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Fostering the Development of Engineering Skills Using Online Tools

Dr. Bryan James Higgs, University of the District of Columbia

Dr. Bryan Higgs is a native of southwest Virginia. Currently, he is an Assistant Professor in the Department of Civil Engineering at the University of the District of Columbia and is serving as the Director for the UDC Center of Climate Change Analytics. Prior to this position, he was an Intelligence Community Postdoctoral Researcher.

Gulen Ozkula, University of the District of Columbia

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Abstract

Engineering education extends beyond mere knowledge acquisition and encompasses the development of a comprehensive skill set valued in the industry. A novel approach to fostering engineering skills using online tools is presented in this paper, addressing the limitations of traditional teaching methods. The alignment between ABET student outcomes and industry-desired skills was analyzed, and the need for improved skill development methodologies in engineering curricula was identified. Five key elements of skill development are focused on: personal investment, practice, feedback, realistic expectations, and supportive environments. An innovative educational tool utilizing online platforms was introduced to create multiple-attempt assignments with randomized variables and immediate feedback. The challenges of implementing effective practice and feedback loops in engineering education are addressed by this tool, while minimizing the additional instructor workload. The methodology was implemented in three engineering courses: Statics, Dynamics, and Traffic Engineering Significant improvements in student motivation, engagement, and achievement of learning outcomes are demonstrated by results from student surveys and ABET assessments. Increases in ABET student outcome achievement ranging from 6.3% to 28.6% across the three courses were observed following the implementation of this tool. Positive student perceptions of the tool's impact on their skill development, problem-solving abilities, and learning experience are indicated by survey responses. A contribution to the ongoing discussion on enhancing engineering education is made by this paper through the proposal of a practical, scalable approach to skill development that aligns with industry needs and accreditation requirements. It is suggested by the findings that the incorporation of principles of skill development into engineering curricula can transform educational approaches, resulting in improved student growth and better-prepared graduates for the workforce.

Introduction

The primary objective of engineering education is to produce proficient and competent graduates who are prepared to enter the workforce and continue their professional development as engineers. In engineering programs, the expectations for the knowledge base and competencies of graduates are established through the attainment of ABET student learning outcomes, which serves as a comprehensive assessment of student capabilities. Conversely, employers seek graduates with a specific skill set. The 12 highly valued skills are problem-solving, computer science, industry skills, pressure management, teamwork, creativity, structural analysis, communication, attention to detail, educational commitment, data modeling, and leadership [1]. While the acquisition of these skills is integrated into ABET student learning outcomes, it is evident that these skills require cultivation and development. Traditional lecturing predominantly focuses on knowledge transmission, and homework assignments primarily function as metrics to evaluate the quantity of knowledge assimilated by students. This approach contrasts with the ultimate goal of developing students into engineers who possess the requisite skills to address societal needs. This paper presents an analysis of the skills that employers desire in engineering graduates and examines how the development of those skills can be enhanced through the utilization of online tools that are focused on skill development.

Review of ABET Student Learning Outcomes

ABET is a nonprofit organization that accredits colleges and university programs across the globe. Graduation from an ABET-accredited program is a requirement for eligibility of students to take the Fundamentals of Engineering Exam, the first step towards professional licensure [2]. The next step of professional licensure is the Principles and Practice of Engineering Exam that can only be taken after gaining four years of experience under the supervision of a Professional Engineer. As part of the ABET accreditation process, engineering programs must assess the attainment of seven student outcomes [3] listed in Table 1 below.

Table 1: Cross Comparison of ABET Student Outcomes to Engineering Skills

ABET Student Outcomes	Valued Engineering Skills
1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	problem solving, computer science, creativity, structural analysis, data modeling,
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	problem solving, industry skills, creativity, attention to detail
3. an ability to communicate effectively with a range of audiences	communications
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	attention to detail, data modeling, leadership
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	pressure management, teamwork, attention to detail, leadership

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	creativity, attention to detail, data modeling
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.	educational commitment

The comparison of the list of valuable engineering skills to the student outcomes in Table 1 shows a clear overlap indicating that the identified engineering skills are required for achievement of the ABET student outcomes. While the student outcomes are focused on student abilities, these abilities are fueled by certain engineering skills and therefore improvements to the development of the engineering skills should improve the achievement of student outcomes.

