Measuring the Pedagogical Impact on Undergraduate Students through Frequent, Low-Stakes Pre- and Post-Lecture Self-Assessments

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Abstract

Frequent, voluntary, and low-risk formative assessments are pivotal in advancing student learning and instructional efficiency. This study explores the impact of low-stakes pre/post lecture self-assessments on bioengineering student learning. Utilizing Bloom's Taxonomy to structure assessment questions, the study monitored student performance and engagement before and after lectures. Strong student buy-in was evidenced through survey feedback, which praised the ease of technology use and the benefit of anonymous participation. Correlation analysis between self-assessment scores and traditional exam outcomes revealed a higher correlation than homework assessments, highlighting the predictive value of such assessments for academic success. Pre/post lecture assessment enables immediate student feedback and the instructor's use of their input for teaching improvements underscores the potential to enhance educational strategies and support student learning. Ultimately, the study advocates for incorporating pre- and post-lecture assessments in courses. This dual benefit approach not only aids students in enhancing their learning experience but also provides instructors with early indicators to identify and assist students who may need additional support.

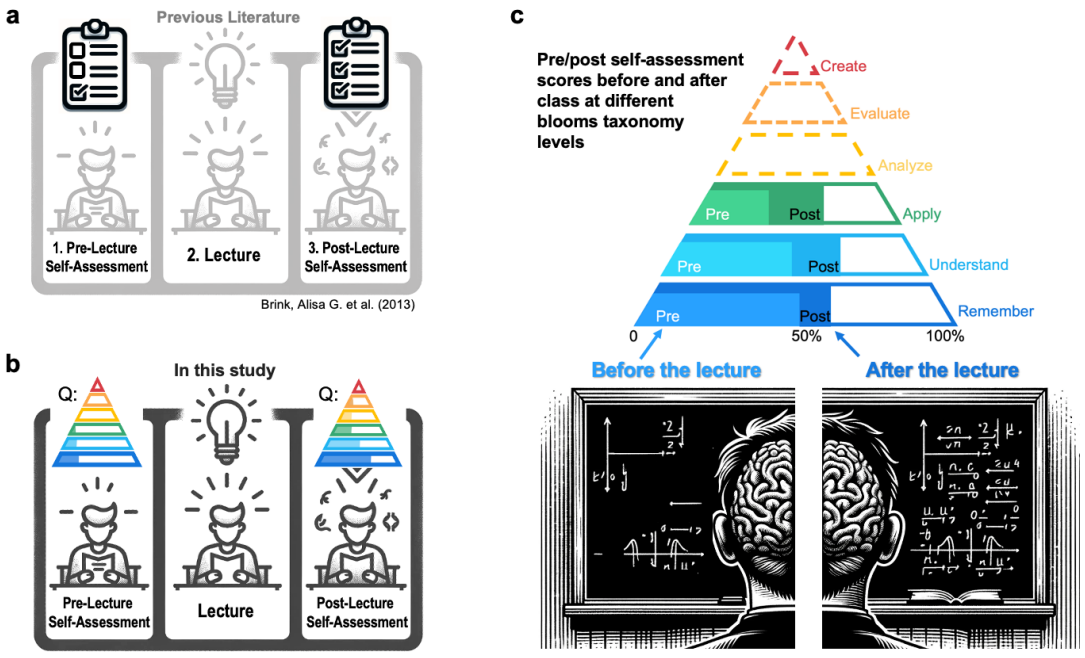

Figure 1. Integrating Pre/Post Lecture Self-Assessments of Lecture Learning Outcome with Bloom's Taxonomy. (a) Illustration summarizing previous literature and a pre/post lecture test study conducted by Dr. Alissa Brink. (b) The illustration depicts this study's method in integrating lecture learning outcomes with Bloom's Taxonomy in pre/post self-assessment to evaluate student learning from the lecture. (c) Students' scores from pre/post self-assessment conducted before and after the lecture, categorized according to different levels of Bloom's Taxonomy.

Introduction

Formative assessment is an ongoing process to check on student's understanding and support their progress. Formative assessment is a crucial tool in engineering education, known for enhancing students' progress towards achieving learning outcomes. In bioengineering education, formative assessment serves as a vital checkpoint. It ensures that students grasp essential engineering concepts thoroughly before they apply this knowledge to biomedical applications. Formative assessment, with its continuous feedback loop, aligns perfectly with these educational needs. Recent research has indicated that timely assessments aligned with course learning outcomes (CLOs) can substantially increase student learning [1,2]. These assessments serve the dual purpose of identifying challenges in student learning and facilitating targeted interventions by instructors, which is particularly important in the context of interdisciplinary bioengineering education [3,4].

