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# Advancing Engineering Education with a Comprehensive and Continuous Course Assessment Framework

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## Abstract

Course assessment plays a crucial role in engineering education, offering valuable insights into student progress and course effectiveness. Traditional course assessment methods, which primarily rely on end-of-semester evaluations, provide feedback only after the course has concluded, hindering opportunities for timely adjustments to improve student learning in the current semester. In response, this paper proposes a comprehensive course assessment framework that begins from the semester's start, aiming to achieve the desired outcomes by its end. This framework relies on summative assessments, such as unit tests, midterms, and finals, to evaluate student understanding at key points in the course. This approach allows for a more comprehensive evaluation of student achievement against course objectives and facilitates the identification of areas for course improvement. The proposed course assessment framework offers several advantages over traditional methods. Firstly, it provides ongoing feedback to students, enabling them to address shortcomings early in the learning process. Secondly, it prioritizes deeper understanding and application of concepts, fostering a more meaningful learning experience. Lastly, it provides a more holistic view of student learning by incorporating summative assessments. While the proposed framework can be implemented across a wide range of engineering courses, tailoring it to the specific needs of the course and the students is crucial.

**Keywords:** Engineering education; assessment techniques; formative assessment; summative assessment; learning objectives.

## Introduction

Each engineering course plots a learning journey, equipping students with essential skills and knowledge. Course outcomes, their guiding map, detail the competencies students master upon completion. Continuous improvement of these outcomes fuels this journey, empowering students to own their learning while instructors hone their methods. For engineering education, assessments are vital instruments, unlocking student progress and course effectiveness. Ultimately, they reveal how well the learning map leads students to their destination. Course outcomes are assessed by students and faculty both. Traditional course assessment methods primarily rely on end-of-semester evaluations, and provide feedback only after the course has concluded (see Figure 1). Students provide an indirect measure by responding to a set of survey questions in the final week of the semester. Their evaluation of the course indirectly measures whether they're acquiring the intended skills and knowledge. To confirm this, faculty conduct a direct assessment within a week after final grade submission, employing rubrics to scrutinize how well course objectives are being

met. Both students and faculty, wielding standardized forms and rubrics, analyze the course achievements, ensuring students graduate with the intended skillset. Traditional course assessment methods may hinder opportunities for timely adjustments to improve student learning in the current semester. The limitations of traditional assessment methods warrant exploring alternative strategies to ensure optimal opportunities for adjusting instruction and enhancing student learning within the current semester.

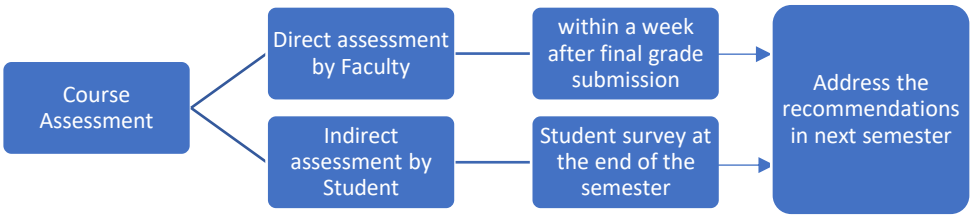


**Figure 1: Traditional Course Assessment Framework**

In response, this paper proposes a comprehensive course assessment framework that begins from the semester's start, aiming to achieve the desired outcomes by its end. This framework prioritizes summative assessment and remains an essential component of the proposed framework, it is utilized to gauge student learning after each unit, midterm, and final exam. This approach allows for a more comprehensive evaluation of student achievement against course objectives and facilitates the identification of areas for course improvement. Additionally, the framework emphasizes deeper comprehension and application of concepts, moving beyond memorization and recall.

## Literature Review

The framework developed in this study is based on two pillars: frequent mini-unit tests and data-driven targeted interventions. Frequent mini-unit tests provide frequent checkpoints and pinpoint areas needing improvement. Targeted intervention then steps in, leveraging data-driven insights to craft personalized support and fill knowledge gaps before students move on. Previous studies related to these two pillars are discussed below:

Frequent Mini Unit Tests: Bangert-Drowns et al. [1] studied the effect of frequent classroom testing which revealed that students who took even just one test within a 15-week term scored about half a standard deviation higher on final exams compared to those who took no tests. Smith et al. [2] also found similar results observing that higher final exam scores with more frequent assessments, though the effect was small and inconsistent across semesters. In a semester-long study, they investigated the impact of testing frequency on student outcomes in an introductory computer science course. They divided students into two groups: one receiving frequent testing (4 quizzes and 4 exams) and the other receiving infrequent testing (1 midterm and 1 final exam). Students in the frequent testing group outperformed their counterparts by 9.1 to 13.5 percentage points on code-writing questions.