Principles of Skill Development

The literature on skill development can be categorized into two primary domains: (I) the development of specific skills, and (II) methods of skill acquisition. The former predominantly comprises books and workbooks focused on cultivating particular skills, utilizing methodologies from the latter category. An extensive review of the literature on skill development methods reveals five recurrent themes:

(I) Personal Investment [4], [5]

(II) Practice [4]–[11]

(III) Feedback [5]–[8], [11]

(IV) Realistic Expectations [4], [5], [9], [10], [12], [13]

(V) Supportive Environment [4], [6].

Personal Investment

The development of new skills requires a foundation of motivation that propels individuals to overcome obstacles that impede their advancement. Most of the literature focuses on identifying valuable skills that offer career prospects and leveraging the prospect of a promising future as a driving force for personal growth. The crucial aspect of following through until the end is that the selected skill must have personal significance.

Practice

The extant literature on skill acquisition consistently emphasizes regular practice as a crucial component in developing proficiency in novel skills. One perspective in the literature [5] posits that dedicating 20 hours of practice can establish fundamental proficiency in a new skill, whereas advancing beyond that level necessitates greater effort to refine the skill. An alternative viewpoint [14] on skill development over time postulates that achieving mastery of a skill requires 10,000 h of practice.

Feedback

Merely dedicating oneself to practice is insufficient for developing a new skill, as practice is significant only when supplemented by feedback. Feedback acts as a roadmap for honing skills, helping pinpoint specific weaknesses that can then be targeted in subsequent practice sessions. However, it is important to note that unfavorable feedback may demotivate individuals and lead them to abandon their pursuit of skill development. To circumvent this problem, feedback must be constructive, and an individual's commitment must generate a powerful motivation to overcome deficiencies.

Realistic Expectations

One of the primary reasons that individuals abandon their efforts to acquire new skills is the setting of excessively high initial expectations. First, the literature [5] recommends a minimum investment of 20 h, meaning that individuals should not anticipate competence in a new skill before meeting this commitment. Second, achieving mastery of a skill is estimated to take 10,000 hours [14] or 20 hours per week for a decade; hence, expecting to attain mastery quickly is utterly impractical. Establishing unattainable expectations can quickly demotivate individuals from meeting them. Moreover, setting expectations based on the performance of others can generate issues comparable to demotivation. Individuals should establish their objectives based on their personal performance history and periodically reassess them as they advance in acquiring new skills.

Supportive Environment

In addition to personal investment, a supportive environment can provide the motivation to overcome obstacles. The main contribution of a supportive environment is that it provides reassurance when doubts arise. This reassurance can simply be a reminder of the importance of the chosen skill and the reasons why the individual began their journey toward skill development.

Review of Traditional Teaching

The central premise of personal investment in education posits that students must ascribe value to their own learning process. Traditionally, this concept has focused primarily on the attainment of satisfactory grades; however, the conventional grading structure may not be optimal for skill development. Typically, assignments and assessments are submitted to instructors who then evaluate them for all students. After a brief interval, the graded assignments and assessments are returned to the students. This system presents an almost dichotomous structure in which, upon completion of an assignment or assessment, students either possess the requisite skills for successful completion or do not. This structure can be motivating for high-achieving students who derive a sense of self-efficacy from demonstrating their capabilities, while students not in that cohort may experience discouragement due to their perceived lack of the necessary skill level.

The primary consideration is that the educational environment should foster students' autonomous skill development and provide them with the requisite feedback to facilitate personal growth. The structure of the engineering curriculum is such that, for numerous courses, there are prerequisite courses in which students must attain a specified grade to be eligible for enrollment in advanced-level courses. This structure is predicated on the principle of knowledge acquisition, wherein the grade serves as a criterion, with students above the threshold deemed to possess knowledge from the given course and those below the threshold considered to lack such knowledge.

The structure of engineering licensure encompasses the Fundamentals of Engineering examinations, which are typically administered near the time of a student's graduation. Subsequently, after acquiring requisite experience, individuals undertake the Principles and Practice of Engineering examinations to attain full professional licensure. This structure is designed to enable students to demonstrate their proficiency in the skills necessary for engineering practice. Moreover, the formulas required for completing the examinations are provided on a reference sheet, and it is incumbent upon the examinees to possess the ability to identify and apply the appropriate formulas to solve given problems. It is evident that the professional licensure structure emphasizes the assessment of problem-solving and stress management skills, which are highly valued in the engineering industry.