Given the interdisciplinary nature of bioengineering, continuous engagement is necessary for a comprehensive understanding of engineering concepts and their practical applications, upon which subsequent lectures and coursework build [5]. Studies have shown that frequent, voluntary, and low-risk formative assessments, such as clickers and other student response systems, provide students with regular feedback that enhances their learning [6,7]. However, these assessments are typically conducted during or at the conclusion of the lecture, such as in the form of an exit ticket. While they offer tangible evidence of what students know at the moment in which the assessment is given, they fall short in measuring the specific learning acquired during the lecture itself. This gap arises because some students may already possess prior knowledge of the topics covered. To address this, introducing a pre-lecture test is essential. Such a test provides measurable data on the learning that occurs specifically during the lecture. Additionally, implementing a pre-lecture assessment has the added advantage of directing students' attention towards the learning objectives of the lecture and activating relevant prior knowledge. This approach helps students focus on the key elements of the lecture, thereby enhancing their overall learning experience and ensuring they grasp the most important concepts.

In this study, we aimed to advance the application of low-stakes assessments by integrating real-time formative evaluations in every lecture, with a systematic measurement of student learning grounded in Bloom's Taxonomy [8]. We concentrated on assessing the lecture objectives within the foundational cognitive domains crucial for learning: Knowledge, Comprehension, and Application. Since higher-order cognitive skills, such as Analysis, Evaluation and Creation, are typically evaluated through traditional class assessments like homework, midterms, and finals, they were excluded in this study. We employed identical quizzes or tests before and after each lecture, designed to be completed within approximately five minutes. Data from these pre- and post-lecture assessments were collected for two primary investigations: First, we examined whether students showed improvement in the domains of Knowledge, Comprehension, and Application as a result of the lecture. Second, we explored whether the outcomes of these pre- and post-assessments could predict students' performance in midterms and finals. At the end of the course, we sought feedback from the students on the pre-post assessments to understand their perceptions and the impact on their learning. This feedback was crucial in evaluating the effectiveness of our approach and its influence on student engagement and understanding.

Literature Review

The implementation of pre-post lecture assessment methods has been a topic of increasing interest in various academic disciplines, as evidenced by a range of studies. For instance, Alisa G. Brink's 2013 study in an accounting course examined the impact of online pre and post-lecture quizzing (Figure 1a) [9]. This study compared three different course sections: those with no quizzes, those with only post-lecture quizzes, and those with both pre- and post-lecture quizzes. The findings highlighted the benefits of using pre/post-lecture assessment method, showing improved student preparation, enhanced participation in class discussions, more effective lecture time utilization, and significant improvements in examination performances. Interestingly, the study also found that the effectiveness of these quizzes varied with student GPA levels, suggesting a tailored approach to quiz formats based on previous student achievement.

The utility of pre/post lecture assessments was further explored in different contexts. Søren Meibom et al. (1994) assessed the viability of web-based lectures as an alternative to traditional lectures, finding that such interactive tools enhanced student understanding of key concepts compared to traditional passive learning environments [10]. Julie Linsey and her team in 2009 used pre/post lecture quizzes to evaluate active learning tools in an engineering mechanics course, observing measurable increases in learning outcomes compared to standard lectures [11]. Similarly, Jeffrey S. Nevid and colleagues in 2009 employed mastery quizzes before and after the lecture in an introductory psychology course, demonstrating their effectiveness as a pedagogical tool to focus student attention on important lecture concepts and predicting course examination performance [12].

The beneficial impacts of pre-post lecture assessments have also been demonstrated in more specialized fields. In 2022, Ashley M. Sweeney et al. utilized pre/post lecture assessments in an interventional radiology lecture series, noting statistically significant improvements in participant technical knowledge of interventional radiology procedures [13]. Quamrul H. Mazumder et al. (2012) found that pre/post lecture tests improved the confidence and performance of first-generation and female students in a mechanical engineering course, indicating the potential of metacognition strategies to enhance performance and retention rates in diverse student groups [14]. Furthermore, Tina Pingting Tsai's 2017 study in a computer programming course emphasized the importance of adapting teaching methods to diverse learning needs, as reflected in varying ratios of correctness in pre-/post-lecture tests [15]. Collectively, these studies underscore the importance of recognizing each class as a unique entity, catering to the diverse learning styles and backgrounds of students.