Data-driven Targeted Interventions: Frequent formative assessments provide crucial insights into knowledge gaps and skill deficiencies across the student population [3]. Data analysis often reveals persistent misunderstandings, which become the springboard for crafting targeted questions that address these misconceptions and offer opportunities for feedback and remediation [4]. By further analyzing student performance on the actual exam, educators can gauge the effectiveness of their questions and refine them for continuous improvement. This data-driven cycle ensures assessments not only measure learning but actively enhance it, leading to a successful assessment experience for all.

**Proposed Course Assessment Framework**

The traditional course assessment method aims to measure student learning, provide feedback for improvement and develop action items for future improvements. The following steps are necessary to successfully complete the traditional course assessment.

1. Identify the learning outcomes for the course.
2. Choose appropriate assessment methods for each learning outcome.
3. Develop clear assessment criteria.
4. Collect and analyze assessment data.
5. Provide feedback to students and adjust the course as needed.

Contrary to conventional practices where steps 4 and 5 occur at the semester's conclusion, the proposed framework implements them within the initial stages of the course, facilitating ongoing evaluation and early intervention. The proposed framework centers on carefully assessed Course Outcomes (COs) using unit tests and exams (see Table 1 below). All the COs are evaluated and divided into two phases: I and II. In Phase I, the first four COs were assessed while the remaining four were assessed in Phase II. To accommodate more thorough assessments, alongside 4-unit tests, there are also midterms and a final exam. Unit tests are conveniently integrated into lecture time, while midterms and the final exam are scheduled separately to allow for extended testing periods.

**Table 1: Course Outcomes (CO) Assessment in Tests/Exams**

<table>
<tr><th>Course Outcomes (CO)</th><th colspan="4">Tests/Exams</th></tr>
<tr><td>1</td><td rowspan="4">Phase I</td><td rowspan="2">Unit Test 1</td><td rowspan="4">Midterm 1</td><td rowspan="8">Comprehensive Final Exam</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td rowspan="2">Unit Test 2</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td><td rowspan="4">Phase II</td><td rowspan="2">Unit Test 3</td><td rowspan="4">Midterm 2</td></tr>
<tr><td>6</td></tr>
<tr><td>7</td><td rowspan="2">Unit Test 4</td></tr>
<tr><td>8</td></tr>
</table>

The assessment process of COs 1 through 8 is shown in Figure 2 and 3. Figure 2 presents the step-by-step evaluation, while Figure 3 depicts the flowchart logic underlying CO assessment. Each outcome gets two chances to be met. Unit tests evaluate them initially, and any unmet outcomes are re-evaluated in the midterm exam. Midterm exam questions are specifically designed to address learning gaps identified in prior evaluations of course outcomes. Specifically, after a unit test, if an outcome was not achieved, those topics under that outcome are reviewed through a focused class and additional practice problems before the next midterm, where they are assessed again. This approach with targeted intervention ensures students have two opportunities to master the material. Given the demanding final schedule, with multiple exams in quick succession, assessing outcomes on the comprehensive final is not recommended. Students under such pressure are likely to underperform, potentially creating an inaccurate picture of their mastery.