Traditional lecture-style teaching employs a structure wherein students submit an attempt on a quiz or assignment and subsequently receive feedback after a brief interval. In the context of skill development, this approach represents an incomplete practice session in which the feedback received cannot be utilized to engage in a subsequent practice session; consequently, the feedback loop is disrupted. Although students can utilize that feedback to review their submissions for personal growth, they remain unable to apply it to engage in an additional practice attempt, which significantly limits the efficacy of the feedback received.

The biggest issue with lecture-style teaching is in the area of realistic expectations, where knowledge is given during lectures and assignments are given in a way that suggests that students should have gained the necessary skills to complete the assignments by purely listening to the lecture. This can create an unrealistic expectation for students, suggesting that they should possess skills without taking the time to develop them.

Another major issue with lecture-style teaching comes in the area of a supportive environment, where feedback is given to students after the course has already moved on to new materials. This creates a situation in which any student who needs assistance or helps them understand a concept is left behind. Even after receiving help to overcome their hurdles, the student has to struggle to catch up with the current material.

Summing up all these issues together shows that traditional lecture-style teaching is not designed for skill development, which can discourage many students. The methodology presented in this paper is designed to address these issues with lecture-style teaching, such that assignments and quizzes can be used as tools to encourage the development of skills in students and therefore generate higher achievement of ABET Student Outcomes.

Methodology

The methodology is presented in two main sections: (1) design of an educational tool, and (2) analysis of alignment with the principles of skill development.

Design of an Educational Tool

Given the critical nature of personal investment in skill development, grades must be a central consideration for a tool used to motivate students'skill development. The implementation of practice and feedback in an educational tool, while important for skill development, can create a significant burden where professors are required to provide feedback for every practice attempt for every student. This would multiply the workload for professors; thus, the tool must be designed to not create a significantly increased workload for professors, while also enabling crucial elements of practice and feedback. Online tools can be used to address this issue. The learning management system Blackboard [15] has a tool called calculated formula problems [16], where questions can be designed such that variables are randomly generated by the system, and the final answers are calculated based on a formula. For example, a question could be written "Calculate the stopping sight distance for a speed of [x] and a grade of [y]%." In this example, speed (x) and grade (y) are variables set to a randomly generated number between the supplied minimum and maximum values. Setting up questions with randomly generated variables is key to enabling multiple attempts on an assignment or quiz such that students cannot merely copy the correct answer from one attempt to the next. By changing the variables between attempts, students could understand the process or formulas necessary to calculate the correct answer. Additionally, students can receive correct answers after each attempt without compromising future attempts.

An added benefit of this tool is that students can be given individualized assignments where they can no longer cheat off each other, and any attempt will result in an incorrect answer. This also enables students to work collaboratively where students working together on an assignment won't be asking the question "what answer did you get for this particular problem?" but it will change to "how did you do this particular problem?" This results in a fundamental shift wherein students must pursue an understanding of the process to determine the final solution rather than merely comparing final answers, which constitutes a critical component of problem-solving.

With the enablement of multiple attempts, the ability to modify the grade allows students to pursue higher grades, motivates them to engage in the practice of their skills, and better engages them with the feedback that they receive. In addition, using this online tool, feedback can be provided immediately after the student clicks submit, thus eliminating the time delay and maximizing the value of the feedback received. Another key change created by this tool is that the interactions between students working on an assignment and their professors can be shifted such that professors can provide specific feedback on attempts that have already been submitted, and then students can integrate that additional feedback in their future attempts.

The implementation of the aforementioned tool in engineering courses yields many benefits including (1) stronger student motivation, (2) immediate feedback, (3) potential for collaborative learning, (4) improved skill development, and (5) improved student outcomes.

Stronger Student Motivation

Multiple homework attempts were found to have a positive effect on student motivation. Studies have shown that students who are allowed to make multiple attempts at homework are more motivated to complete their assignments and are more engaged in the learning process than those who are not given the opportunity to do so. A study [17] showed that students' grades on exams improved by one letter when assignments with multiple attempts were implemented.