In this research, we aim to broaden the application of pre-post lecture assessments, elevating them from feedback tools to more refined instruments that measure learning at different cognitive levels, as defined by Bloom's Taxonomy (Figure 1b). Our strategy involves aligning key lecture learning outcomes with pre/post assessment questions, crafted to probe varying cognitive depths. This method will provide instructors with a more nuanced understanding of student comprehension across diverse cognitive processes. By doing so, educators can finely tune their teaching methods to these cognitive stages, thereby more adeptly addressing the varied learning needs of their students. This approach is expected to foster a dynamic and responsive educational environment, enhancing both teaching effectiveness and student learning experiences (Figure 1c).

Methodology

Nature and Scope of Assessment Questions

The assessment questions are designed based on the lecture learning outcome to span a range of Bloom's Taxonomy levels, including knowledge, comprehension, and application. This selection is intentional, aiming to establish a baseline of the students' knowledge and their readiness to engage with the lecture material. We deliberately exclude the higher tiers of Bloom's Taxonomy — analyze, evaluate, and create as these are more suitably addressed in homework or exam assessments. An example of knowledge question "What data type can store multiple data types within the same variable?", comprehension question "Describe the purpose of logical operators", and application question "Apply a polynomial fit to a dataset where Y = [120 90 70 80 60 30 90 130 200 170] and t = 1:10". In the lecture, the questions themselves are not directly discussed. However, the topics they encompass are covered in the normal course of instruction.

Implementation in Class Sessions

In a 2-unit course "Introduction to Programming for Bioengineers" at the University of California San Diego, we conducted a study involving pre/post-lecture assessments in six out of ten sessions. The rationale for frequent formative assessment in this context is that programming, being a cumulative skill for bioengineers, requires mastery of concepts before progressing to subsequent sessions in a short amount of time. This contrasts with computer science education, which often focuses more on deep principal exploration. Our method involves using the same set of questions at the beginning and at the end of the lecture. This approach is crucial to capturing students' comprehension levels before and after the lecture. Before beginning each assessment, students are reminded that this assessment score will not contribute to their final grade and their sole purpose is to provide the student direct feedback on their current level of grasping the lecture's learning objectives. Students complete a brief, low-stakes pre-lecture assessment. Students take approximately 5 minutes to answer predominantly multiple-choice questions. The instructor ensures that everyone has adequate time to reflect and respond without feeling rushed. The post-lecture assessment follows a similar format and duration, facilitating a direct comparison of students' responses before and after lecture (i.e. intervention). These low-stakes, non-graded assessments are designed to reduce test anxiety and encourage genuine responses.

Use of Technology for Assessment and Survey

In the pre/post lecture assessment, we used Poll Everywhere, an interactive online tool. Students registered on Poll Everywhere with their names and emails, but their responses during the lectures remained anonymous to promote candid participation. This platform was advantageous as it displayed questions in a slide format, as demonstrated in appendix A, facilitating ease of presentation and discussion. It also ensured anonymity in both the live presentation during the lecture and the final reports, which were shared with students and uploaded to Canvas after the class ended. However, with students' consent for research purposes, we utilized a feature called 'grade report' that allowed us to link the student's Poll Everywhere score to other traditional formative assessments in the class, such as midterm and final exam scores. At the end of the course, we conducted a student survey via Google Forms to gather feedback from students on the pre-post lecture assessment method.

Pre-post Lecture Questions Review and Feedback at End of the Lecture

Each class session concluded with reviewing responses from the post-lecture assessment and presenting the correct answers. This is essential for identifying and addressing any misconceptions, discussing areas where students commonly face difficulties, and emphasizing the lecturer's critical concepts. The goal of this interactive review is to confirm that students depart with a thorough and accurate understanding of the material, thereby setting a robust foundation for future lectures and assignments. By carefully examining each response, we ensure that misconceptions are clarified, fostering a uniform understanding across the class before moving on to the next lecture. Composite score for pre- and post-lecture assessments were used to measure the holistic improvement in students' cognitive abilities across various levels of Bloom's taxonomy. The pre-lecture baseline determines the extent of improvement or to identify which specific levels of Bloom's taxonomy show the most significant change. By comparing the composite scores before and after the lectures, we can assess the overall impact of the educational intervention on students' learning progressions, providing a nuanced understanding of how different cognitive domains are affected.

