How Do First-Year Undergraduate Engineering Students' Self-Reported Reasons and Motivations to Participate in Formative Assessments Translate into Their Learning Achievement: An Exploratory Study

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Abstract – This full research paper uses sequential explanatory mixed-method design to explore and understand the reasons and motivations behind students' decisions to participate or not participate in completely optional, online formative assessments and how these reasons and motivations explain the different relationships between their formative assessment participation and summative achievement in a large first-year undergraduate fundamental engineering course in a land grand university in the western United States.

In purpose terms, formative assessment is a learner-centered approach that allows students to assess their learning, identify their misconceptions, and address them early in the learning process. Formative assessments also help teachers to receive feedback that may help them adjust their instruction to students' learning needs. Extensive empirical and theoretical research has established the benefits of formative assessments in improving learning and instructional effectiveness within different subject areas, educational levels, and learning contexts. However, the fact that formative assessments are for feedback purposes and are usually low-stake or no-stake assessments might hypothetically affect students' motivation to participate in these assessments. This research could provide insights into enhancing students' motivation and engagement in formative assessments, thereby improving their learning outcomes.

Students' formative assessment participation and summative achievement data in a class of 140 students were quantitatively analyzed to identify a purposive sample of eight (08) students with different levels of participation in formative assessments and different summative achievements. These eight students were selected based on the criteria as follows: students with (1) high formative assessment participation and high summative achievement, (2) high formative assessment participation and low summative achievement, (3) low formative assessment participation and high summative achievement, and (4) low formative assessment participation and low summative achievement. These students were then interviewed using semi-structured interviews with open-ended questions to collect insights into their reasons and motivations regarding different levels of participation in these assessments and to explore how these reasons and motivations explain their summative achievements.

A deductive approach was employed to code and analyze the data and identify emerging patterns and themes. Results show that students' reasons and motivations are guided by their diverse achievement goal orientations. Moreover, these orientations also seem to dictate their strategies in formative assessment participation, which may, in turn, affect their achievement. One very significant finding of the study is that the voluntary and optional nature of formative assessments encourages students with a performance-avoidance orientation to participate because there is no fear of judgment or failure. These findings significantly impact our understanding of students' participation in formative assessments and have implications for practice. The study was approved by the Institutional Review Board (IRB).

Keywords – formative assessments, achievements, undergraduate engineering, participation.

I. Introduction

Formative assessments play a critical role in the educational process, providing valuable feedback to students and instructors to inform instructional strategies and support student learning [1]. In engineering education, where the development of problem-solving skills and conceptual understanding is paramount, formative assessments are particularly beneficial. These assessments allow for continuous monitoring of student progress and identifying student misconceptions, and the areas they are struggling with [2]. Despite their significance in enhancing learning and instruction, there is limited research on students' motivation, reasons, and decisions regarding participation in optional online formative assessments, especially in fundamental engineering courses. This research explores the reasons and motivations influencing students' decisions to participate or not participate in optional online formative assessments in a fundamental engineering course. By investigating these factors, this study seeks to contribute to the existing literature on formative assessments in engineering education and provide actionable insights for educators aiming to enhance student engagement and learning outcomes.

II. Brief Literature Review

Integrating formative assessments in engineering education has enhanced learning outcomes by encouraging active engagement and timely feedback [3]. Formative assessments help bridge the gap between teaching and learning by allowing students to gauge their understanding and receive feedback to guide the learning process [4]. Furthermore, formative assessments have been linked to improved retention and understanding of materials, and increased student motivation and engagement [5].

In the context of undergraduate engineering education, formative assessments are essential due to the complexity and cumulative nature of the subject matter. Engineering students often encounter challenging concepts that require iterative learning and continuous feedback to master [6]. Online formative assessments offer flexibility and accessibility, allowing students to engage with the material at their own pace and convenience [7]. However, the optional nature of these assessments raises questions about the factors that influence students' decisions to participate in these assessments or abstain from participation.

Understanding the reasons and motivations behind students' participation in optional online formative assessments is crucial for several reasons. Firstly, it can inform the design of more effective assessment strategies that encourage higher participation and better learning outcomes [8]. Secondly, it can help educators identify barriers to participation and develop interventions to address them, ensuring that all students can benefit from formative assessments [9].