Immediate Feedback

Research has also examined the impact of feedback on student practice assignments. One study [18] found that feedback on homework assignments had a positive impact on student achievement. The study found that feedback was most effective when it was immediate, specific, and provided to all students.

Potential for Collaborative Learning

One study [19] found that collaborative learning improved academic achievement and interpersonal skills among students. The study concluded that students who engaged in collaborative learning had a deeper understanding of the subject matter and were better able to apply what they learned to new situations. Another study [20] found that collaborative learning increased students' motivation and engagement in the learning process. The study found that students who participated in collaborative learning were more likely to enjoy the learning experience and feel a sense of ownership over their own learning.

Improved Skill Development

Many studies have shown that 10,000 h of practice are needed to fully master a skill [14], [21]. Thus, implementing practice in the curriculum is necessary to move students from discovering new skills to mastering them. Allowing students to practice their skills in an environment with immediate feedback greatly aids their skill development and puts them on the pathway to becoming professional engineers.

Improved Student Outcomes

The aforementioned tool has been implemented in three engineering courses: Statics, Dynamics, and Traffic Engineering. Statics and Dynamics are considered fundamental to both civil and mechanical engineering and are typically taught at the sophomore level. Traffic Engineering is a specialized course for Civil Engineering and is taught at the senior level. Statics and Dynamics were assessed for a single student outcome, whereas Traffic Engineering was assessed for four student outcomes. A comparative analysis of the ABET assessment results before and after implementation of the developed tool yielded significant improvements. In Statics, the achievement of student outcomes increased by 0.8 points on a 4.0-point scale, representing a 28.6% increase. In Dynamics, the achievement of student outcomes increased by 0.2 points on a 4.0-point scale, corresponding to a 6.3% increase. In Traffic Engineering, the achievement of student outcomes increased by an average of 0.41 points on a 4.0-point scale, with an average percentage increase of 13.1%.

Analysis of Alignment to Principles of Skill Development

From the perspective of personal investment, this tool uses the grade achieved as a motivation for students to engage in further attempts to achieve the highest grades. This gives students the drive to fully utilize the feedback provided to develop their skills further until a satisfactory grade is achieved.

From the perspective of practice, this tool enables practice where there was previously no option. Allowing students to engage in quizzes and assignments multiple times allowed them to sharpen their skills to their own satisfaction. In addition, by allowing multiple attempts, it removes the level of stress that quizzes and assignments were previously carried out, where students now have the ability to correct any mistakes that they make in their future attempts.

From the feedback perspective, this tool enables effective feedback by implementing feedback loops that are critical for optimizing the effects of practice. Feedback is critical to correcting any errors in the process or knowledge that must be carried into practice to be reinforced.

From the perspective of realistic expectations, this tool creates an environment in which students are not expected to possess the requisite level of skills immediately after a lecture, but are given the opportunity to develop those skills through engagement in assignments and quizzes. This better aligns with the way skills are developed in people, thus creating a more natural flow from the knowledge being disseminated in lectures to the achievement of skill levels in students.

From the perspective of a supportive environment, it is imperative that the instructor is available to students to request additional feedback that the learning management system does not automatically provide. For example, a student who misunderstood a core concept from the course will struggle to complete assignments or quizzes until an intervention is made in which the instructor corrects the misunderstood concept. In traditional lecture style teaching, the intervention would occur after the assignment has been submitted and therefore would reflect poorly upon the student, where with the new tool, the student can recognize their gap in knowledge and seek the aid of the instructor to be able to correct that gap in knowledge and then go attempt quizzes or assignments once more to verify that the issues have been corrected; in this case, the grades would reflect greatly upon the student.

Results

The effectiveness of the newly developed teaching strategy was evaluated in a Statics class comprising 21 students through a survey consisting of 29 questions that focused on the themes of skill development. Sixteen out of 21 students completed the survey. The responses to the survey questions were subsequently categorized into sets representing the themes of skill development. The findings for each theme are presented below.

Personal Investment

Appendix A presents the survey questions. Questions 1, 2, 6, 9, 13, and 14 focused on personal investment. The survey results indicate a significant positive impact of the multiple-attempt feature on students' personal investment in their learning process. This aligns with the literature emphasizing the importance of motivation in overcoming obstacles during skill development [1]. Students reported high levels of motivation to improve their performance on assignments and quizzes due to the multiple attempts feature (mean score: 4.29). This suggests that the opportunity for improvement functioned as a catalyst for personal growth, consistent with findings from previous studies on the effects of multiple homework attempts. The ability to improve grades through repeated attempts significantly increased students' investment in their learning (mean score: 4.38). This outcome supports the notion that personal significance is crucial for following through with skill development. Students also reported a greater sense of ownership over their learning process (mean score: 3.94), indicating that the methodology fostered autonomy and self-directed learning.