End-of-Class Follow-Up

After the class ends, the instructor shares the pre- and post-lecture assessment questions and answers in Canvas. This is designed to share the overall learning and understanding of the lecture material across the class. The reports from the pre and post lecture assessment, it is facilitated using Poll Everywhere. This tool is particularly effective for its quick aggregation of responses and its feature of anonymized student's responses, which promotes open and unbiased participation. In cases of confusion over certain questions, the instructor provides clarifications and documents these in the Poll Everywhere report before it is subsequently uploaded to Canvas for student access.

Statistical Analysis

To investigate the improvement of student performance, we compared two paired samples: the pre-lecture and the post-lecture scores, using the paired t-test. To study the relationships between different types of assessments, a correlation analysis was performed. The Pearson correlation coefficient was used to measure the strength and direction of the linear relationship between pairs of assessment scores. We analyzed the correlation between student performance in pre-post lecture assessments and student performance in midterm and final exams. The results of the correlation analysis were visualized using a heatmap, which provided a graphical representation of the correlation matrix data. The heatmap used a color spectrum to indicate the strength of correlations, with varying shades representing different magnitudes of the correlation coefficients. We used Python for data analysis and Matplotlib for data visualization. The survey was conducted using Google Forms and Excel.

Ethical Approval

The manuscript includes results from anonymous end-of-course evaluation survey, end-of-course student performance and pre/post lecture assessment performance survey. Students were provided with an informed consent statement, approved by the University of California San Diego Institutional Review Board (IRB) (IRB-807339). The University of California San Diego has determined that this project to be exempt under category 45 CFR 46.104(d) and CFR 46.117(c)(1)(ii).

Results and Discussion

Student Demographic:
The Programming for Bioengineers course engaged in pre-post lecture self-assessments have a diverse background of 22 students enrolled that are predominantly consisting of college freshmen (Figure 2). 18 of these students have filled the survey, approximately 61% are female. In this class, the ethnic composition is diverse, with Asian/Chinese students making up 50.0% of the class, followed by White students at 27.8%. Latino/Latinx students represent 11.1%, and the remaining 11.1% consists of students from other ethnic backgrounds, including Indian, Persian, and Filipino. This shows a broad multicultural mix. 28% of students identified as first-generation college attendees. Freshmen form the majority at about 61%, followed by juniors, with around 33%. The class also includes a sophomore and a transfer student, each representing about 3% of the total. This demographic overview offers insights into the various perspectives and experiences that contribute to their educational assessments.

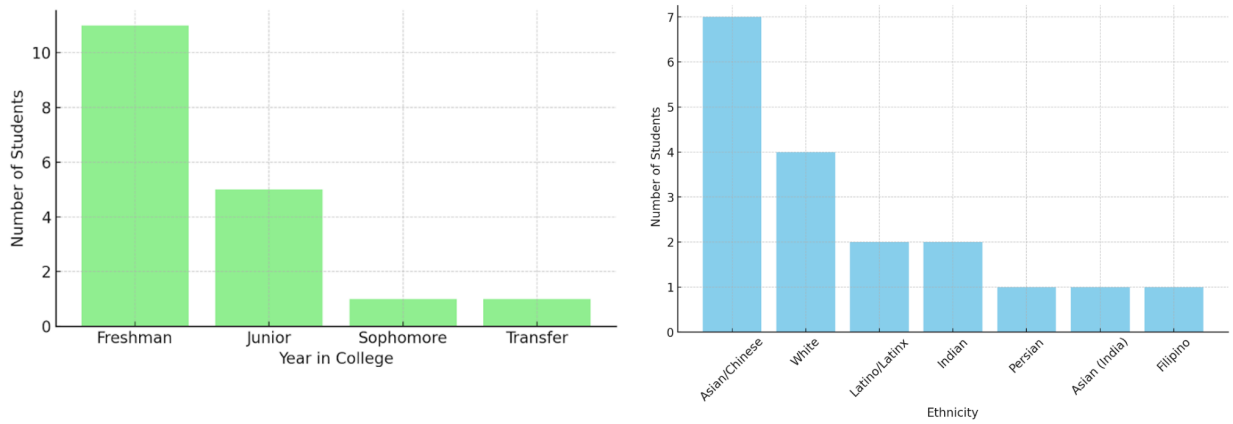

Figure 2. Demographic Overview of Student Participants in Pre/post Lecture Self-Assessment.

