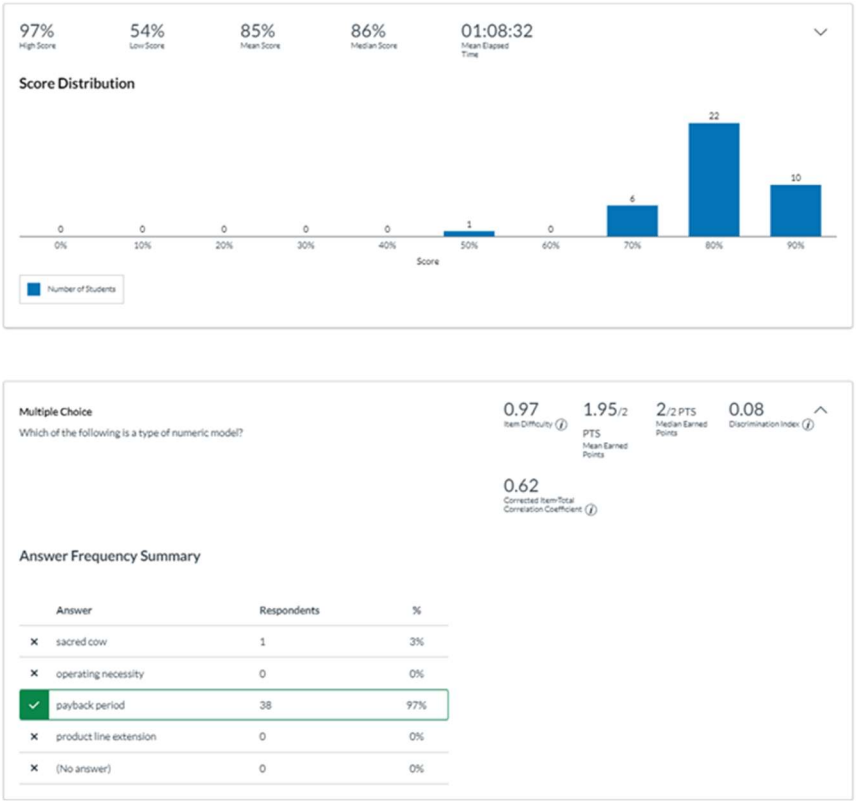
1) Your estimate of how much each team member contributed (anonymously shared)
2) Positive feedback to your teammates (anonymously shared)
3) Constructive feedback to your teammates (anonymously shared)
4) Comments about team dynamics (confidential response to instructor)

Students received emails requesting feedback the day after a group assignment was completed, so their feedback for teammates would be freshest. A complete roll-up of the feedback session's results is then available for instructors and students to consider. For the course, team evaluations influenced a peer evaluation grade, with the most recent evaluation weighing most heavily on their grade. The feedback provides valuable insight for all parties to understand how they develop softer skills such as teamwork and relationship building, essential to students' futures as engineering leaders.

Digital vs. Traditional Assessments

One of the major changes implemented with Canvas was the transition from traditional paper assessments to digital and hybrid assessments. In previous academic years, EM411 administered multiple quizzes and exams via an in-class paper copy. In the course's first year with Canvas, all quizzes were moved into Canvas, and the major midterm was conducted in a hybrid digital/paper format. This section will share the pros and cons of digital transformation.

The first major advantage in transitioning to digital delivery of quizzes and exams is the superior understanding of student assessment [7]. Before integrating the Canvas LMS, instructors needed help to assess the learning of specific outcomes in a standardized and automated way. After hours of grading, teachers formerly aggregated student assessment data into a data table to see which sections of content or questions students understood. Usually, this only left time for the instructor to conduct a cursory level of analysis, which would include average performance metrics. Canvas enables linking objectives to individual questions on an assessment, further supporting an instructor's ability to assess student learning holistically. An automated report details overall assessment metrics and more advanced metrics by question, including data like a 'Discrimination Index.' An example of some of these features is shown in **Error! Reference source not found.** below. A simple histogram distribution of student performance is depicted in Figure 8, and an example of the detailed analysis by question. One can see the number of respondents who selected any given answer for a quiz question, along with other useful metrics like 'Item Difficulty,' which will tell you the overall proportion of students who answered the question correctly on a 0 to 1 scale. These metrics benefit instructors for many reasons, such as highlighting concepts students are still struggling with or which questions may have been too difficult for the assessment.



(Figure 8: EM411 Quiz and Item Analysis Example)

The benefits of automated grading from Canvas cannot be understated as detailed by numerous studies [8]. Canvas automates grading all question types that do not require a short-answer response. Automated grading removes any potential for human error, which most instructors familiar with grading hours of exams can resonate with. Canvas also supports easy mechanisms to 'Regrade' questions in mass, for instance, if an instructor introduces an unintended error into a question and wishes to award points for a different answer. Additionally, the time-saving potential for faculty utilizing a hybrid or fully digital approach to assessment is significant.

With EM411, a hybrid digital and paper midterm exam was successfully administered with major grading efficiencies for faculty. The hybrid format allowed students to show all their work for more complex engineering questions so that faculty could award partial credit. The showing of work is particularly useful for questions with multiple steps to arrive at a definitive answer, as is the case with applying the critical path method to solving a network. It is the authors' perspective that faculty should not seek to transform their exams for a fully digital modality in Canvas if the assessed material is not appropriate. However, the hybrid approach optimizes efficiency and may provide the best path for faculty and students. The midterm for EM411 consisted of 42 questions with a mix of multiple-choice, fill-in-the-blank, matching, true/false, and show-your-work format questions. Some students experienced technical issues with their laptops during the in-class exam and were provided backup hard copies instead. Approximately 2/3 of the exam consisted of questions delivered digitally via Canvas. Manual grading of the sections that Canvas could have automatically graded took instructors about 6 minutes each. If the authors were to hand-grade all

portions of the exam that could have been automatically graded, this would equate to an additional 10-man hours of work for a course with 100 students enrolled. A supplemental paper portion of the exam was provided for students to show their work. All final answers were still submitted through the Canvas interface, allowing faculty to quickly identify the students who required more in-depth grading of the supplemental paper portion. Grading the supplemental paper portion of the EM411 midterm exams took approximately 15 minutes each, so considerable time is still required to evaluate students properly. (Figure *9* below summarizes the grading efficiency before and after the digital transformation of the midterm. Overall, a full or hybrid digital approach to quizzes and exams led to greater efficiencies for faculty and did not measurably impact student assessment in a negative manner.