Notably, students demonstrated an understanding that developing engineering skills requires time and practice beyond lecture attendance (mean score: 4.5). This recognition aligns with the literature on deliberate practice and its role in skill acquisition. Furthermore, students acknowledged that engineering learning is an iterative process (mean score: 3.88), suggesting an appreciation for the continuous nature of skill development. The multiple attempts feature also encouraged more frequent practice of course concepts (mean score: 3.75). This increased engagement with the material is crucial for skill development and aligns with research on the importance of repeated practice in learning.

Overall, the mean scores for questions related to personal investment ranged from 3.88 to 4.38, indicating a highly positive response. The high levels of agreement (68.75% - 93.75%) across these questions suggest that the implemented methodology successfully fostered personal investment in learning and skill development among students. These results demonstrate that providing multiple attempts and emphasizing the iterative nature of skill development can significantly enhance students' motivation and investment in their learning process. This approach appears to effectively address the need for personal significance in skill development, as highlighted in the literature [1].

Practice

Survey questions 3, 5, 18, 19, 20, and 21 in Appendix A focused on the practice on skill development. The survey results demonstrate a strong positive impact of the multiple-attempt feature on students' practice and skill development, aligning with the literature emphasizing the importance of regular practice in acquiring proficiency in new skills. Students reported that the ability to make multiple attempts on assignments and quizzes significantly facilitated their practice and skill improvement (mean score: 4.25). This finding corroborates the literature's emphasis on the crucial role of practice in skill acquisition [1]. The high mean score suggests that students recognized the value of repeated practice opportunities, which is consistent with research indicating that deliberate practice is essential for skill development. The opportunity to improve grades through repeated attempts increased students' willingness to engage with challenging problems (mean score: 4.19). This outcome aligns with the concept that skill development requires sustained effort and persistence, as suggested by studies on the development of expertise. The increased willingness to engage with difficult material indicates that the methodology successfully encouraged students to invest time in practicing and refining their skills.

Students reported improvements in their problem-solving skills as a result of the teaching methodology (mean score: 3.75). This finding is particularly significant, as problem-solving is a fundamental skill in engineering and requires extensive practice to develop. The positive response suggests that the multiple-attempt approach provided students with the necessary opportunities to hone their problem-solving abilities. Notably, students reported increased confidence in their ability to apply course concepts to new situations (mean score: 3.63) and perceived improvement in this ability throughout the semester (mean score: 3.63). These results indicate that the practice opportunities provided by the methodology contributed to the development of transferable skills, which is a key goal in engineering education. The survey also revealed an improvement in students' time management skills (mean score: 3.44) as they learned to balance multiple attempts with other coursework. While this score is lower than others in the practice category, it still represents a positive outcome. Effective time management is crucial for sustained practice and skill development, as highlighted in studies on self-regulated learning in engineering education.

Overall, the mean scores for questions related to practice ranged from 3.44 to 4.25, indicating a positive response to the methodology's impact on skill development through practice. The agreement levels (62.5% - 75%) across these questions suggest that the implemented approach successfully fostered an environment conducive to regular practice and skill improvement. These results demonstrate that providing multiple attempts and emphasizing the iterative nature of skill development can significantly enhance students' engagement in practice and their perception of skill improvement. While the survey does not directly measure the 20-hour fundamental proficiency or 10,000-hour mastery thresholds mentioned in the literature, it does indicate that students perceive value in the increased practice opportunities provided by the methodology. The positive outcomes in problem-solving, concept application, and time management skills suggest that the implemented approach is effective in promoting the regular practice necessary for skill development in engineering education. Future research could focus on longitudinal studies to assess the long-term impact of this methodology on skill mastery.