Student Perspectives on Low Stakes Pre/Post Lecture Self-Assessments

Strong Student Buy-in to Pre/Post Lecture Assessment and Successful Execution: At the end of the course, 82% of students volunteered to provide feedback on the impact of participating in pre- and post-lecture assessments on their learning. The survey data reveals a highly positive response from students regarding the execution of pre- and post-lecture assessments, as well as significant student buy-in (Figure 3). A unanimous 100% of volunteered students found that the polleverywhere online platform used to execute pre/post lecture assessment was accessible and easy to use. Notably, 94.4% of the students reported that the instructor's engagement and interaction with their answers during these assessments were highly effective, emphasizing the successful implementation of an interactive and inclusive learning environment. The same proportion of students reported feeling encouraged to participate in self-assessment due to anonymous participation. Furthermore, 88.8% of respondents agreed that the pre- and post-lecture assessments were a beneficial use of class time. This indicates significant student buy-in, which is important for implementing any new active learning tool. These results collectively underscore the efficacy of integrating technologically advanced, interactive, and student-centric approaches in teaching, enhancing both engagement and the overall educational experience.

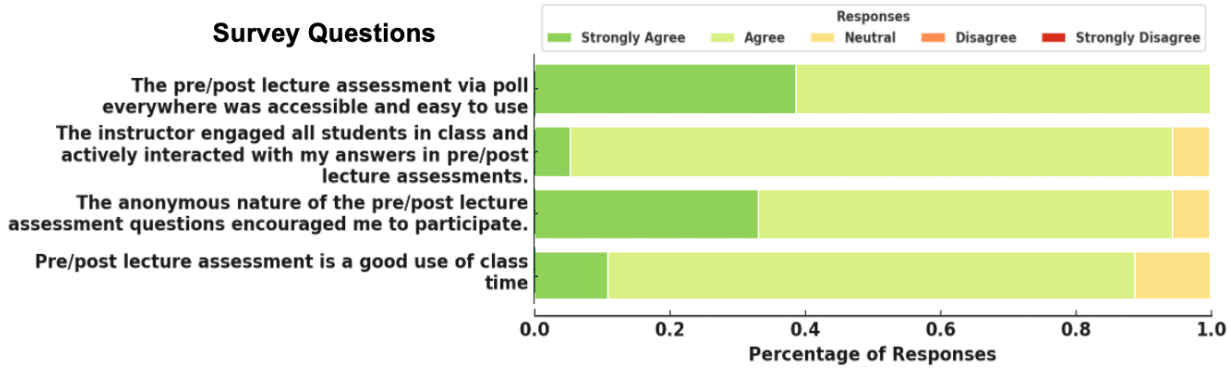

Figure 3: Student Feedback Survey Reveals Strong Student Buy-in to Low-stakes Pre/post Lecture Self-Assessment. Students report high approval for the methodology, Poll Everywhere ease of use, and anonymity of pre/post lecture assessment encouraged participation in class.

Pre/post Lecture Assessment Improved Student Learning Experience in Class: In further analysis, we aimed to investigate questions where the majority of students responded positively regarding their learning and teaching perspectives on the instructional impact (Figure 4). Approximately 77.7% of the students acknowledged that the assessments effectively highlighted the important parts of the lecture, suggesting that these tools helped in emphasizing key concepts and reinforcing critical learning points. Additionally, 72.2% of the students felt that the posting of assessment results after the lecture was beneficial in helping them assess their understanding of each topic, indicating the value of immediate feedback in self-evaluation and learning reinforcement. Notably, 66.67% of the students perceived that the instructor utilized their feedback to improve teaching, reflecting a responsive and adaptive teaching approach that values student input. The same percentage of students also believed that the pre/post lecture assessments contributed positively to their understanding of the lectures. However, we noticed a 16% decrease in participation rate at the end of the quarter that may suggest survey fatigue. Overall, these findings suggest that the assessments not only served as tools for gauging student comprehension but also played a pivotal role in enhancing the overall learning experience. This data underlines the effectiveness of the assessment method in fostering a dynamic and responsive educational environment where student feedback directly informs and improves teaching strategies.

The qualitative feedback from students further emphasized the positive impact of these assessments. Students' comments from the course evaluations include:

"Professor Khojah and our TA were very kind instructors. With the short amount of time we actually had in class, they definitely tried to create an interactive environment with PollEv quizzes. I do like how we had independent work, but they were always very kind and helpful whenever we had questions."

"The pre/post lecture quizzes helped me know how was I doing with the subject, if I needed to put more effort or if I had to keep in line with the topic that was introduced that day."