III. Methods

A. Study Design

The study utilized a sequential explanatory mixed-method design, specifically employing the participant selection model [10]. This research is part of a larger mixed method study. The primary intent of sequential explanatory mixed method design is to use qualitative data to explain specific quantitative trends, e.g., outliers, positive-performing exemplars, or confusing and/or surprising results. However, the participant selection or case-selection variant of the sequential mixed-method design can also be employed to use quantitative data to guide purposeful sampling for the exploratory qualitative phase of the study [11].

B. Context of the Study

To understand the context and rationale for this current study, it is important to share that the analysis of the quantitative data in the larger study [12] resulted in statistically significant positive correlations between students' formative assessment participation and achievement on summative exams. Quantitative analysis in the larger study also revealed statistically significant mean differences in summative achievements between students who participated and those who did not participate in formative assessment quizzes. Moreover, there were also statistically significant mean differences in summative achievements between students with different (e.g., low, moderate, high) levels of formative assessment participation. However, despite the statistically significant results in favor of formative assessment participation, the authors identified some (anomaly) cases inconsistent with the statistically significant quantitative trends. For example, there were students with high formative assessment participation yet low summative achievements. On the contrary, there were students with no or low formative assessment participation yet high summative achievement. These anomaly cases led the authors to conduct this current study to explore the reasons and motivations behind students' decisions to participate or not participate in formative assessments and how these reasons and motivations may be associated with their summative achievements. Therefore, the focus of this study is to explore undergraduate engineering students' self-reported reasons and motivations to participate in no-stakes online formative assessments (practice quizzes).

This study was conducted with students enrolled in the Fundamentals of Electronics for Engineers course at a public land-grant research university in the western United States. This fundamental engineering course is mandatory for undergraduate engineering students from all engineering disciplines. The course enrolls 100 to 200 students every fall and spring semester. The quantitative phase of the study included 140 students enrolled in the course for the fall 2021 semester.

The course is divided into twelve (12) modules. The course facilitator (co-author) carefully developed twelve (12) formative assessment quizzes (one quiz per module), each quiz comprising ten (10) multiple-choice type questions. Each question had only one correct answer and three (03) wrong options (distractors). Distractor options were carefully chosen to make it challenging for students to eliminate wrong answers and encourage them to apply problem-solving strategies to identify the correct answer. Each quiz offered short feedback for each question after the attempt submission. Feedback comprised correct answers to each question and a single-line description of the underlying concept/law/theory required to solve the problem correctly. Feedback was always displayed to reinforce the concepts irrespective of the correctness of the student's attempts (see Figure 1 for the sample question and associated feedback).

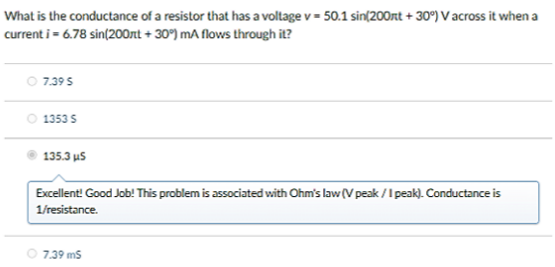

Figure 1: Example of Minimal Automatic Feedback to Students

Formative assessment quizzes were available online to all students through the Canvas learning management system throughout the semester. All students were informed about the availability of these formative assessment quizzes via Canvas announcements, syllabus, and orientation class. It was clearly explained to the students that these quizzes are for practice purposes, and their scores will not affect their final grades in the course. It was also clarified that there is no limit on the number and duration of attempts on these quizzes.

C. Participants and Data Collection

In the first phase of this study, quantitative data were obtained. Quantitative data comprised students' formative assessment participation and achievement on summative examinations. Formative assessment participation was

measured by the total number of formative assessment quizzes a student completed. Table 1 details formative assessment quizzes, relevant course modules, and associated summative examinations.

Table 1: Formative Assessment Quizzes, Modules, and Exams

Formative Assessment	Course Modules	Summative Exam
Quiz 1 – 4	Module 1 – 4	Mid-Term Exam 1
Quiz 5 – 8	Module 5 – 8	Mid-Term Exam 2
Quiz 9 – 11	Module 9 – 11	Mid-Term Exam 3
Quiz 1 – 12	Module 1 – 12	Final Examination

Formative assessment participation was measured based on the number of completed formative assessment quizzes corresponding to each summative exam. Students were grouped into different categories based on their level of formative assessment participation (i.e., the number of formative assessment quizzes completed before each exam), as shown in Table 2.