Feedback

Survey questions 7, 8, 10, and 15 in Appendix A focused on feedback on skill development. The survey results demonstrate a positive impact of the implemented feedback system on students' skill development, aligning with the literature that emphasizes the crucial role of feedback in the learning process. Students reported that the combination of multiple attempts and immediate feedback was significantly more helpful than the traditional grading methods (mean score: 4.24). This finding strongly supports the literature's emphasis on the importance of timely and constructive feedback for skill development. A high mean score suggests that students recognized the value of immediate feedback in guiding their learning process, which is consistent with research indicating that prompt feedback enhances skill acquisition and retention.

Notably, the students did not find immediate feedback after each attempt to be overwhelming or unhelpful (mean score: 3.88, with a lower score indicating disagreement with the statement). This result is particularly significant, as it addresses a common concern in the literature about the potential for feedback to be demotivating if not properly implemented. The positive response suggests that the feedback provided was constructive and well balanced, allowing students to identify areas for improvement without feeling discouraged. Students reported feeling comfortable seeking additional clarification from the instructor when needed (mean score, 3.63). This outcome aligns with the concept that effective feedback should encourage further engagement and inquiry, as suggested by studies of feedback in higher education. The moderately positive response indicates that the implemented methodology created an environment in which students felt supported in seeking additional guidance to overcome their deficiencies. There was a slight increase in the students' comfort level in seeking help from the instructor when struggling with concepts (mean score: 3.5). While this score is lower than the others in the feedback category, it still represents a positive outcome. This finding suggests that the feedback system may have contributed to building a more supportive learning environment, although there is room for further improvement in this area.

Overall, the mean scores for the questions related to feedback ranged from 3.5 to 4.24, indicating a moderately positive to very positive response to the feedback aspects of the methodology. The agreement levels (56.25% - 82.35%) across these questions suggest that the implemented approach successfully fostered an environment in which feedback was perceived as helpful and constructive. These results demonstrate that providing immediate constructive feedback in conjunction with multiple attempt opportunities can significantly enhance students' engagement with the learning process and their perception of skill improvement. The positive outcomes in students' comfort in seeking clarification and their preference for this feedback method over traditional grading suggest that the implemented approach is effective in promoting the type of feedback necessary for skill development in engineering education. The findings align with research on the importance of feedback in educational settings, such as Hattie and Timperley (2007), who emphasized the power of feedback to enhance learning when it provides information specifically related to the task or process of learning. The results also support the assertions of Nicol and Macfarlane-Dick (2006) regarding the role of feedback in developing self-regulation among students. Future research could focus on further refining the feedback mechanisms to address slightly lower comfort levels in seeking help from instructors. Additionally, longitudinal studies could assess the long-term impact of this feedback methodology on students' skill development and their ability to self-regulate their learning processes.

Realistic Expectations

Survey questions 4, 11, 12, 25, 28 and 29 in Appendix A focused on realistic on skill development. The survey results demonstrate a mixed to positive impact of the implemented methodology on students' realistic expectations for skill development, aligning with the literature emphasizing the importance of setting appropriate expectations in the learning process. Students reported that the multiple attempts feature helped them set realistic expectations for their skill development (mean score: 3.88). This finding supports the literature's emphasis on the gradual nature of skill acquisition and the importance of avoiding excessively high initial expectations. The moderately high mean score suggests that students recognized the value of incremental progress, which is consistent with research indicating that skill development is a process requiring sustained effort over time. Notably, students felt less pressured to perform perfectly on the first try due to the multiple attempts feature (mean score: 3.69). This outcome aligns with the concept that setting realistic expectations can prevent demotivation, as suggested by studies on skill acquisition. The positive response indicates that the implemented methodology created an environment where students felt more comfortable with the iterative nature of learning and skill development. Students reported being more motivated to understand underlying concepts rather than just memorizing answers due to the randomly generated variables in problems (mean score: 3.69). This finding is particularly significant as it suggests that the methodology encouraged a deeper approach to learning, which is crucial for long-term skill development and aligns with the literature's emphasis on understanding over rote memorization.