Student feedback from the end-of-class survey, responding to the question "How did pre/post-lecture assessments affect or improve your learning in class," further validates the role of pre/post lecture assessment in tracking and enhancing learning progress:

“it allowed me to see how much I learned over the course of the class, because I could answer more questions confidently at the end of class than at the beginning.”

“It gave me measurable to check my understanding, as well as a comfort in being able to check with classmates for where I stood in the class”

“Being able to see what I was supposed to learn at the beginning and later being able to see what I needed to continue studying helped me develop a better idea of what I was expected to know, and what I needed to practice or understand better.”

“It helped me realize what part of the assignment that I needed to relearn or focus on. It also help me know when other people are struggling with the topic as well.”

“It helped me see how test questions could be worded and let me see areas where I needed to study more.”

“I think they provided a good, immediate indicator of what you learned in class.”

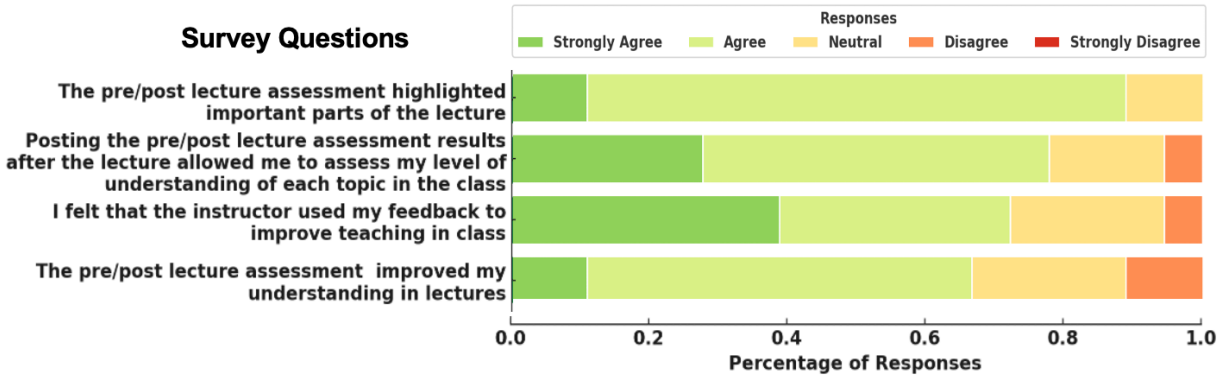

Figure 4: Student Feedback Survey Shows That Majority of Class Indicates Pre/Post Lecture Assessments Enhances Teaching and Learning.

Pre-post Lecture Assessment on Student Learning

To assess the impact of lecture sessions on student learning across various cognitive levels, students completed a pre/post-lecture self-assessment with questions targeting the knowledge, comprehension, and application levels of Bloom's Taxonomy (Figure 5).