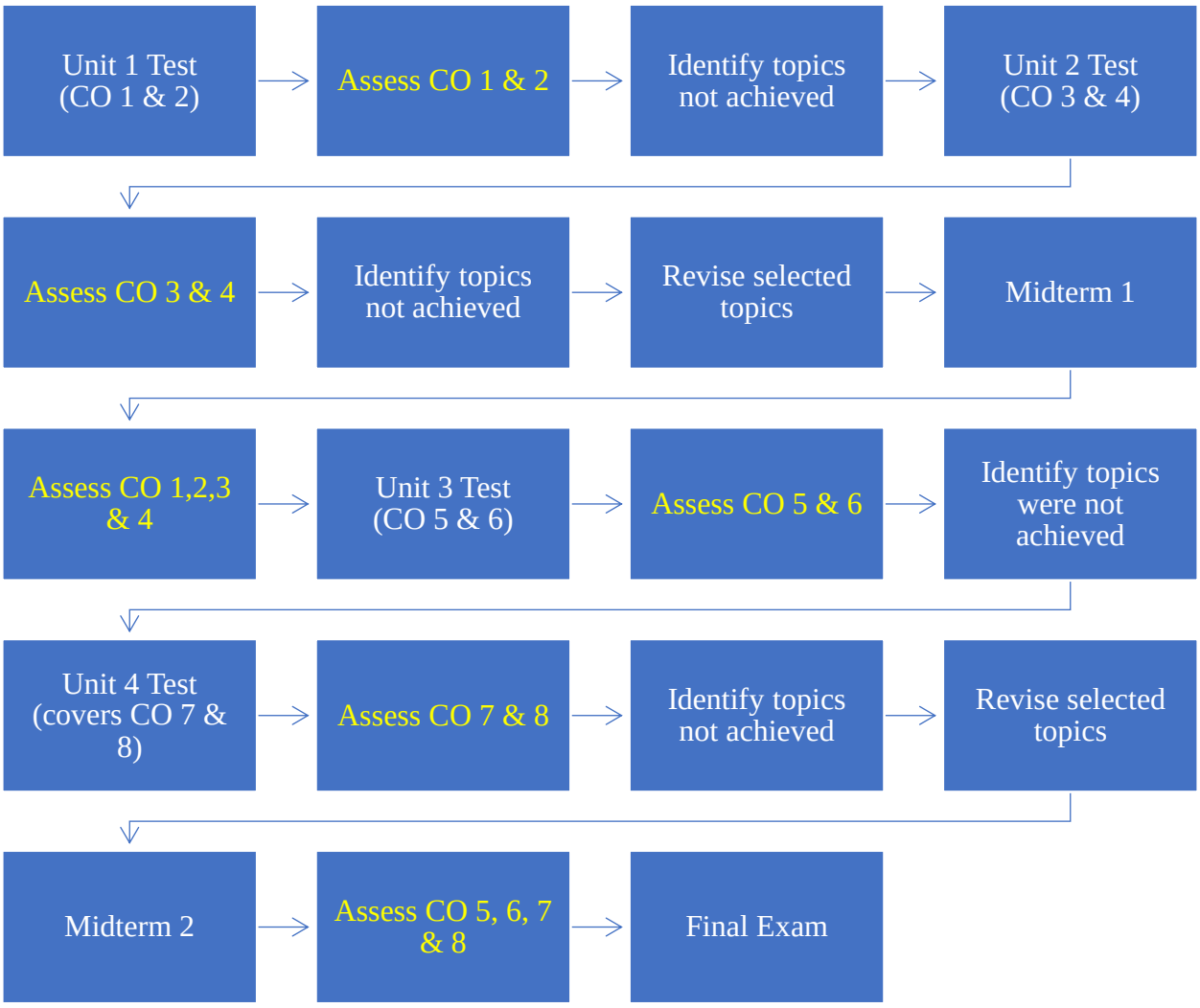


**Figure 2: Course Assessment Process of CO 1 through 8**

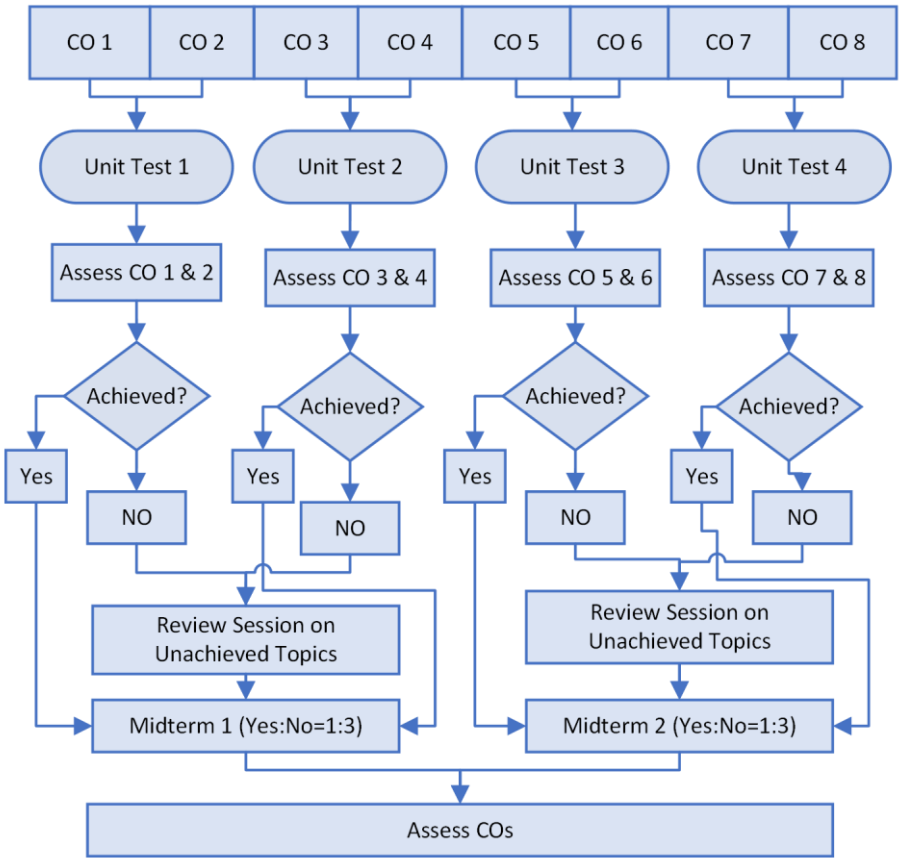


**Figure 3: Flow Chart of Assessment of Course Outcomes (COs)**

**Instructor Observations on Targeted Assessment (Case Study: CE 100 Intro to Geomatics)**
Student mastery of course outcomes on horizontal and vertical curves has consistently been a challenge in this course, as evidenced by performance in Fall 2022. Only 55% and 64% of students achieved mastery of the horizontal and vertical curves learning outcome (see Table 2) comparing the target 70%. Note that to achieve a CO, 70% students must get more than 60% grade in this particular topic. Recognizing this gap, an innovative approach was implemented to target and overcome this challenge in Fall 2023. Before the midterm exam, students were given a focused unit test specifically on this topic. This targeted assessment proved instrumental in pinpointing the areas where students still encountered difficulties. Equipped with this valuable data, instructors then meticulously analyzed the results and identified the specific concepts causing trouble. Subsequently, these identified problem areas were promptly addressed and re-explained in a dedicated class session before the midterm. This targeted intervention proved highly effective, as evidenced by the significant improvement in student performance on the related mid-term exam questions (94% in Fall 2023 vs. 55% in Fall 2022 and 94% in Fall 2023 vs. 64% in Fall 2022). This success story demonstrates the power of data-driven, focused interventions in addressing specific learning deficiencies and ultimately facilitating student mastery of challenging course material.

**Table 2: Comparison of Targeted Course Outcome Assessment**

| Course Outcomes | Tools Used | Limit | Fall 2022 | Fall 2023 |
|---|---|---|---|---|
| Apply mathematics … | Midterm(s) | 70% | 100% | 83% |
| Measure and layout… | Midterm(s) | 70% | 73% | 72% |