Interestingly, students believed that this methodology better prepared them for their future engineering careers (mean score: 4.0). This result is encouraging as it indicates that students perceive the value of the skills they are developing in a broader, professional context. This aligns with the literature's emphasis on the long-term nature of skill mastery and the importance of viewing skill development as a continuous process. However, when asked about their performance in this course compared to other courses using traditional teaching methods, the response was moderately positive (mean score: 3.31). This suggests that while students see benefits in the new methodology, they may still be adjusting to the different approach or comparing their progress against familiar benchmarks from traditional courses. It's noteworthy that students' confidence in their mastery of the course material was relatively lower (mean score: 3.13). This finding, while potentially concerning at first glance, may actually indicate a more realistic self-assessment of skills. As the literature [5] suggests, true mastery of a skill takes considerable time and practice. The lower confidence score might reflect students' growing awareness of the complexity of the subject matter and the long-term nature of skill development, rather than a failure of the methodology.

Overall, the mean scores for questions related to realistic expectations ranged from 3.13 to 4.00, indicating a mixed to positive response to the methodology's impact on setting appropriate expectations for skill development. The agreement levels (37.5% - 81.25%) across these questions suggest that while the implemented approach has successfully fostered more realistic expectations in some areas, there is still room for improvement in others. These results demonstrate that providing multiple attempts and emphasizing the process of skill development can help students set more realistic expectations for their learning. The findings align with research on the importance of appropriate goal-setting in educational settings, such as the work of Locke and Latham (2002), who emphasized the role of specific, challenging but attainable goals in motivation and performance. Future research could focus on further refining the methodology to help students better calibrate their expectations and self-assessments. Additionally, longitudinal studies could assess how students' expectations and confidence levels evolve over time as they progress through their engineering education and into their professional careers.

Supportive Environment

Survey questions 16, 17, 22, 23, 24, 26 and 27 in Appendix A focused on supportive environment on skill development. The survey results demonstrate a strong positive impact of the implemented methodology on creating a supportive environment for skill development, aligning with the literature emphasizing the importance of a supportive context in the learning process. Students reported that the learning environment created by this methodology was supportive of their skill development (mean score: 3.75). This finding corroborates the literature's emphasis on the crucial role of a supportive environment in providing reassurance and motivation during the skill development process. The moderately high mean score suggests that students recognized the value of the supportive context in their learning journey. Notably, students strongly agreed that the flexibility to improve grades at any point during the semester fostered a more supportive learning environment (mean score: 4.38). This outcome aligns with the concept that a supportive environment should provide opportunities for growth and improvement, as suggested by studies on effective learning environments. The high positive response indicates that the implemented methodology created an environment where students felt supported in their ongoing efforts to develop their skills. Students reported that the methodology encouraged meaningful collaboration with their peers (mean score: 3.94) and that working with others helped them better understand the course material (mean score: 4.0). These findings are particularly significant as they highlight the social aspect of a supportive environment, which is crucial for overcoming obstacles in skill development. The positive responses suggest that the methodology successfully fostered a collaborative learning community. Students also found themselves more engaged in collaborative learning with peers because they focused on understanding processes rather than just comparing final answers (mean score: 4.13). This result is encouraging as it indicates that the supportive environment promoted deeper learning and understanding, aligning with research on effective collaborative learning practices.

A significant finding indicates that the opportunity for multiple attempts on assignments and the ability to attain the highest grade throughout the semester substantially reduced students' stress levels (mean score: 4.40). This observation aligns with the literature's emphasis on the importance of mitigating anxiety and stress in learning environments to facilitate skill development. The high mean score suggests that the methodology was particularly effective in creating a low-stress, supportive environment. It's noteworthy that students strongly disagreed with preferring traditional lecture-style teaching over this methodology in future courses (mean score: 2.25, indicating disagreement). This finding, while not directly related to the supportive environment, reinforces the overall positive perception of the new methodology and its supportive aspects compared to traditional teaching methods.

The mean scores for questions pertaining to the supportive environment ranged from 3.75 to 4.40, indicating a highly favorable response to the methodology's impact on creating a supportive learning context. The high agreement levels (75–93.33%) across these questions suggest that the implemented approach has effectively fostered a supportive environment conducive to skill development. These results demonstrate that providing flexibility, encouraging collaboration, and reducing stress can significantly enhance the supportive nature of the learning environment. The findings align with research on the importance of supportive learning environments in educational settings, such as the work of Bransford, Brown, and Cocking (2000), who emphasized the role of supportive contexts in facilitating learning and transfer. The strong preference for this methodology over traditional lecture-style teaching (62.5% disagreement with preferring traditional methods) further underscores the perceived value of the supportive environment created by this approach. This aligns with recent trends in engineering education that emphasize active, collaborative learning environments over passive, lecture-based instruction. Future research could focus on further exploring the specific aspects of the supportive environment that students found most beneficial and investigating how these supportive elements contribute to long-term skill retention and application in professional settings. Additionally, longitudinal studies could assess how the supportive environment impacts students' professional development and career readiness after graduation.

Conclusions

Engineering graduates are highly prized for their skill sets; therefore, engineering curricula should be based on the principles of skill development to maximize student value. The key takeaway from skill development is that growth requires multiple opportunities for skilled practice. A review of the literature on skill development has yielded the following recommendations for implementation in engineering curricula.

- Providing multiple attempts on assignments and quizzes to offer students practice opportunities.
- Utilizing online tools that provide instant feedback to improve the impact of each practice session.
- Providing support and intervention if practice does not yield improvements.
- Setting realistic expectations of the skill development process to prevent student disengagement.

While the initial results are encouraging, indicating potential for significant enhancements in engineering education, it is important to recognize that this project is an ongoing endeavor. As the fall semester of 2024 progresses, additional data will be collected to further validate and refine our understanding of the impact of these pedagogical strategies. Specifically, the end-of-semester survey results, which are yet to be gathered, will provide crucial insights into the effectiveness of the implemented methodology on a broader scale and over a longer term. The anticipated survey results will not only allow for a more comprehensive evaluation of the current methodology's impact on student outcomes but will also guide future iterations of the project. By analyzing the data collected at the semester's end, we aim to identify areas of strength and opportunities for improvement, ensuring that the approach remains aligned with the evolving needs of engineering students and the industry at large.

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Appendix A: Statics Class Survey Questions Fall 2024

#	Question	Mean Score
1	The multiple attempts feature motivated me to improve my performance on assignments and quizzes.	4.29
2	I felt more invested in my learning because of the opportunity to improve my grades through repeated attempts.	4.38
3	The ability to make multiple attempts on assignments and quizzes helped me practice and improve my skills.	4.25
4	I was more motivated to understand the underlying concepts rather than just memorizing answers because of the randomly generated variables in problems.	3.69
5	The opportunity to improve my grade through repeated attempts made me more willing to tackle challenging problems.	4.19
6	I felt a greater sense of ownership over my learning process due to the ability to make multiple attempts.	3.94
7	When I needed additional clarification, I felt comfortable seeking further feedback from the instructor.	3.63
8	I found the combination of multiple attempts and immediate feedback more helpful than traditional grading methods.	4.24
9	I found myself practicing course concepts more frequently due to the multiple attempts feature.	3.75
10	I found the immediate feedback after each attempt to be overwhelming and unhelpful.	3.88
11	The multiple attempts feature helped me set realistic expectations for my skill development.	3.88
12	I felt less pressured to perform perfectly on the first try because of the multiple attempts feature.	3.69
13	I understood that developing engineering skills requires time and practice beyond just attending lectures.	4.5
14	I understand that same as engineering learning is an iterative process.	3.88
15	I felt more comfortable seeking help from my instructor when I struggled with concepts.	3.5
16	The learning environment created by this methodology was supportive of my skill development.	3.75
17	Flexibility allows me to improve my grades at any point during the semester, fostering a more supportive learning environment.	4.38
18	I believe my problem-solving skills improved as a result of this teaching methodology.	3.75
19	I feel more confident in my ability to apply course concepts to new situations.	3.63
20	I felt that my ability to apply course concepts to new situations improved throughout the semester.	3.63
21	My time management skills improved as I learned to balance multiple attempts with other coursework.	3.44
22	The methodology encouraged me to collaborate with my peers in a meaningful way.	3.94
23	Working with others helped me better understand the course material.	4.0

24	I found myself more engaged in collaborative learning with my peers because we focused on understanding processes rather than just comparing final answers.	4.13
25	I believe this methodology has better prepared me for my future engineering career.	4.0
26	The opportunity to make multiple attempts on assignments and achieve the highest grade throughout the semester has significantly reduced my stress levels.	4.4
27	I would prefer traditional lecture-style teaching over this methodology in future courses.	2.25
28	How does your performance in this course compare to your performance in other courses that use more traditional teaching methods?	3.31
29	How confident do you feel in your mastery of the course material?	3.13