Table 2: Formative Assessment Participation Categories

Participation Level	Formative Assessment Quizzes Done before			
	Exam1	Exam2	Exam 3	Final Exam
No	0	0	0	0
Low	1	1	1	1 – 4
Moderate	2 – 3	2 – 3	2	5 – 8
High	4	4	3	9 – 12

Summative achievement was measured using students' scores on three midterm and one final term examination. High summative achievement was defined as mean plus one standard deviation (M + 1SD) while low summative achievement was defined as mean minus one standard deviation (M – 1SD). Four target groups of students were identified using the criteria as presented in Table 3. The study was approved by the Institutional Review Board (IRB) and permissions from participating students were obtained using an informed consent form.

Table 3: Purposive Sampling

		Formative Assessment Participation	
		High	Low
Summative Achievemen	High	2	2
	Low	2	2

The question of an appropriate sample size for a qualitative study is still under debate. Boddy (2016) argues that determining an appropriate sample size for a qualitative research study is contextual and dependent upon the research paradigm and overall goal [13]. Boddy exemplifies that qualitative research based on positivism as a paradigm would require a larger sample size to gain a representative picture of the population. However, a detailed investigation into a single case can also be more beneficial for an in-depth study of a new, potentially highly relevant area. Moreover, Boddy also identifies theoretical saturation as one of the potential criteria for choosing a qualitative sample size. Research shows that theoretical saturation in most cases is achieved by qualitatively investigating 12 cases [13]. Therefore, the researcher targeted to select a sample size of 12 to avoid the collection of redundant information and reach theoretical saturation. However, due to a low response rate from students, the researcher could only manage to select 8 participants for this study, which was close to appropriate.

Semi-structured interviews were conducted with the purposively selected eight (08) students to gain insights into their reasons and motivations behind different levels of participation in formative assessment quizzes. Each interview lasted 20 – 40 minutes. The Institutional Review Board (IRB)-approved semi-structured interview protocol was designed to elicit information about students' perceptions of available learning resources, awareness about the formative assessment quizzes, available feedback, and their reasons and motivations to participate in the formative assessments. To gain an in-depth understanding of the reasons and motivation, follow-up questions were also asked where appropriate to understand their views and concerns about the formative assessments and how their motivation could be enhanced to promote better participation.

IV. Data Analysis

The qualitative strand of the research aimed to identify common themes and patterns to explain trends in students' formative assessment participation, their relationship with summative achievement, and how students' self-reported reasons and motivations to participate explain these relationships.

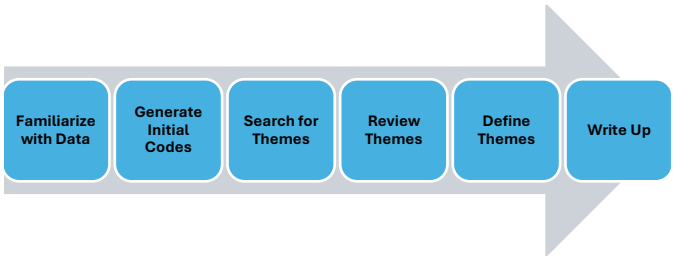

Figure 2: Six-Phase Thematic Analysis Framework [14]

Thematic analysis, as described by Braun and Clarke (2006), was used to analyze and report themes in the interview data, offering flexibility to match the research objectives without being constrained by specific epistemological or theoretical perspectives [14]. Interview data (audio recordings) were transcribed and meticulously verified and then de-identified using unique alphanumeric codes for the privacy and

confidentiality of the participants. The six-phased thematic analysis framework [14] was followed sequentially, as shown in Figure 2.

The researcher and a fellow graduate student independently conducted the first three phases of thematic analysis for interviews with two participants and discussed their findings to reach a consensus. The researcher then completed the coding and thematic analysis of the remaining interview data and reviewed them with the fellow coder to ensure they accurately reflected participants' narratives, thus achieving a 100% inter-coder agreement. Themes and findings were then interpreted, focusing on common and exceptional cases, and integrated with the quantitative results. Table 4 summarizes results from the thematic analysis of the qualitative data.