Midterm Grading Time by Paper-Copy (non-digital)	**Midterm Grading Time by Hybrid-Canvas (digital)**	**Time Savings**
21 minutes per exam	15 minutes per exam	6 minutes per exam
35 man-hours with 100 exams	25 man-hours with 100 exams	10 man-hours with 100 exams

(Figure 9: EM411 Midterm Grading Efficiency Comparison)

The many benefits of digitally transforming a course's assessments introduce some downsides. A digital assessment method means increased opportunities or temptations for students to cheat. Some best practices are detailed in various articles available online [9]. One robust way of mitigating this potential is through a Canvas feature called LockDown Browser. LockDown Browser is a custom browser that locks down the testing environment in Canvas. Students cannot print, copy, visit other sites, access other applications, or close the quiz until it is submitted. While this may sound foolproof, overly zealous students may still find successful ways around the LockDown Browser, such as through virtual machine software [10]. While the authors did not encounter any known instances of cheating, that does not mean it did not definitively occur. Another way to mitigate this is by an active presence in the classroom, such as walking around as students complete their assessments. Increased risk of technical difficulties is an increased concern, although this is generally the exception to the norm. Other limitations in Canvas exist with question design that may frustrate the mind of a determined faculty member. The authors found that with some creativity, most course content can be retooled to be asked in a digitally friendly manner.

Canvas empowers course instructors to have an intuitive, efficient, and modular system to support student learning management, delivery, and assessment. Overall, EM411 experienced broad success in its first year, digitally transforming the course within the Canvas LMS to be more learner-friendly for students and more efficient and informative for faculty with student assessment. Success in the transformation translated as time saved in understanding student learning from both a grading and a more holistic outcomes-based perspective. Success also manifested as positive feedback from students who found the Canvas course delivery user-friendly and fair in its assessment. Most failures in digitally transforming EM411 arose from a need for more familiarity with the system. For example, needing to fully understand how to apply formula-style questions correctly led to a time loss in re-grading a digital portion of an assessment. Future faculty seeking to adopt a similar digital transformation should complete all

embedded Canvas training material, such as the useful ‘Growing with Canvas’ course available to all new faculty users.

Conclusion

The insights from the material presented in this paper offer valuable and scalable lessons for the future development of undergraduate engineering management programs, particularly in digital delivery and assessment. The shift in focus from traditional engineering assessment to a technology-enhanced approach, as exemplified by the evolution of the USMA’s Engineering Management Program, underscores the need for continuous adaptation to meet the interdisciplinary demands of modern engineering management and recognition that speed, and thoroughness of assessment allow for much improved program director and faculty decision quality when it comes to continuous improvement initiatives. The integration of a cutting-edge LMS, Canvas, at USMA, provides a case study for successfully implementing digital tools to enhance the educational experience.

The paper sheds light on the advantages and challenges of digital transformation in the Project Management course offering a nuanced understanding of the implications for students and faculty. The alignment of learning objectives with assessments within the Canvas system is highlighted as a significant advantage, providing a structured and efficient approach to evaluating student outcomes. The ability to automate grading processes and generate detailed reports on student performance contributes to a more holistic assessment, allowing instructors to glean insights into specific outcomes and adjust teaching strategies accordingly.

Furthermore, the transition from traditional paper assessments to a hybrid digital format is explored, emphasizing the benefits of increased efficiency and a more thorough understanding of student learning. The authors provide a balanced perspective on digital assessments' advantages and potential drawbacks, addressing concerns such as cheating and technical difficulties. In addition, the TEAMMATES peer evaluation tool demonstrates an automated and digital way to increase students’ self-awareness of soft skills such as teamwork and relationship building.

In conclusion, this paper's exploration of digital transformation in the Project Management course contributes to the ongoing discourse on engineering management education. It offers practical insights for educators and institutions considering similar transitions. The successes and challenges outlined in the paper pave the way for future developments in engineering management programs, emphasizing the importance of aligning educational practices with the evolving demands of the field and the accreditation standards set by organizations like ABET. As the landscape of engineering education continues to evolve, these insights will be instrumental in shaping effective strategies for delivering and assessing engineering management programs in the digital age.

Implications for Engineering Management Education

The evolution of assessment methods aligns with the dynamic demands of the engineering management field and the rigorous expectations set forth by ABET. Traditionally rooted in evaluating fundamental engineering skills and knowledge, the assessment process has become

more comprehensive. The emphasis on broader competencies such as leadership, communication, and teamwork reflect a keen response to the interdisciplinary demands inherent in modern engineering management and by extension, EM undergraduate programs. Adopting a cutting-edge LMS such as Canvas at USMA exemplifies this adaptation to the changing landscape. The digital transformation of assessment methods ensures the visibility of progress toward the achievement of student outcomes in essential technical skills and the development of management and interpersonal abilities. This alignment with evolving industry demands and ABET's expectations reinforces the pivotal role of assessment methods in shaping a contemporary and robust engineering management education.

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