| Understand units… | Midterm(s) | 70% | 82% | 83% |
| Understand the theory of errors… | Midterm(s) | 70% | 100% | 94% |
| Carry out profiling and grid… | Midterm(s) | 70% | 100% | 89% |
| Measure horizontal and vertical angles. | Midterm(s) | 70% | 82% | 72% |
| Determine coordinates of … | Midterm(s) | 70% | 82% | 89% |
| Conduct quality control … | Final Exam | 70% | 100% | 100% |
| **Design basic horizontal alignment…** | **Final Exam** | **70%** | **55%** | **94%** |
| **Design basic vertical alignment…** | **Final Exam** | **70%** | **64%** | **94%** |
| Function in a team during … | Final Exam | 70% | 100% | 100% |
| Ability to use the techniques… | Final Exam | 70% | 100% | 100% |

## Conclusion

This paper challenges the limitations of traditional end-of-semester course assessment in engineering education by proposing a comprehensive and flexible framework that prioritizes continuous feedback and active learning. By leveraging a combination of summative assessments throughout the semester, this framework empowers students to identify and address weaknesses early, cultivate deeper understanding of concepts, and ultimately achieve the desired course outcomes. While summative assessments remain vital for measuring overall achievement, their strategic placement within the framework provides a more nuanced picture of student progress at key milestones. Importantly, this framework emphasizes the targeted interventions. This aligns with the core objectives of engineering education. While readily adaptable to various engineering courses, tailoring the framework to the specific context and student needs is key to maximizing its effectiveness. By embracing this dynamic approach, educators can move beyond the limitations of traditional assessment and foster a genuine learning journey for their students, enabling them to confidently navigate the complex world of engineering.

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