V. Results

The qualitative analysis of interview data revealed a major higher-order theme influenced by the framework of achievement goal orientation [15], with subthemes referring to master goal orientation, performance goal orientation, and performance-avoidance goal orientation. However, it seems that different reasons, motivations, and strategies associated with different goal orientations translated into different relationships between formative assessment participation and summative achievement. For example, one student with performance goal orientation uses effective strategies (e.g., utilizing feedback and revisiting relevant concepts) while participating in formative assessments to improve their performance (summative achievement), while another student exhibiting performance goal orientation may use poor strategies like repeatedly attempting quizzes to see answers without using feedback, or may not participate in formative assessments because they do not contribute to final grades. The results of the analysis are discussed here below group-wise:

A. High Participation, High Achievement

As shown in the summary of results (Table 2), various themes emerged in the qualitative data, revealing that students' higher participation in formative assessments and high achievement may be explained by reasons and strategies influenced by their achievement goal orientations. An emerging theme in this group was Mastery Goal Orientation. Mastery goal-oriented individuals are interested in learning the concepts and mastering the material irrespective of grades. Such students tend to self-assess, reflect on their learning, and seek feedback to improve their learning.

As indicated by a participant in this group, formative assessments provided an opportunity to self-assess their learning progress, identify learning gaps, and use feedback and other learning resources (textbook, video lectures) to fill those gaps. The following excerpt from the participant's interview refers to the purpose of formative assessment participation.

> *"...I wanted to know that I have learnt the stuff (refers to concepts) right. And when I did them I knew what I learnt right and what I need to repeat. The results will tell me if I need to study them again and learn the concepts more"*

One significant finding revealed that formative assessment participation supported summative achievement among participants who exhibited performance-avoidance goal orientation, as revealed by analyzing their responses. For example, a participant with high formative assessment participation and high summative achievement mentioned (see excerpt below) that the voluntary and optional nature of practice quizzes (formative assessments) helped them practice and learn the concepts without worrying about the grades as in summative exams. The participant narrates that,

> *"yes they (formative assessments) helped me learn because I could repeat them without worrying about being awarded a bad grade for it. Like I will always try them after finishing the topic and the homework, and then do them to see if there is anything I don't know. You can't do that in exams and homework because there is a pressure of time and grades."*

Performance-avoidance goal-oriented students typically tend to avoid situations where they might be evaluated or where there is a risk of demonstrating low confidence. Such orientations are usually adopted by individuals with a high fear of failure. Higher participation and high summative achievement among such students may be attributed to the optional nature of online formative assessments. As these assessments were not graded, performance-avoidance-oriented students could participate without fear of judgment or failure. This may have enabled such students to self-assess, reflect on their learning, and use feedback to improve without fear of failure.

Similarly, a participant explained that formative assessments helped them self-regulated and verify their learning. Self-regulation is characterized by self-assessment to identify and address misconceptions and verify learning. Explaining the purpose of participation in formative assessments, this participant responded as below:

> *"I always want to know that I have learnt everything and can solve any problem and like you know I want to stay on top of everything. So I always used these practice quizzes to do that. It was good to see when I verify my learning before going to next topic."*

He further added that,

> *"Sometimes I make mistakes on easy questions you know when you think it's very easy and then do it wrong. So I took notes of those mistakes so I don't repeat them again."*

Unlike mastery orientation, performance orientation shifts students' focus to achieve higher grades and gain favorable judgments. Such students seek positive reinforcement and feedback. Performance orientation in this study seemed to help a participant decide to participate in formative assessments

despite no stakes associated with them. A participant with high achievement and high participation explained how formative assessments helped improve his summative achievement (exam grades) as follows:

> *"I participated in these quizzes to know the format of questions for exam and be ready for exam to perform better. So I did all of them and repeated them after every topic and homework weekly and then before exam to make sure I do well on each exam."*

B. High Participation, Low Achievement

An emerging theme in this group revealed that performance goal orientation may misguide students' strategies of formative assessment participation, resulting in low summative achievement. One such scenario emerged in the interview data where a student participated in formative assessments to know answers to the questions and the format of expected exam questions to get good grades. The strategy employed was repeatedly attempting the quizzes without understanding the feedback and revisiting the concepts to clear misconceptions. Such a tendency among performance-oriented students hypothetically does not contribute to student learning and does not help achieve the purpose of formative assessment participation. The following excerpt represents the stated case.

> *"I did the quizzes most often on exam day or a day before it. I repeated them again and again to know the questions formats and correct answers."*

C. Low Participation, High Achievement

This anomaly group was very interesting because, hypothetically, researchers would expect to see low summative achievement among students with low formative assessment participation. However, as explained by the participants, students' goal orientations may dictate their strategies to help achieve high scores on summative exams despite no or low participation in formative assessments. A potential mastery-oriented participant narrated the reasons for not participating in formative assessments as a lack of detailed feedback. The student added that they focused on other learning resources, such as homework, video lectures, labs, and textbook materials, to learn the concepts.

> *"I used reading materials, enhanced guided notes, and video lectures to learn the materials and prepare for exams. I tried one quiz, but the feedback was very short, and it was not helpful to learn more difficult questions."*

Similarly, a potential performance-oriented participant justified low participation in formative assessment and narrated alternate strategies as below:

> *"I think it was extra time that these quizzes required and there was no incentive like grading of quizzes or extra credit to help my grade. So, I did not participate. I worked hard on homework and labs because they were not only graded but also helped me get better results on exams. I check all my homework solutions before exam to prepare well."*

D. Low Participation, Low Achievement

Reasons for low participation or lack of participation in this group seemed to be influenced by performance orientation and other factors like the student's workload and other commitments. Tough schedules, family commitments, full course loads, and full-time jobs were the codes that appeared to explain students' lack of formative assessment participation within this group.

VI. Discussion, Conclusions, and Implications

These results indicate that students with mastery goal orientations tend to take advantage of formative assessments as supplemental help resources to self-assess and reflect on their learning and use feedback to improve their learning and, hence, summative achievement. Students characterized by performance goal orientation used two different approaches to formative assessment participation. Some used them as an opportunity to familiarize themselves with the format of exam questions and achieve better scores on exams. Some others with similar goal orientations did not participate because it was extra time and effort with no extra rewards (credits) that might be counted toward final grades. Yet some other students explained that they used the assessments because they could assess their learning without someone noticing them. In that sense, these assessments allowed students with performance-avoidance goal orientation to self-assess their learning. Whether these assessments helped students improve their summative achievement depended upon the strategies and approaches they used. In the purposive sample, students who employed self-regulated learning (SRL) strategies and used the assessments systematically in their SRL helped them achieve higher achievement scores on exams. Similarly, these assessments benefited students who used them effectively to improve their exam scores. However, students who participated in these assessments merely saw the type of questions and made multiple attempts to find the correct answers without putting time into seeking and using the feedback. They did not benefit from these assessments despite participation. These findings are in harmony with those of Dijksterhuis et al., who found connections between individuals' preferences for various types of assessments and their achievement goal orientation [16]. More specifically, Jijksternuis et al. state that performance goal orientation is associated with preferences for high-stake summative assessments, where competence is assessed against pre-defined standards, while mastery goal orientation is associated with choices of learning through feedback, self-assessment, self-evaluation, and self-reflection through formative assessments [16].

The results indicate that formative assessment participation can help students with various achievement goal orientations. However, students' motivations must be guided and supported in the right direction. Interventions may need to be introduced to guide performance-oriented students to participate in formative assessments with the right strategies, which can

satisfy their desire to achieve higher grades by contributing to their learning. For mastery-oriented students, formative assessments may need to be enhanced in terms of more effective and detailed feedback. The most significant finding of the research is that the voluntary and optional nature of formative assessments supports and encourages participation among performance-avoidance-oriented students.

The findings of this research encourage researchers and educators to introduce optional online formative assessments into undergraduate engineering courses and guide students' strategies to take advantage of these assessments with the right reasons and motivations. Educators may also need to recognize the different goal orientations of students and tailor formative assessments to cater to these varying needs, ensuring that all students can benefit regardless of their preferred learning strategies. The research findings can help educators and researchers create a more inclusive and effective learning environment that supports diverse student needs and enhances overall academic achievement.

However, it is important to acknowledge that the sample size did not meet the minimum of participants suggested by Boddy for qualitative research [13]. This limitation was due to the study's exploratory nature and resource constraints. Despite this, the findings provide valuable insights and a strong foundation for future research. Moving forward, expanding the sample size in subsequent studies could enhance the robustness and generalizability of the results. Additionally, future research could explore these findings in different contexts or with more diverse populations to gain a broader understanding of the phenomena.

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