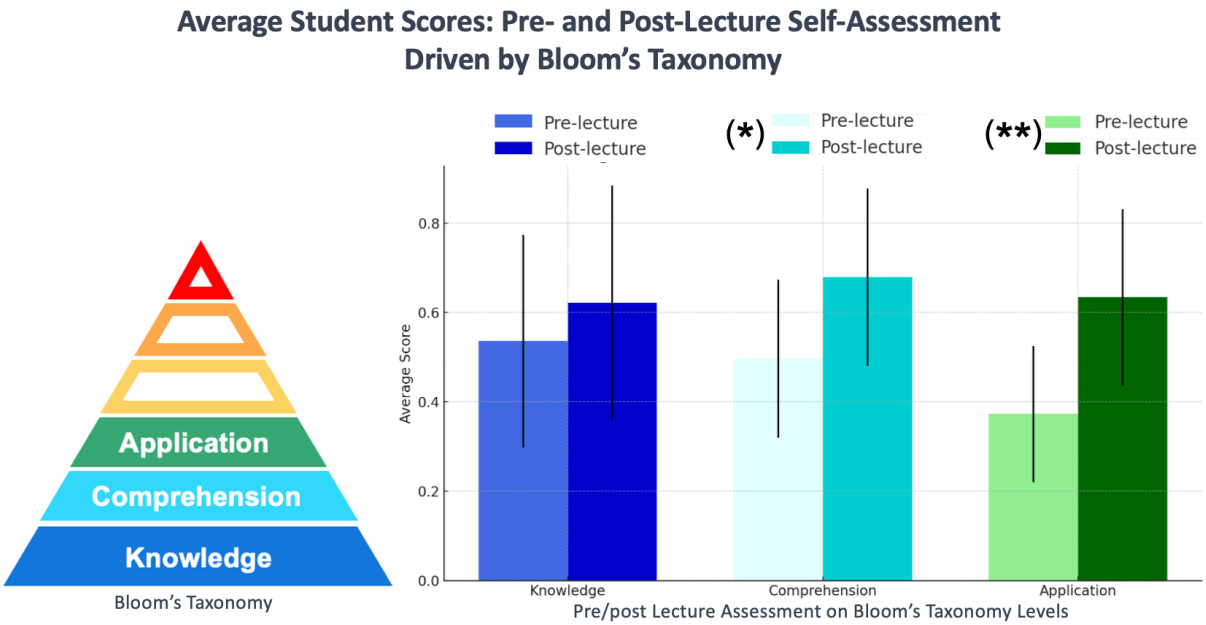

Figure 5: Average Scores of Students in Self-Assessment Tests Conducted Before and After Lectures, Across Various Bloom's Taxonomy Levels: Learning Categories: Knowledge, Comprehension, and Application. Students show significant improvement in the Comprehension (p=0.032) and Application (p=0.004) categories compared to the Knowledge category (p=0.075) of pre/post lecture assessment (*p < 0.05 and ** p<0.01 in two-sample t-test).

The investigation comprised three distinct phases: initially, a pre-lecture self-assessment was conducted to set a baseline of the students' understanding, followed by the lecture phase without referencing the initial questions, and concluding with a post-lecture self-assessment with the same question of the pre-lecture test. Post-lecture analysis revealed that students initially scored lower in the pre-test, particularly in comprehension and application, suggesting a limited grasp of complex topics. This is typical, as students often lack practice and application in these areas. However, the post-lecture results displayed consistent improvement across all cognitive levels, with around 60% of students correctly answering the post-test questions. Moreover, the students show significant improvement in the Comprehension and Application categories of pre/post lecture assessment This indicates the lecture's effectiveness not only in imparting knowledge but also in enhancing deeper understanding and application skills among the students.

Correlation Study with Traditional Assessment (i.e. Midterm and Final Exam)

To study the correlation between students' performance in pre/post-lecture self-assessments and their major exam results, namely midterms and finals, we analyzed the average outcomes of all the pre/post self-assessment tests administered in class and the results of the midterm and final exams (Figure 6). The dataset comprised grades from finals, midterms, homework, and a series of pre-post lecture self-assessments. Significantly, the correlation analysis revealed that while all components positively correlated with the total grade, the pre/post self-assessment grade exhibited

a notably higher correlation compared to the homework grade for low-performing students in the class. This finding demonstrates the pivotal role of regular in-class formative assessments in student learning and performance. We observed that homework scores tend to skew towards higher grades, primarily because students have ample time to complete their assignments. This higher average in homework grades might not fully capture the students' understanding or performance in real-time, unlike the pre/post lecture assessments. The negative correlation observed between homework scores and formative assessment performance particularly among low-performing students has prompted a deeper analysis. We hypothesize that this may be due to the formative assessments' ability to more accurately reflect immediate comprehension and learning challenges, which are not as evident in the homework results. This aspect is especially true for students who might be struggling but can still achieve high homework scores through extended effort or access to resources. Low-stakes pre/post-lecture self-assessments can be perceived as incremental checkpoints and have a more substantial impact on overall academic success than homework. This could be attributed to the ability of these assessments to immediately reinforce learning, encourage consistent study habits, and provide timely feedback. These insights hold potential implications for pedagogical strategies, emphasizing the importance of frequent, varied assessments in academic curricula, particularly in engineering education. The findings suggest that early intervention with low-performing students can be established based on real-time pre/post-lecture assessment in the class, providing better support and potentially improving their academic outcomes.

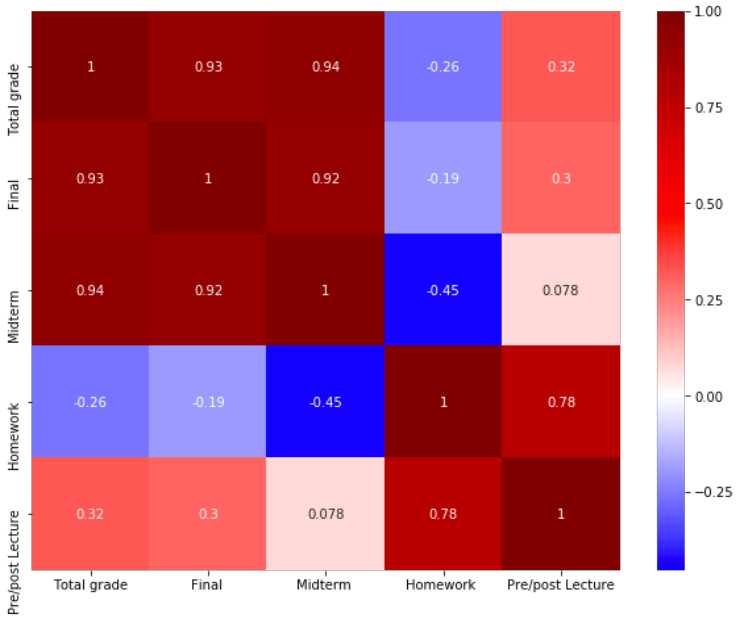

Figure 6. Correlation Matrix Heatmap of Different Assessments in Class. Pre and post-lecture show stronger correlation with traditional exams compared to homework scores and traditional exams. Color spectrum to indicate the strength of correlations (red:strong) and (blue:weak).

Conclusion

Low-Stakes, real-time assessments in pre/post-lecture activities have shown effectiveness in teaching bioengineering topics. They establish an ongoing feedback mechanism, allowing instructors to tailor their lectures and develop equitable learning tools. Our research indicates that frequent formative assessments significantly enhance the students' learning experience. Utilizing Bloom's Taxonomy facilitates the observation of gradual learning, which is often overlooked in traditional evaluations and demonstrates a correlation with students' performance in standard assessments.

Student feedback has been overwhelmingly positive, highlighting the success of this approach in improving learning and engagement. Poll Everywhere proved user-friendly for instructors, integrating seamlessly into lecture presentations, and allowing for the efficient anonymization and sharing of student responses. The reusability of questions for future classes enhances the method's sustainability for instructors.

We plan to extend this study to larger undergraduate classes and apply it to graduate level courses. This initiative lays the groundwork for further investigation into formative assessment strategies in engineering education, aiming to refine an educational framework that aligns with interdisciplinary bioengineering courses. Moreover, this real-time assessment tool offers early intervention opportunities to support students who are underperforming, ultimately aiming to improve educational outcomes and guide educators in interdisciplinary bioengineering education.

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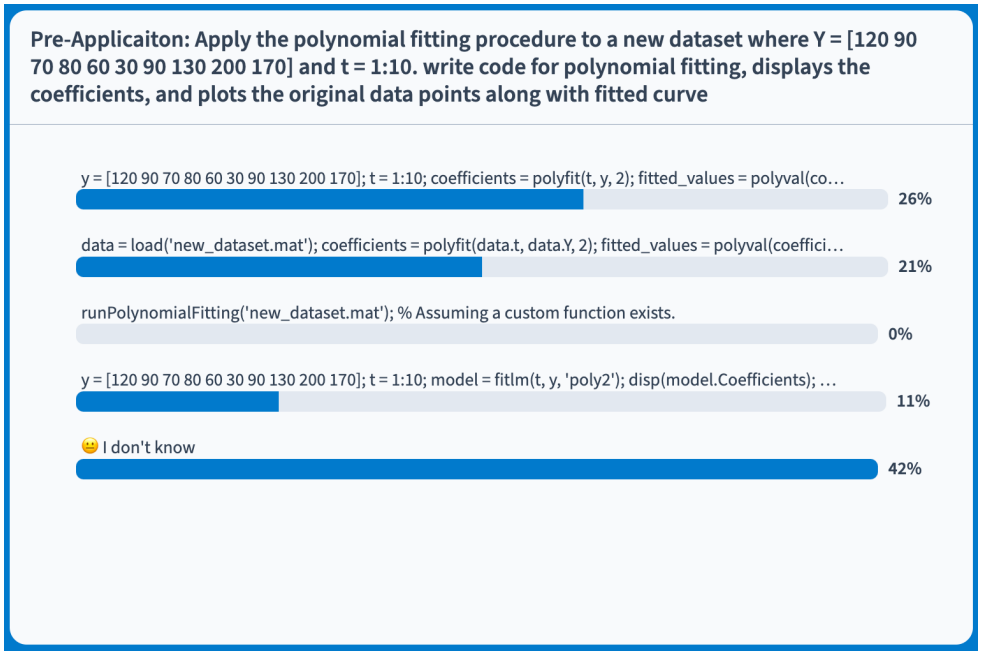
Appendix A

Example of a pre/post lecture application-level assessment in Poll Everywhere

Pre-lecture application question:



Post-lecture application question: