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Formative Assessment in Engineering Education: Exploring Ways to Enhance Students' Learning Achievement

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FORMATIVE ASSESSMENT IN ENGINEERING EDUCATION: EXPLORING WAYS TO ENHANCE STUDENTS' LEARNING ACHIEVEMENT

by

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ABSTRACT

Formative Assessment in Engineering Education: Exploring Ways to Enhance Students' Learning Achievement

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Testing in education has been extensively researched and proven to contribute to students' learning and exam achievement over decades now. Positive effects of testing in enhancing students' learning have been strongly associated with backward (i.e., retention of learnt information) and forward (i.e., potentiation of new learning) testing effects. Although formative as well as summative assessments represent different forms of testing, they differ from each other in definition and purpose and may contribute differently to students' learning. Summative assessment refers to high stake testing offered to test students' learning terminal to a module, semester, or academic year to decide on progression to next level. High stakes attached to this type of assessment has been associated with high induced test anxiety which in turn hinders students' learning. on the other hand, formative assessments are completely optional, no stake assessments offered to students as an extra opportunity to assess and reflect on their learning progress, and, identify and address learning gaps and misconceptions (if any) early in learning process through feedback. These characteristics make formative assessments a better

choice to address concerns of test anxiety and contribute to students' learning more effectively. However, most of the research emphasizes integration of systematic personalized feedback to get the most out of formative assessments in terms of students' learning.

Despite proven positive effects of formative assessments, there are two challenges in utilizing and capitalizing on the benefits of formative assessments. First, optional nature of formative assessments and no stakes associated with them makes it hard to convince students to participate in these assessments. Second, in large classes particularly in fundamental engineering courses with heavy enrollment, administration of personalized feedback becomes difficult. Therefore, purpose of this dissertation research was three-fold. Firstly, this research tried to understand students' different participation trends in completely optional, online formative assessments with minimal automatic feedback. Secondly, this research assessed relationships between students' formative assessment participation and summative exam achievement, and how their task value beliefs (i.e., importance, usefulness, and interest) in the course materials moderate these. Third, a qualitative investigation into the reasons and motivations behind selected quantitative trends in participation and associations was carried out to identify, explore, and understand these reasons for future improvement.

To achieve purpose this research, sequential explanatory mixed method research design was employed. Quantitative strand of the study assessed relationships between students' formative assessment participation, their task value beliefs, and their summative achievement scores, in "Fundamentals of Electronics for Engineers" course over 8 semesters at a public sector land grand university in the western United States. Secondary

data (of 978 students) for the purpose of this analysis was acquired from academic and instructional services for students' analytics department and registrar office of the educational institution in de-identified form after approval of Institutional Review Board. Semi-structured interviews were conducted with a purposive sample of 8 students from fall 2021 semester to explore students' reasons and motivations for decisions regarding participating or not participating in formative assessments.

Results of the quantitative analysis showed an overall formative assessment participation from around 50% participants. Gender based differential participation trends showed higher participation from female students. However, relationships between formative assessment participation and summative achievement did not show many significant differences based on gender. Analysis of the moderation effects of task value beliefs on the relationships between formative assessment participation and students' summative achievement showed very interesting results. Statistically significant positive associations between formative assessment participation and summative achievement were found for students who reported the course materials as important, useful, and/or interesting and vice versa. Research findings have implications for students' self-regulated, self-directed learning.

(193 pages)

PUBLIC ABSTRACT

Formative Assessment in Engineering Education: Exploring Ways to Enhance Students' Learning Achievement

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Formative assessments have been found to enhance students' learning across a variety of disciplines, educational levels, and laboratory and classroom settings. Research attributes the positive effects of formative assessments in improving students' learning to its (backward and forward) testing effects. Moreover, formative assessments provide an extra opportunity to students to assess their learning early in the learning process, reflect on their learning, and identify address learning gaps and misconceptions (if any) using feedback.

However, optional nature of formative assessments and having no stakes associated with them to have any bearing on final grades offers two challenges to capitalize on their benefits. Firstly, optional nature offers a challenge in formative assessment participation and secondly, large enrollment classes particularly in fundamental engineering courses make it difficult to administer frequent formative assessments and provide systematic personalized feedback.

Therefore, purpose of this dissertation research was three-fold. Firstly, this research tried to unfold students' different participation trends in completely optional, online formative assessments with minimal automatic feedback. Secondly, this research assessed relationships between students' formative assessment participation and summative exam achievement, and how their task value beliefs (i.e., importance, usefulness, and interest) in the course materials moderate these. Lastly, a qualitative

investigation into the reasons and motivations behind selected quantitative trends in participation and associations was conducted to identify, explore, and understand these reasons for future improvement.

To achieve purpose this research, sequential explanatory mixed method research design was employed. Quantitative strand of the study assessed relationships between students' formative assessment participation in 12 practice quizzes corresponding to 12 major topics (modules), their task value beliefs, and their achievement scores on three midterm and one final comprehensive examination, in fundamentals of electronics for engineering course at a public sector land grand university in United States, over the course of 8 regular semesters (spring 2018 – fall 2021). Secondary data (of 978 students) for the purpose of this analysis was acquired from academic and instructional services for students' analytics department and registrar office of the educational institution in de-identified form after approval of Institutional Review Board. Semi-structured interviews were conducted with a purposive sample of 8 students from fall 2021 semester to explore students' reasons and motivations for decisions regarding participating or not participating in formative assessments.

Results of quantitative analysis showed overall participation trend by around 50% students. Gender based differential participation trends showed higher participation from female students. However, relationships between formative assessment participation and summative achievement did not show many significant differences based on gender. Very interesting were the moderation effects of task value beliefs on the relationships between formative assessment participation and students' summative achievement. Statistically significant positive associations between formative assessment participation and

summative achievement were found for students who reported the course materials as important, useful, and/or interesting and vice versa. Research findings have implications for students' self-regulated, self-directed learning.

DEDICATION

I dedicate my dissertation to Abbaji (my father) and Ammaji (my mother) who spent their lives helping us make our dreams come true. Abbaji always wanted to see me as Dr. Assad Iqbal. He even taught me my name as Dr. Assad Iqbal when I barely learnt to talk.

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Assad Iqbal

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CHAPTER 1

INTRODUCTION

Research both in laboratory as well as classroom settings has provided convincing evidence that testing improves both students' learning achievement and retention. More significantly, testing has proven to be beneficial to not only retain studied information (backward testing effect) but also to potentiate new learning (forward testing effect) (Adesope, Tresvisan, & Sundararajan, 2017; Chan, Meissner, & Davis, 2018). These (backward and forward) effects of testing have been established for a variety of subject areas, from elementary schooling to college and university level as well as across genders (Yang, Vadillo, & Shanks, 2021). Research has found theories of motivation, additional exposure to the problem situations and transfer-appropriate processing of information as providing viable accounts for these positive effects of testing (Yang, Vadillo, & Shanks, 2021).

Testing becomes high stakes when higher weights and/or extra credits are associated with them. Such testing has bearing on final grades. Research shows that high stake testing (i.e., allocating higher weightages and extra credits to testing) is associated with higher test anxiety among learners (Khanna, 2015; Michaels, 2017). Higher test anxiety ultimately hinders students' learning processes and subsequently their learning performance (Khanna, 2015; Tobias, 1985; Tse & Pu, 2012). Therefore, there is need to consider no-stake assessments to benefit from positive effects of testing (i.e., formative assessments).

In purpose terms, formative assessment refers to assessing students' learning to monitor their progress, identify misconceptions (if any) and provide feedback to clear misconceptions (Bloom et al., 1971). More precisely, formative assessment is termed as assessment for learning (i.e., to identify problem areas and provide feedback to address those issues) instead of assessment of learning (i.e., to award grades and/or make decisions on progression to next module/term). Contrary to formative assessment, summative assessment is meant to evaluate students' learning progress against some standard or benchmark at the end of a course unit (e.g., module, topic, week, mid semester or semester). Summative assessment is also referred to as assessment of learning (Bloom et al., 1971). In measurement terms, the two types of assessments (i.e., formative, and summative) are differentiated by the stakes (i.e., weightage or credits) associated with them. Formative assessment by definition does not have any bearing on final grading, while summative assessments have a bearing on final grading (William, 2011).

In research literature, formative assessment has been shown to have promising effects for students' learning achievement (Pick & Cole, 2021; Cummings, 2020; O'Connell, 2015) at all levels of education including undergraduate engineering education. The value of formative assessment lies in the fact that this type of assessment is focused on assessment for the purpose of identifying learning gaps, addressing those gaps and improving learning through feedback during the process of learning rather than terminal to the learning process (i.e., assessment of learning) as in case of summative assessments. Timely feedback based on students' performance on formative assessment during the learning process provides students with an opportunity to reflect on their learning, identify misconceptions (if any) and correct misconceptions as well as revise their learning strategies at an early stage. Additionally, formative assessment provides an opportunity to instructors and instructional designers to not only assess the students' progress towards the intended learning outcomes but also to assess the validity and quality of instructional methods and materials and make adjustments.

Expectancy-value theory claims that individuals' choice, persistence and performance on a task are driven by the intrinsic value (i.e., usefulness, importance, interest) that individuals find in doing that task (Atkinson, 1957; Eccles et al., 1983; Wigfield, 1994; Wigfield & Eccles, 1992). Collectively referred to as task value beliefs, this intrinsic value has been associated with motivation, learning goal orientation, and deep learning (Lavasani, Malahmadi, & Amani, 2008, 2010). Wolters et al (1996) found positive associations between task values, mastery goal orientation and self-efficacy which are positive predictors of academic outcomes and learning achievement (Bong, 2004; Multon, Brown, & Lent, 1991). It may be hypothesized that students' participation in formative assessments and impact of this participation on their learning achievement might be mediated by students' task value beliefs.

To conclude, effective integration of formative assessments and feedback into instructional design may not only help students to assess and improve their learning, but also help instructors and instructional designers to identify, understand and fill the gaps between students' learning needs and instructional design to promote a learner-centered instruction. Thus, effective integration of formative assessment in the instruction can work as a two-way feedback mechanism to improve both students' learning as well as instructional design. Moreover, task value beliefs may be of special significance in its role as a mediator between students' participation in formative assessments and the impact of this participation on their achievement.

Background of the Problem

Formative assessment has been researched extensively for decades now. Researchers have investigated various facets of formative assessment ranging from understanding the term "formative assessment" (Winninger & Norman, 2005), to its impact on students' learning outcomes, retention of learned concepts, engagement with learning materials, and satisfaction with the learning materials and processes (Fiel & Okey, 1974; Popham, 2008; Block & Burns, 1976; Pick & Cole, 2021; Cummings, 2020; O'Connell, 2015). However, students' participation in completely optional formative assessments with automatic, minimal feedback, its role in enhancing students' summative achievement, and factors moderating this role particularly in technology facilitated virtual (online) learning environment is still under-researched. Formative assessment can take the form of practice quizzes, homework problems, projects, and pre, post, or in-lecture questions to test students' concepts and assess where they stand in the learning process. A differentiating factor between formative assessment and summative assessment is that formative assessments have no bearing on the final grading.

Extensive research on testing (assessment) has found convincing evidence to conclude that it is the *testing effect* associated with assessments that not only helps long term retention of studied information i.e., *Backward Testing Effect* (Adesope, Tresvisan, & Sundararajan, 2017; Roediger & Karpicke, 2006a; Roediger, Putnam & Smith, 2011;

Rowland, 2014; Lyle & Crawford, 2011) but also potentiates learning of new concepts *i.e., Forward Testing Effect* (Chan, Meissner, & Davis, 2018; Pastotter & Bauml, 2014; Yang et al., 2018; Szpunar, McDermott, & Roediger, 2008). These testing effects justify the crucial role of formative assessments in students' learning. Yang, Vadillo, and Shanks (2021) in a systematic and meta-analytic review of 222 independent studies involving 48,478 students found testing as an effective intervention raising students' academic achievement. The review found strong support for direct benefits of testing like *additional exposure* (Glover, 1989; Slamecka & Katsaiti, 1988; Thompson, Wenger, & Bartling, 1978; Adesope et al., 2017; Roediger & Karpicke, 2006b; Rowland, 2014) and *retrieval effort* (Glover, 1989; Karpicke & Roedinger, 2007; Pyc & Rawson, 2009; Bjork, 1994; Bjork & Bjork, 2011; Rowland, 2014) and indirect benefits like *transfer-appropriate processing* (Blaxton, 1989; Morris, Bransford, & Franks, 1977; Veltre, Cho, & Neely, 2015; Adesope et al., 2017; Duchastel & Nungester, 1982) and *Motivation* (Cho et al., 2017; Yang et al., 2018; Szpunar, Jing, & Schacter, 2014; Agarwal & Roediger, 2011; Szpunar, McDermott, & Roediger, 2007; Yang, Chew, Sun, & Shanks, 2019) as viable accounts for the testing effects. This meta-analysis found enormous supporting evidence in relevant literature to register that more frequent testing and corrective feedback enhances the learning gains. Moreover, testing has proven to enhance learning gains similarly across 18 academic subject categories, as well as across elementary, secondary, and postsecondary education (Yang et al., 2021). The analysis (Yang et al., 2021) also found similar gains in learning performance through testing across genders.

Grades and stakes associated with testing and its effects on students' participation and learning outcomes has been debated extensively in the research and practitioner community. Research suggests that higher stakes associated with testing by allocating them weights in final grading (Khanna, 2015) or extra awards for superior performance (Michaels, 2017) have been found to induce higher test anxiety which has been associated with detrimental effects on students’ learning achievement (Khanna, 2015; Tobias, 1985; Tse & Pu, 2012). As discussed earlier, formative assessments are by definition no stake assessments used for the purpose of feedback on students’ learning. These characteristics in combination with positive bearings on students’ learning achievement make formative assessments as the most favorable choice of assessment to capitalize on *forward and backward testing effects* to enhance students’ learning achievement while avoiding test anxiety.

Research literature emphasizes the role of systematic personalized feedback to be crucial to exploit benefits of formative assessment as an effective intervention (Aschbacher & Alonso, 2006; Black & William, 2008; Fiel & Okey, 1974; Popham, 2008; Ruiz-Primo & Furtak, 2006). Zhu et al., (2021) found formative assessment coupled with personalized feedback to not only improve students’ performance but also their satisfaction with the course. Moreover, students with relatively poor grades were found to benefit more from formative assessments. However, their research is limited by sample size as well as by the fact that comparison was made between control-group from one year while an experimental-group from another year.

Research findings discussed above on one hand justify the importance of formative assessment as an important intervention to improve students’ learning. While on the other hand these findings raise two very important concerns. Firstly, personalized feedback is a tedious process as it requires the instructors to look deeper into the work of individual students and identify and understand their thinking processes and particular misconceptions (Aschbacher & Alonso, 2006). This makes personalized feedback a difficult choice for instructors particularly those teaching larger classes (as in most fundamental courses). The issue of personalized feedback becomes even more challenging when it comes to online learning environment where students and instructors are separated by distance in time and space. The challenges of personalized feedback due to larger class sizes and prevalence of online learning trends equally apply to engineering education context.

Additionally, the fast pace of developments in the engineering industry and demand from engineers to continuously learn new skills requires self-directed learning. Understanding which engineering students participate in formative assessments, how do they participate, and how this participation and performance on formative assessments improve their learning is crucial to the design and development of learning resources to promote self-directed learning skills among engineering students to cope with fast pace industrial environment.

Problem Statement

As discussed, both empirical and theoretical research has established convincing evidence of the association between formative assessment and students' learning achievement (i.e., achievement on summative assessments). Backward and forward testing effects and low test-anxiety associated with formative assessments (as they have no bearing on final grades) make them the most favorable choice of intervention to promote students' learning. However, research also shows that for formative assessment to be more effective, it must be coupled with systematic and personalized feedback tailored to the specific learning needs of individual students (Aschbacher & Alonso, 2006; Black & William, 2008; Fiel & Okey, 1974; Popham, 2008; Ruiz-Primo & Furtak, 2006; Zhu et al., 2021). Since the existing literature shows that testing benefits students' learning irrespective of gender, therefore, there is a need to further explore and understand the gender differences in benefits of formative assessments towards learning achievement in engineering education. Focus on gender differences will help understand differential needs and implications of this research for the underrepresented population of women in engineering.

Larger class sizes, particularly in fundamental engineering courses, make it challenging for instructors to provide personalized feedback to each student. Moreover, engineering education has been mandated to produce life-long learners (ABET, 2015), which necessarily requires self-directed learning skills. Hence there is a need to investigate how a minimal level of feedback (in the form of correct answers and/or a quick reference to relevant concepts and learning materials) embedded into online formative assessments may help improve students' learning achievement. Since formative assessments have no bearing on students' grades, it is important to understand the trends in students' participation in formative assessments and the factors influencing their participation in formative assessments. Advances in educational and instructional technologies may help facilitate frequent administration of feedback-integrated optional online formative assessments.

The optional nature of formative assessments and the fact that they have no bearing on final grades, might present another challenge in terms of motivation of students to participate in these formative assessments. Hence task value beliefs (i.e., intrinsic value that students find in the learning materials) need to be considered to understand differential formative assessment participation trends and how these trends relate to students' achievement on summative assessments. To further explain and understand these differential relationships and trends, there is also a need to qualitatively investigate into students' reasons and motivations for differential participation trends and ways these resources can be further improved to attract more participation in the larger interest of students' self-directed learning and achievement.

Purpose of the Study

This study investigates the relationship between students' participation in completely optional, online formative assessments (practice quizzes) with minimal feedback, and their achievement on summative assessments (3 midterm and one final exam) in "fundamentals of electronics for engineers" course. The study also investigates, how students' task value beliefs (i.e., importance, interest, and usefulness) about the fundamentals of electronics for engineers course, drive their participation in formative assessments and, subsequently their achievement on summative assessments. Moreover, a qualitative investigation into the reasons and motivations behind different levels of participation in formative assessment has been carried out to understand and possibly explain various quantitative trends and to find directions for future improvements.

Significance of the Study

Most of the research establishing positive relationships of formative assessments on students' learning achievement strongly advocates to incorporate systematic and personalized feedback along with formative assessments in the instructional design. However, increasing prevalence of online learning, and larger class sizes in fundamental engineering courses makes the provision of systematic personalized feedback a challenge. This study is significant in that it will be exploring the impact of online formative assessments coupled with minimal feedback. The study will also try to explore the role of task values in driving students' participation in online formative assessments and hence their learning achievement. Mediating role of task values in the relationships between formative assessment and summative achievement has not been extensively studied. Understanding these relationships will have implications for self-regulated and self-directed learning which is high in demand particularly in engineering industry (Morris, & König, 2021). Moreover, understanding the reasoning behind different participation levels and their relationship to students' learning achievement will guide improvement of instructional design with formative assessment better aligned to the students' needs and choices.

Research Questions

This research study is guided by the following research questions:

RQ#1: What is the relationship between students' *participation* in optional/online *formative assessments* with minimal automatic feedback, *their learning achievement*, and their *task value beliefs?*

RQ#2: What are students' reasons and motivations behind differential formative assessment participation?

Research Approach

As explained in the purpose of the study and the guiding research questions, this study is looking for quantitative trends in formative assessment participation of students and its relationship with their performance on summative assessments (exams) and their task value beliefs. Therefore, sequential explanatory mixed-method research design is deemed most appropriate to answer these questions and achieve the purpose of the proposed research.

This study utilized a sequential explanatory mixed method design (Creswell & Plano Clark, 2007) with specific focus on participant selection model. Sequential explanatory mixed method design follows a sequential model with more emphasis and weightage placed on quantitative data collection and analysis followed by selection of purposive sample based on specific criteria for qualitative investigation. The qualitative part of the research design collects and analyzes qualitative data through semi-structured interviews to find reasons, motivations and explanations exhibited by selected participants to understand trends in quantitative data.

Quantitative part of this mixed-methods study relies on ***descriptive statistics*** to provide basic descriptions about the variables in the dataset and highlight potential relationships. Descriptive statistics help summarize and describe participants' data in meaningful and useful ways. Correlational analysis is carried out to assess if there are any associations between different variables in the dataset and whether these associations are statistically significant. To draw possible meaningful inferences about relationships, *t*-Tests and ANOVA are used to explore significant mean differences in students' learning achievement that might be attributed to participation trends in formative assessment.

To further explain the trends in quantitative data, purposive sampling guided by quantitative analysis has been done to select best, worst and anomaly cases for qualitative data collection and analysis. The purpose of analyzing these selected cases is to explore and understand detailed reasoning behind particular trends in formative assessment participation and its relationships with students' achievement on summative exams.

Assumptions of the Study

1. It is assumed that all students had equal opportunity, awareness about and access to all the formative assessment quizzes.
2. Students who participated in the formative assessment quizzes are assumed to have solved the formative assessment quizzes with the purpose of learning concepts and have not merely tried to use blind guesses to find the correct answers to the given questions.

3. It is assumed that students' responses to the task values survey represent purely their own honest opinions and perceptions about the course, in the absence of any bias or pressure.

Limitations of the Study

This study is conducted in the context of "*Fundamentals of Electronics for Engineers"* course and the outcomes of the research may not be equally applied to other courses with different structure, nature, and requirements for learning the related concepts. Assessments used in this study are based purely on multiple choice questions, each question with only one correct answer. Multiple choice questions have been evidenced to assess students' basic concepts and higher order thinking. This study uses only multiple choice questions for formative assessments and the outcomes of the study may not be generalized to the use of other types of questions for the purpose of formative assessments. Another major limitation is that students' participation in formative assessment participation was completely optional and voluntary to make it more of their natural choice, therefore the control and experimental group comparison and random assignment of participants to the two settings were sacrificed. Every effort was made to inform all the students equally of the availability of these practice quizzes (formative assessments), however the assumption that their participation was completely natural may not necessarily be true, which might have limited the actual natural choice participation. As can be seen in the demographic analysis, sample included students from different genders and ethnic backgrounds, however, the sample was white, and male dominated. Hence, the statistical significance and generalization of differences in results based on gender and ethnicity may be limited by these factors.

This research has been conducted using secondary data for quantitative part. Instruments of data collection therefore were already developed, and data were present in CANVAS databases. The researcher could not assess the test-retest reliability of the formative assessment quizzes used. Secondary data provided was organized into groups based on aggregate times of attempts (between or before examinations) and hence the time stamps could not be reliably used to assess test-retest reliability. Similarly, due to secondary nature of data, there was no way to check alternate form reliability because the participants were not accessible to assess their concepts on an alternative form of assessment.

Definitions of Important Terms

This section presents definitions of important terms used in the context of this current study.

Formative Assessment: Testing students' learning of concepts for the purpose assessing their progress in learning the course having no bearing on their final grades in the course.

Minimal Feedback: Feedback given to students on their formative assessments in the form of quick references to relevant concepts and learning materials.

Formative Assessment Quizzes: Formative assessment can take any form (e.g., quizzes, projects, homework assignments, reflections etc.). In this research, the scope of formative assessment is limited to quizzes comprising multiple choice questions format only.

Learning Achievement: Learning achievement in the context of this study refers to students' scores on 3 midterm exams, one final comprehensive exam, and overall grade of the students in the course.

Participation in Formative Assessments: A student is considered to have participated in a formative assessment quiz if s/he has provided correct answers to at least 5 out of 10 questions on at least one formative assessment quiz.

Performance on Formative Assessments: Total number of questions for which correct answers have been provided by the participant.

Task Values: The intrinsic value (i.e. usefulness, importance, interest) a learner finds in doing a task. Task values in the context of this research are defined by intrinsic value (i.e., usefulness, importance, interest) students find in learning the course material (fundamentals of electronics) as a whole.

Course: Course in this study refers to "Fundamentals of Electronics for Engineers (ENGR 2210) offered to all undergraduate engineering programs.

Students/Participants: Students and participants in this study refer to all those students who enrolled in Fundamentals of Electronics for Engineers course in the past 7 semesters or current fall 2021 semester.

CHAPTER 2

LITERATURE REVIEW

Research shows a dire need for enhancing and motivating students' agency (i.e., to motivate and enhance their capacity to set goals, reflect and act responsibly to affect change, and make responsible decisions and choices), to ensure success (Nieminen & Tuohilampi, 2020). Students' agency can prove to be a source of fulfilling industry needs for self-directed engineering learners. These engineers will be ready to take initiatives and responsibility, work independently, and reflect on and respond to feedback (Pick & Code, 2021).

Research in engineering education has supportive evidence to claim the benefits of formative assessments towards not only motivating students' agency but also enhancing students' learning achievement (Pick & Cole, 2021; Cummings, 2020; O'Connell, 2015). However, literature emphasizes the need for effective systematic, personalized feedback to capitalize on the benefits of formative assessments towards students' agency and learning achievement. Larger class sizes particularly in fundamental engineering courses makes it challenging for instructors to provide personalized feedback. This might affect students' motivation towards formative assessment participation to help them assess and reflect on their learning. Advances in learning and educational technologies promote an increasing prevalence of online engineering education on one hand while on the other hand these advances separate instructors and learners in time and space. Therefore, there is need to investigate students' participation behaviors in online formative assessments, factors affecting these behaviors, effects of these behaviors on students' learning achievement and finding ways to enhance this participation.

Outcomes of research around the above discussed themes will have direct implications not only for promoting students' learning achievement in the context of classroom but will also help motivate and enhance students' agency through self-directed learning. The purpose of this literature review is to explain this need and define the gap in the existing literature and hence justify the need for this research.

Defining Formative Assessment

As discussed earlier, research literature shows that formative assessment informing instruction might have significant impact in motivating students' agency and enhancing their learning. However, William (2011) in his review of literature on the benefits of formative assessments found effect sizes varying as largely as from a low of 0.32 standard deviation to a high of 0.96 standard deviation. William (2011) attributes this variability in effect sizes to the differences in how researchers and instructional designers operationalize the definition and idea of formative assessment. Hence this is important to discuss the definitions of formative assessment in the available literature first.

In the context of curriculum development, the term *"formative assessment"* (or evaluation) was first pitched by Scriven (1967), however Bloom et al. (1971) is credited to not only define the term but also outline the instructional use of formative assessment for students' learning (Dixon & Worrel, 2016). They initially defined formative assessment as contrasting to summative assessment. According to Bloom et al. summative assessment is the evaluation of students' learning used terminal to the learning process (i.e., end of the module, course, term, or program) "for the purpose of awarding grades, certifications, deciding progression to the next level, or effectiveness of curriculum, course, or educational plan" (p. 155). In contrast summative assessment, formative assessment is *"the use of systematic evaluation in the process of curriculum construction, teaching, and learning for the purpose of improving any of these three processes" (p. 155)*. The contrasting view on formative and summative assessment also applies when these two terms are defined in measurement terms. William (2011) identifies summative assessment as high stake testing while formative assessment is considered as concerning low-stakes testing. Black and Williams (1998) explain that assessment encompasses all activities undertaken by teachers and students to produce feedback to modify teaching and learning activities. They further clarify that this assessment becomes formative assessment when the evidence is utilized to inform teaching for the purpose of meeting students' needs.

There are several other definitions of formative assessment which emphasize the need for assessment to inform changes in instruction during the process of learning to improve and adapt the learning process to students' needs. For example, according to Cowie and Bell (1999), formative assessment is "the process used by teachers and students to recognize and respond to student learning, during the learning" (p. 32). Shepard et al (2005) holds somewhat similar view defining formative assessment as, "assessment carried out during the instructional process for the purpose of improving teaching or learning". Loony (2005) defines formative assessment as "frequent interactive assessments of students' progress and understanding, to identify learning needs and adjust teaching appropriately. Kahl (2005) calls formative assessment as a tool to measure students' learning and identify their misconceptions during the process of learning.

The above definitions and descriptions show that the term *"formative assessment"* is open to a variety of interpretations. However, summarizing, formative assessment is characterized by using assessment tools to gauge students' learning of the taught concepts, during the process of learning (instead of terminal to the process), to help teachers identify if the students are understanding the concepts, or if there are any misconceptions that need to be addressed. This helps teachers identify the gaps in learning to improve not only students' learning, but also the instructional design and activities. Formative assessment is supposed to be low stake or no stake at all in order to encourage and motivate students to focus on the mastery of the concepts instead of how much it will affect their grades, which potentially leads to test anxiety (discussed later in this chapter).

For the purpose of this research, formative assessment has been considered as assessment activities (multiple-choice practice quizzes), to inform students about their learning progress. These assessments are coupled with minimal feedback in the form of quick references to relevant concepts and learning materials. These references have been embedded in assessments for students to reinforce the relevant concepts and identify any misconceptions or gaps in their learning.

Formative Assessment and Students' Summative Achievement

Learning achievement is a broad term, but for the purpose of this research learning achievement refers to students' performance on summative assessments (i.e., obtained marks on midterm and final examinations and overall grades in the course). This section discusses research literature concerning the impact of formative assessment on students' learning achievement.

Empirical research shows evidence of the positive impact of formative assessments in a variety of forms (homework, quizzes, and projects etc.), learning contexts (online, face-to-face, hybrid), and subject areas (Black & Williams, 1998). Also theoretical research backs up empirical findings with encouraging explanations. Guskey (1996) describes formative assessment as an effective intervention raising students' achievement because it helps teachers assess the effectiveness of their instruction and students to identify and correct their misconceptions. According to Popham (2008) and Popham (2011) this helps build a teacher-student relationship where both parties gain an understanding of students' progress towards learning goals. Theoretical perspectives of both Popham and Guskey support the notion that teacher-student relationship formed through formative assessment increases students' achievement. In numerical terms, Black and William's (1998) meta-analysis found an improvement in students' learning achievement by a standard deviation range of 0.5 to 1. Formative assessment coupled with feedback has been associated with higher levels of achievement (Fiel & Okey, 1974; Popham, 2008). Block and Burns (1976) analysis of 17 studies not only found improvement in students' achievement but also ascertained higher retention after few weeks, as a result of incorporating formative assessment followed by an intervention period in the instruction.

Research on the impact of formative assessment on students' learning achievement in the context of engineering education shows similar results. Pick and Cole (2021) found significant improvement in students' learning outcomes, engagement, and satisfaction levels as a result of introducing formative assessments in a large class of undergraduate aerospace, mechanical and product design engineering students studying first-year fluids and thermodynamics course. While delivering the redesigned course online during COVID-19 pandemic situation, they found that formative assessment informed students' learning strategies to effectively engage the students and enhance their learning achievement. Cummings (2020) found significant positive correlations between students' participation in formative assessments (i.e., practice quizzes) and their achievement on final exam scores across thermodynamics, heat transfer, and dynamics courses in an undergraduate mechanical engineering program. O'Connell (2015) investigated the differential impact of presence and absence of formative assessment on students' performance by introducing formative assessment for the two-third (2/3) of the electric circuit theory course. Results of within subject comparative analysis revealed significant improvement in students' achievement on part of the course that was formatively assessed compared to remaining one-third (1/3) of the course which was not formatively assessed. O'Connel (2015) attributed these differences in achievement to introduction of formative assessments to establish the positive impact of formative assessment on students' learning. Review of literature convincingly favors formative assessment as a valuable intervention to enhance students' learning achievement in engineering education. Hence it is worth considering to further explore and understand it to improve instruction and learning in engineering education context.

Formative Assessment and Testing Effects

Formative assessment can take the form of practice quizzes, homework, assignments, projects, pre/post/in-lecture questions by the instructor and many more as long as they provide an opportunity to students to assess and reflect on their learning while having no bearing on their final grades. This refers to the fact that formative assessment involves testing of students' learning (concepts). This section of the literature review tries to explain the role of testing to enhance students' learning achievement and to justify how formative assessment is a better form of testing to enhance students' learning compared to summative assessments.

Although testing in educational settings has usually been considered to assess learners' progress towards achieving learning outcomes, more recent research has also found convincing evidence that testing can help in enhancing students' learning. Research on testing effects shows that testing not only helps long term retention of studied information i.e., "*Backward Testing Effect*" (Adesope, Tresvisan, & Sundararajan, 2017; Roediger & Karpicke, 2006a; Roediger, Putnam & Smith, 2011; Rowland, 2014; Lyle & Crawford, 2011) but also learning of new concepts and information, a phenomenon called "*Forward Testing Effect" or "Test-Potentiated New Learning"* (Chan, Meissner, & Davis, 2018; Pastotter & Bauml, 2014; Yang et al., 2018; Szpunar, McDermott, & Roediger, 2008). Yang, Vadillo, and Shanks (2021) in a systematic and meta-analytic review of 222 independent studies involving 48,478 students found testing as an effective intervention raising students' academic achievement. The review found strong support for direct benefits of testing like *additional exposure* (Glover, 1989; Slamecka & Katsaiti, 1988; Thompson, Wenger, & Bartling, 1978; Adesope et al., 2017; Roediger & Karpicke, 2006b; Rowland, 2014), and *retrieval effort* (Glover, 1989; Karpicke & Roedinger, 2007; Pyc & Rawson, 2009; Bjork, 1994; Bjork & Bjork, 2011; Rowland, 2014) and indirect benefits like *transfer-appropriate processing* (Blaxton, 1989; Morris, Bransford, & Franks, 1977; Veltre, Cho, & Neely, 2015; Adesope et al., 2017; Duchastel & Nungester, 1982) and *Motivation Theories* (Cho et al., 2017; Yang et al., 2018; Szpunar, Jing, & Schacter, 2014; Agarwal & Roediger, 2011; Szpunar, McDermott, & Roediger, 2007; Yang, Chew, Sun, & Shanks, 2019) providing viable accounts for the forward and backward testing effects. This meta-analysis also found enormous supporting evidence in relevant literature that more frequent testing of the content and corrective feedback enhances the learning gains associated with testing.

Literature shows that positive effects of testing are not limited to a particular academic discipline, educational level, and/or a gender group (Yang et al., 2021). It is encouraging to know that testing has proven to enhance learning gains similarly across 18 academic subject categories and at elementary, secondary, and postsecondary levels of education (Yang et al., 2021). These findings justify that testing can be used in engineering education context to benefit from forward and backward testing effects. The analysis also found no significant differences in learning gains based on gender which implies similar gains in learning performance through testing across genders.

As discussed earlier, testing has been traditionally used to assign grades to students or make decisions on their progression to next level (e.g., module, semester, academic level etc.). To make these decisions, instructors associate stakes with testing which means these tests have bearing on students' final grades and/or decisions on their progression to next level. Research shows that increased stakes associated with testing by allocating them weights in final grading (Khanna, 2015) or extra awards for superior performance (Michaels, 2017) may induce high test anxiety (Khanna, 2015; Tobias, 1985; Tse & Pu, 2012). This anxiety is detrimental to students' learning.

As discussed earlier, formative assessment by definition is a no-stake testing and does not have any bearing on students' final grades. Considering higher test anxiety associated with high-stake testing, makes formative assessments (i.e., optional practice testing as the most favorable type of assessment to contribute to students' learning achievement.

Task Value Beliefs and Students' Learning Achievement

The optional nature of online formative assessment might present a challenge in terms of motivation for students to participate in these assessments. According to expectancy-value theory, individuals' choice, persistence, and performance on a task are driven by the extent of perceived intrinsic value of the activity in terms of interest, importance and usefulness (Atkinson, 1957; Eccles et al., 1983; Wigfield, 1994; Wigfield & Eccles, 1992) collectively referred to as task value beliefs. Task value beliefs refer to perceived interest, importance and usefulness of a task performed by student learners. This section describes research literature on the relationships between students' task value beliefs and their learning achievement. Hypothetically, it is assumed that task value beliefs might relate to students' choice, motivation, and persistence towards formative assessment participation and hence their learning achievement.

Task values have been extensively researched in connection with students' motivation and learning achievement. Lavasani, Malahmadi, and Amani (2008 & 2010) found task values as strong predictors of mastery goal orientation. Mastery goal orientation refers to individuals' tendency to engage in a task with a desire to advance their capability (Elliot & Harackiewicz, 1996) and accomplish mastery (Dweck & Elliot, 1983; Nicholls, 1984) in task at hand. Cerasoli and Ford (2014) research to establish causal relationship between intrinsic motivation and performance concluded that mastery goal orientation intercedes the association between intrinsic motivation and performance. Moreover, Wolters et al (1996) found mastery goal orientation as positive predictor of higher task values and self-efficacy. Both higher task values and self-efficacy have been established as positive predictors of academic outcomes and hence learning achievement (Bong, 2004; Multon, Brown, & Lent, 1991).

Lawanto, Santoso, and Liu (2012) further explored the relationship between task values and expectancy for success in engineering design activity among 9 – 12 grade students, finding significant relationships between task values and students' expectancy for success. Lawanto et al (2014) investigated the relationship between task values, self-regulated learning and students' performance in web-intensive undergraduate engineering course. The study found significant relationships between task values and performance of students. Lawanto et al. (2014) further reported significant positive correlations between task values and goal setting, task strategies, help seeking, and self-evaluation components of self-regulated learning. These findings encourage the researcher to investigate if task values may play a mediating role in enhancing students' participation in formative assessments and hence learning achievement.

Summary

Review of literature shows that formative assessment is an important tool to enhance students' learning achievement. This relationship is evidenced by research findings regarding retention of learned information (backward testing effects) and potentiation of new learning (forward testing effects. Moreover, evidence of support from theories of motivation, additional exposure to various problem situations, and transfer-appropriate processing of information further establish the significance of testing in learning achievement. Formative assessments are most favorable choice of intervention to achieve the benefits of testing because, formative assessments, by definition, have no bearing on students' final grading. This characteristic of formative assessments helps reduce the test anxiety associated with high stake testing. However, research emphasizes the importance of systematic and personalized feedback for formative assessments to be effective. Heavy enrolment fundamental courses and more reliance on online learning environment brings in challenges which make it hard to provide personalized feedback. Additionally, establishing positive contribution of formative assessments in learning achievement with minimal feedback might have implications for promoting self-directed learning among students who might not have an opportunity to get personalized detailed feedback on their learning while learning new things in their professional life.

These findings justify an investigation students' participation and performance on formative assessment and its relationship with their learning achievement with minimal supportive feedback. Moreover, understanding the reasons of their participation will have implications for designing appropriate formative assessments to ensure maximum participation of learners in these assessments. Literature review also registers the relationship between task values and learning achievement. However, how do these task value may interact with students' participation in formative assessments and hence their learning achievement has not been studied well. Thus this literature review raises several important research questions regarding relationships between participation of students' in formative assessments, their performance on formative assessments, and subsequently their learning achievement. Additionally, an investigation into students' reasons for higher or lower participation in formative assessments and its possible relationship with task values is also critical to understand how participation in formative assessments may be improved and aligned with students' learning needs. These gaps are not only critical to fill but also under researched in the context of engineering education.

CHAPTER 3

METHODOLOGY

Selection of appropriate research method is significant to answering research questions in an authentic manner to ensure reliability and validity of research results (Styhre, 2013). Research literature in engineering education witnesses use of one or other of three research methods (i.e., quantitative, qualitative, and mixed). Borrego, Douglas, and Amelink (2009) identified more frequent use of quantitative methods in engineering education research and advocated that an increase in use of qualitative methods will expand range of questions that can be addressed in engineering education research. However, they also argue that none of these methods has any special privilege over any other method. Instead, they strongly support the notion of Creswell (2002) who recommends that choice of a certain method ought to be driven by the specific research questions and must be aligned with aims of research. A methodology that is well-aligned with the research questions and aims of the research study guides the design of the study and helps researchers in answering the research questions to meet the goals of the study in a systematic manner by providing a plan of action to follow (Yin, 1994).

This chapter provides a synopsis of research methodology employed to conduct this research. Sequential mixed-method research design with participants' selection model has been employed in this research to measure, explore, explain, and understand relationships between students' formative assessment participation, their achievement on summative assessment (examinations) and their task value beliefs (i.e., intrinsic value in terms of interest, importance, and usefulness they find in learning concepts and materials in the *"Fundamentals of Electronics for Engineers"* course). In addition to the detailed methodology, this chapter also provides a justification for the use of mixed-methods approach.

Research Questions

This dissertation research is guided by two main research questions stated as follows;

RQ#1: What is the relationship between students' participation in optional/online formative assessments with minimal automatic feedback, their learning achievement, and their task value beliefs?

RQ#2: What are students' reasons and motivations behind differential formative assessment participation?

First research questions (RQ#1) is asking for a detailed quantitative investigation into students' levels of participation in optional online formative assessments. An answer to this question gives researcher an overview of common and specific quantitative trends about students' participation in formative assessments, their achievement on summative assessments, and the extent to which they intrinsically value (i.e., interest, importance, and usefulness) the learning materials and concepts in course under investigation (i.e., Fundamentals of Electronics for Engineers). However these trends do not provide detailed reasoning for why some students participate in formative assessments more than others and how do high, low, and no participation relate to students' achievement on summative assessments (exam scores). Therefore, researcher deems it necessary to answer the second research question as well. Second research question (RQ#2) calls for a qualitative data collection and analysis to find answers to questions related to specific trends in the quantitative data analysis.

Research Design

Based on the research questions identified, this study was looking for quantitative trends in participation of students in formative assessment quizzes, and its relationship with students' learning achievement. Moreover, this research also tried to explore how students' task value beliefs about the course drive their participation in formative assessments and hence their learning achievement. However, the last research question is qualitative in nature and aimed at exploring reasons and motivations behind students' different participation trends in formative assessments and their resulting learning achievement (i.e., achievement on summative assessment). To find these explanations (reasons), there is a need to collect and analyze qualitative data from students. To identify quantitative trends in relationships between formative assessment participation, summative achievement, and task value beliefs, and then explain those identified trends, explanatory mixed-method design is the most suited to conduct this research. Hence this research utilizes explanatory mixed-method design to answer the research questions. Here is brief overview of the research design and its components.

Figure 3.1 below shows a visual representation of sequential explanatory mixed-method design with participant selection model employed in this research study. FAP in the figure below refers to "Formative Assessment Participation".

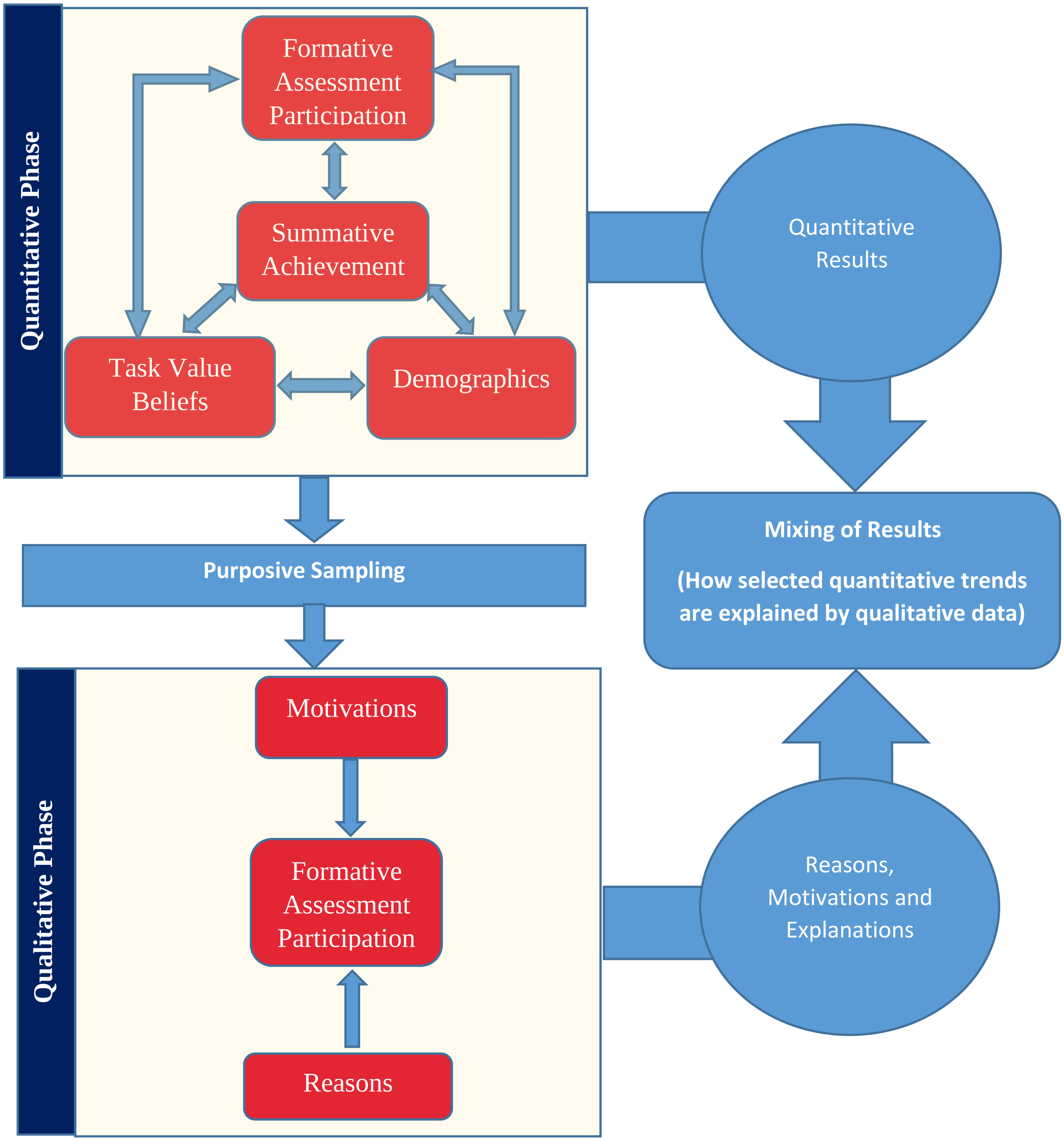

Figure 3.1: Sequential Explanatory Mixed-Methods Design

Justification of Chosen Research Design

Explanatory mixed-method design helped researcher take advantage of both quantitative and qualitative data collection and analysis within the same study. Specifically in mixed-method design, the quantitative strand helps identify various quantitative trends in the data, while qualitative strand looks for a deeper understanding of the identified trends for further explanation. Mixed-method design provides an opportunity to utilize the potential strengths of both qualitative and quantitative methods enabling the researcher *"to explore diverse perspectives and uncover relationships that exist between the intricate layers of multifaceted research questions"* (Shorten & Smith, 2017).

More specifically, the research utilized explanatory mixed-method design with participant selection model. According to Borrego, Douglas and Amlink (2009), explanatory mixed method design with participant selection model follows a sequential mixed-method design with more emphasis and weighting placed on quantitative data collection and analysis (extensive quantitative strand) followed by selection of purposive sample based on specific criteria (identified in quantitative analysis) for qualitative data collection and analysis. Qualitative data collection and analysis strand is then used to deeply understand and explain the identified quantitative trends.

Extensive quantitative data collection and analysis yields various trends while qualitative part of the research design tries to further explore, explain, and understand selected trends of interest exhibited by selected participants in greater detail (Creswell & Plano Clark, 2007). Moreover, mix-methods research helps compensate deficiencies of both quantitative and qualitative methods (Creswell & Clark, 2017) to answer questions that any of the two other methods may not be able to answer in isolation.

The Journal of Engineering Education presents several articles where engineering education researchers pursue explanatory mixed methods approach. Articles explicitly credit mixed method designs where qualitative strand data collection and analysis helped unexplained quantitative scenarios (Gall et al., 2003; Hacket & Martin, 1998; Olds & Miller, 2004). Therefore, mixed method design is believed to be the most appropriate and well aligned to the requirements and purpose of this proposed study.

Quantitative Strand

Researcher utilized quantitative strand of this study to explore relationships between students' formative assessment participation, their achievement on summative assessments (3 midterm and 1final examination), and their task value beliefs. All the variables in this strand are purely quantitative in nature.

A quantitative analysis of these variables provided a detailed overview of levels of formative assessment participation and its relationship with students' achievement on summative assessments, and their task value beliefs. This strand also provided valuable information in terms of group comparisons based on gender (e.g., males and females) and formative assessment participation levels (e.g., high participation, low participation, and no-participation groups).

During quantitative strand of the study, the researcher identified various trends of students' formative assessment participation and its relationship with students' achievement. To further explain various trends identified during quantitative strand, the researcher selected a limited participant sample for qualitative data collection and analysis.

Participant Selection

As discussed earlier, in sequential mixed-method design with participant selection model, quantitative analysis findings guide participants' selection for the qualitative strand of the study. In the case of this research, anomaly-group identification in quantitative strand guided criteria for selection of purposive sample (explained later in this chapter).

Qualitative Strand

To understand, explore and explain reasons and motivation behind students' differential participation trends, researcher collected and analyzed qualitative data from selected purposive sample of participants using semi-structured interviews.

Participants & Sampling

Aligned with the purpose of research as laid down by the posed research questions, and research design, this study used two different sampling methods to select two separate samples for quantitative and qualitative strands of this research as detailed below:

Participants Selection for Quantitative Strand

Convenience sampling was used to select participants for quantitative strand of this mix-method study. Participants include all students who enrolled and completed Fundamentals of Electronics for Engineers (ENGR 2210) course in any one of 8 semesters between spring 2018 and fall 2021 both inclusive. This is mandatory fundamental course offered to all undergraduate engineering students in summer, spring and fall semester each year. The course is enrolled by 100 to 160 students on average every regular (i.e., spring and fall) semester. Excluding students who dropped out of the course before completion, a total of nine hundred and seventy-eight (978) students were included in the sample for quantitative part of this research. Students who studied the course in summer semesters were also excluded from the study because of the expedited nature and different structure of the course offered in summer semesters. The course which is 14 weeks in regular semesters is usually condensed to 7 weeks in summer semesters.

Table 3.1 shown below summarizes participants' demographics. As can be seen, study sample comprised a total nine hundred and seventy-eight (978) participants who studied Fundamentals of Electronics for Engineers course spanning eight semesters (i.e., spring 2018 – fall 2021). Sample included a majority of males (83.6%) compared to females (16.4%). In terms of ethnic diversity, the sample included a majority of White or non-Hispanic/Latino (95.2%) followed by Hispanic/Latino (3.3%). There were only 0.1%

Asians and 0.2% participants with multiple ethnicities. Information about ethnic backgrounds of 1.2% of the participants was not available. Most of the participants were domestic (99.4%). The table also shows semester-wise distribution to show how many participants from each semester/year were included in this study. Lastly, there were 129 (13.2%) participants who were first generation. To summarize, the sample is pre-dominantly non-Hispanic/White, with a majority of male students (818), most of whom are domestic and continuing generation. Sample included a majority (63.4%) of students with previous semester CGPA of 3.5 and above.

Table 3.1: Participant Demographics

Variable		**Frequency**	**Percentage**
Gender	Male	818	83.6%
	Female	160	16.4%
	Total	978	100%
Ethnicity	Hispanic/Latino	32	3.3%
	White/Non-Hispanic	931	95.2%
	Asian	1	0.1%
	Multiple Ethnicities	2	0.2%
	Unknown	12	1.2%
	Total	978	100%
Semester/Year the course was taken	Total	978	100%
	Spring 2018	100	10.2%
	Fall 2018	158	16.2%
	Spring 2019	112	11.5%
	Fall 2019	122	12.5%
	Spring 2020	102	10.4%
	Fall 2020	136	13.9%
	Spring 2021	108	11%
	Fall 2021	140	14.3%
	Total	978	100%
Generation	First	129	13.2%
	Continuing	849	86.8%
	Total	978	100%
Previous CGPA	3.5+	620	63.4%
	3.0 – 3.49	283	28.9%
	2.5 – 2.99	67	6.9%
	2.0 – 2.49	7	0.7%
	Below 2	1	0.1%
	Total	978	100%

Participants Selection for Qualitative Strand

The question of an appropriate sample size for a qualitative study is still under debate. Boddy (2016) argues that determination of appropriate sample size for a qualitative research study is contextual and dependent upon the research paradigm and overall goal. Boddy exemplifies that a qualitative research based on positivism as a paradigm would require larger sample size to gain a representative picture of the population. However, for an in-depth study of a new, potentially highly relevant area, a detailed investigation into a single case can also be more beneficial. Moreover, Boddy also identifies theoretical saturation as one of the potential criteria to look for when choosing size of qualitative sample. Research shows that theoretical saturation in most cases is achieved by qualitatively investigating 12 cases (Boddy, 2016). Therefore, the researcher targeted to select a sample size 12 to avoid 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.

Based on quantitative analysis of the existing formative assessment participation and summative achievement data, 8 students from fall 2021 cohort of the course were selected for qualitative data collection and analysis. There are three major reasons for using only fall 2021 cohort for sampling, qualitative data collection and analysis; a) First fall 2021 students enrolled in this course were easily accessible because they were studying the course at the time of sampling for qualitative part of the study; b) second, these students had fresh exposure to the course materials, concepts and canvas course structure including all learning resources and therefore were assumed to be able to reflect on their experiences more accurately compared to students who experienced this course earlier in time; and c) third, there were 150 students enrolled in fall 2021 providing a good enough population to do sampling for qualitative strand of the study and still be representative of the overall population studying this course in the past.

Formative assessment participation details and scores of three midterm and one comprehensive final examination conducted in fall 2021 semester were used to identify students with high/low formative assessment participation and summative achievement. This process of selection involved students' personal identifiable information and access to their academic records which is protected by Federal Education Rights and Privacy Act (FERPA). Therefore, an IRB-approved pre-screening survey was sent to these students to ask their consent to participate in this study and their permission through an informed consent form to access their academic information. Formative assessment participation and summative achievement data of students who agreed to participate in the study and provided their informed consent was analyzed to select purposive sample for semi-structured interviews. The following selection criteria were used for purposive sampling:

i. Participants with least or no participation in formative assessment quizzes but highest learning achievement (anomaly group 1)
ii. Participants with maximum participation in formative assessment quizzes but lowest learning achievement (anomaly group 2)

iii. Participants with maximum participation in formative assessment quizzes and highest learning achievement (general trend group)

iv. Participation with least or no participation in formative assessment quizzes and low learning achievement (general trend group)

v. Efforts were done to make the sample representative of gender, ethnic, ability, and generation diversity.

High and low participation and summative achievement students were identified by using means and standard deviations. High formative assessment participation and summative achievement was defined by mean plus one standard deviation *(M + 1SD)*, while low formative assessment participation and summative achievement group was defined by mean minus one standard deviation *(M – 1SD).* The following matrix defines the four target groups of the participants:

	Learning Achievement	
Formative Assessment Participation	High	Low
High	2	2
Low	2	2

Data and instruments

This section describes the data used in this research and the data collection instruments used for data collection for two separate strands of this mixed-method dissertation research.

Formative assessment participation

Fundamentals of Electronics for Engineers (ENGR 2210) course consists of 12 modules (topics). All students who enroll in ENGR 2210 are offered an opportunity to participate in 12 formative assessment practice quizzes. Each of the 12 quizzes corresponds to one specific module (topic) in the course. These quizzes have been carefully developed to help students assess their own learning of the concepts taught in the course. Each quiz corresponding to a particular module consists of 10 multiple choice questions to cover concepts taught in that module. Each multiple-choice question in these quizzes has 4 answer-choices. Each question has only one correct answer and 3 distractors. The distractor options are selected in a way to ensure they offer students enough challenge. For example, distractors were not distinctively different from the correct answers so that students must evaluate each answer option. Distractors which appear closer to the correct answer tend to force students to evaluate their solution approach and look for more correct answer rather than just eliminating answer choices. Careful selection of distractors helps avoid blind guesses or obvious clues so that selection of a correct answer should represent an understanding of the concept by the students.

These formative assessment quizzes are available to all the students through common learning management system (i.e., CANVAS). Students are informed in course orientation lecture and syllabus document about the availability of these quizzes. They are explicitly informed that these quizzes are a form of helpful resource for them to assess their learning and that their participation in and/or performance on these quizzes has no bearing on their final grades. Moreover, participation in the quizzes is completely optional and online and there is no limit on the number of attempts or time spent on any of these quizzes. All these quizzes are available to students throughout the semester. Students' participation and performance data on these formative assessments is available in the form of CANVAS analytics.

Formative assessment quizzes were developed and validated by content area expert who was also the instructor for this course for all the semesters included in this research. Formative assessments were further content validated by two graduate students working with this course as graduate teaching/research assistants. Discrimination indices of the formative assessment quizzes ranged from 0.4 – 0.7. The range shows that the formative assessments were designed such that they could optimally differentiate between low and high performing students.

De-identified formative assessment participation data was provided by the office of Academic and Instructional Services (AIS) for Student Analytics. AIS for Student Analytics is responsible for maintaining student analytics data at the educational institution where the study was conducted. AIS for Student Analytics extracted the data from CANVAS analytics. For each participant, formative assessment participation data received from AIS included the following information:

i. Total number of quizzes done before exam 1
ii. Total number of quizzes done between exam 1 and exam 2
iii. Total number of quizzes done between exam 2 and exam 3
iv. Total number of quizzes done between exam 3 and final exam

v. Total number of attempts on each quiz

vi. Average score for total attempts on each quiz

vii. Total time spent on each quiz before each exam

Summative Achievement and Demographic Data

Students' summative achievement and demographic data was received from registrar office of the educational institution. Learning achievement or summative achievement in the context of this study refers to students' achievement scores on three (3) midterm and one (1) comprehensive final examination, and the final awarded letter grade for this course. In addition to students' scores on midterm and final examinations, their cumulative grade point average (CGPA) at the beginning of the term and at the conclusion of the term in which they studied this course were also provided by registrar office. All the four summative examinations (assessments) were prepared by the same course instructor. Summative assessments (as reported by the instructor) were also carefully developed to be consistent with concepts assessed by formative assessments and overall learning outcomes of the course. With minor changes in between different versions of each summative assessment, these assessments were very consistent with each other assessing similar concepts for all the participants of the research (over eight semesters). Summative assessments were also content validated by the instructor as well as graduate students.

Task Value Beliefs Data

Every semester a 3-item Likert-scale survey had been administered to the students who enrolled in the course (i.e., Fundamentals of Electronics for Engineers) regarding their task value beliefs about the learning material and concepts taught in this course. This secondary ordinal data has been collected using an inventory adopted from Pintrich (1991) asking students' perceptions about how useful, important, and interesting the course materials of Fundamentals of Electronics for Engineers were for them. The instrument has been validated and extensively used in research to measure students' task value beliefs in engineering education (Lawanto et. al, 2012, 2014).

Each of the 3 questions had four response options for students to select from (i.e., very useless, useless, useful, very useful, very unimportant, unimportant, important, very important, very uninteresting, uninteresting, interesting, and very interesting respectively). These data were part of CANVAS analytics (secondary data source) and were provided by Academic and Instructional Service (AIS) for Student Analytics of the educational institution through IRB approved procedures in a completely de-identified form

Qualitative Data

Qualitative data from the purposively sampled participants was collected through semi-structured interviews (see Appendix D). Interviewees were given a short introduction to the purpose of the interviews and how their responses will be de-identified and used for research purpose.

Through these semi-structured interviews, the researcher asked questions to elicit information about students' perceptions about available learning resources, awareness about the formative assessment quizzes, available feedback, and their reasons for participating or not participating in these formative assessments. Follow up questions were asked where deemed necessary regarding their views and concerns about the formative assessment quizzes and about how students' motivation could enhanced to participate in these assessments to gain an in-depth understanding of the reasons.

The semi-structured interviews helped researcher dig deeper into their learning experience, preferences, and reasons for using or decisions of not using formative assessment resources. Before recruitment for the semi-structured interviews, all participants were introduced to the purpose, possible outcomes, and importance of the study. They were informed that their class records will be accessed as part of the study and based on those records, selected students will be interviewed. Students' who agreed to participate in the study were requested to sign an informed consent form approved by Institutional Review Board (IRB) of the educational institution.

Purposive sampling was done among students who agreed to participate in the study and provided their consent to the researcher to access their educational records to recruit them for semi-structured interviews. All the semi-structured interviews were audio-recorded. The interview recordings were transcribed into text for further analysis. After clear interview transcriptions were obtained and verified, the audio recordings were discarded for the protection of participants' privacy as mentioned in the IRB approved procedures.

Interviews followed the IRB approved protocol attached as Appendix – D The protocol includes some follow up questions, however, depending upon students' answers to the protocol questions, different follow up questions emerged and were asked when researcher believed they would be useful to improve the understanding about students' motivation to participate and utilize formative assessments.

Ethical Considerations and Data Privacy and Protection

All measures were taken to protect the privacy of the participants and data protection. Since students' academic data and personal identification information is protected by Family Education Rights and Privacy Act (FERPA), all the study procedures and instruments were reviewed and approved by the Institutional Review Board (IRB) for the protection of human research participants. All the data collection, data processing, analysis, de-identification, storage, and presentation measures as mentioned in the IRB approved protocols were strictly followed.

Formative Assessment Participation and Task Values data is stored and maintained by the office of Academic and Instructional Services (AIS) for student analytics, while students' demographic information and academic achievement data is stored, maintained, and protected by the registrar office of the educational institution. Upon IRB approval, office of the Academic and Instructional Services (AIS) for student analytics was requested through email to provided formative assessment participation and task values data to registrar office for further processing. Registrar office of the educational institution was then requested to append students' demographics and academic achievement data to the formative assessment and task value data. Registrar office prepared a consolidated file of all the requested data, de-identified this data (removed personally identifiable information), and provided the researcher with a completely de-identified consolidated data in excel sheet format.

Data Analysis

This section presents how quantitative and qualitative data were analyzed to present results. The first subsection presents details about statistical tests applied to the data, reasons for selected tests, and procedures followed. Second subsection presents details of qualitative data analysis carried out to identify common themes that may explain specific trends identified in quantitative data analysis.

Quantitative Data Analysis

A series of descriptive and inferential statistical tests were used to analyze relationships among students' formative assessment participation, their achievement on summative exams, and their task value beliefs. All statistical analysis tests on the quantitative data were run using IBM SPSS 2021.

Descriptive Statistics

Quantitative data analysis includes ***descriptive statistics*** to provide basic information (frequencies, percentages, means, standard deviations etc.) about the variables in the dataset and describe the sample of the study. Descriptive statistics helped summarize and describe participants' data in meaningful and useful ways.

Correlational Analysis

Correlational analysis was done to assess strength and direction of associations between different variables in the quantitative dataset and whether these associations were statistically significant. Pearson correlation coefficient was used to measure the strength and direction of these associations. Significance value of $p < .05$ was used to determine the statistical significance of various tests and results. However, statistically significant correlations (Pearson correlations) only show that there is an association between the variables under consideration and shows the strength and direction of that relationship. It does not tell enough to interpret the relationship in terms of how much variability in a dependent variable can be explained by an independent variable.

Moreover, correlational analysis was used to select two measures of participation (TQD-FAP and Ac_FAP) with highest and statistically significant correlations, for further analysis of main and interaction effects. TQD-FAP in the context of this study refers to Formative Assessment Participation (FAP) as measured by Total Quizzes Done (TQD) while Ac_FAP refers to Formative Assessment participation (FAP) as measured by students' Achievement (Ac) on formative assessment quizzes.

Analysis of Mean Differences (Main Effects)

Independent Sample t – Tests and Analysis of Variance (ANOVA)

Independent sample *t*-Tests and Analysis of Variance (ANOVA) were used to explore significant mean differences in students' summative achievement that might be attributed to their different levels of participation in formative assessments. Independent Sample *t*-Test and ANOVA assume the data under study to be normally distributed. Moreover, different comparison groups for which mean differences are analyzed, must have equal variances for results to be valid and reliable. Normality requirement/assumption is not very strict for *t*-Tests and ANOVA. Simulation studies (Glass et al. 1972; Harwell et al., 1992; Lix et al. 1996) with various sets of non-normal data provide convincing evidence that due the robustness of ANOVA and *t*-Tests, violation of normality assumption does not affect the rate of false positive results of these tests. However, equal variances assumption must be true to consider *t*-Test and ANOVA results to be valid and reliable.

Testing for Assumptions of t-Test and ANOVA

For each mean comparison, Levene's test was performed on all comparison groups to test for equality of variances. If the Levene's test was not significant at $p < .05$, variances between comparison groups were assumed to be equal and then ANOVA or *t*-Test results were checked for significance. If ANOVA or *t*-Test results were significant, it indicated that there are statistically significant mean differences between/among comparison groups.

Significant ANOVA test results only tell us that there are mean differences between some comparison groups. It does not tell us which of comparison groups have statistically significant mean differences and size of these differences. To know exactly which of group pairs have statistically significant mean differences, and the magnitude of those differences, Post hoc HSD (Honest Significant Difference) test was applied to the groups which returns a multiple group comparisons table with mean differences and their statistical significance.

If the Levene's test was not significant, it indicated that comparison groups did not have equal variances in which case, Welch's test of unequal means was performed on the groups. Significant results of Welch's test indicate that there are statistically significant mean differences even if the comparison groups have unequal variances. A non-significant ANOVA and/or Welch's test indicates that there are no statistically significant mean differences between/among comparison groups.

Analysis of Interaction Effects

Two-way Analysis of Variance (ANOVA) was used to determine if gender, task values or students' prior CGPA had any interaction effects on relationships between formative assessment participation and their summative achievement. Two-way ANOVA has same assumptions as those of one-way ANOVA (i.e., homogeneity of variance, and normality).

The following flow of analysis was followed to determine interaction effects followed by main effects using two-way and one-way ANOVA respectively.

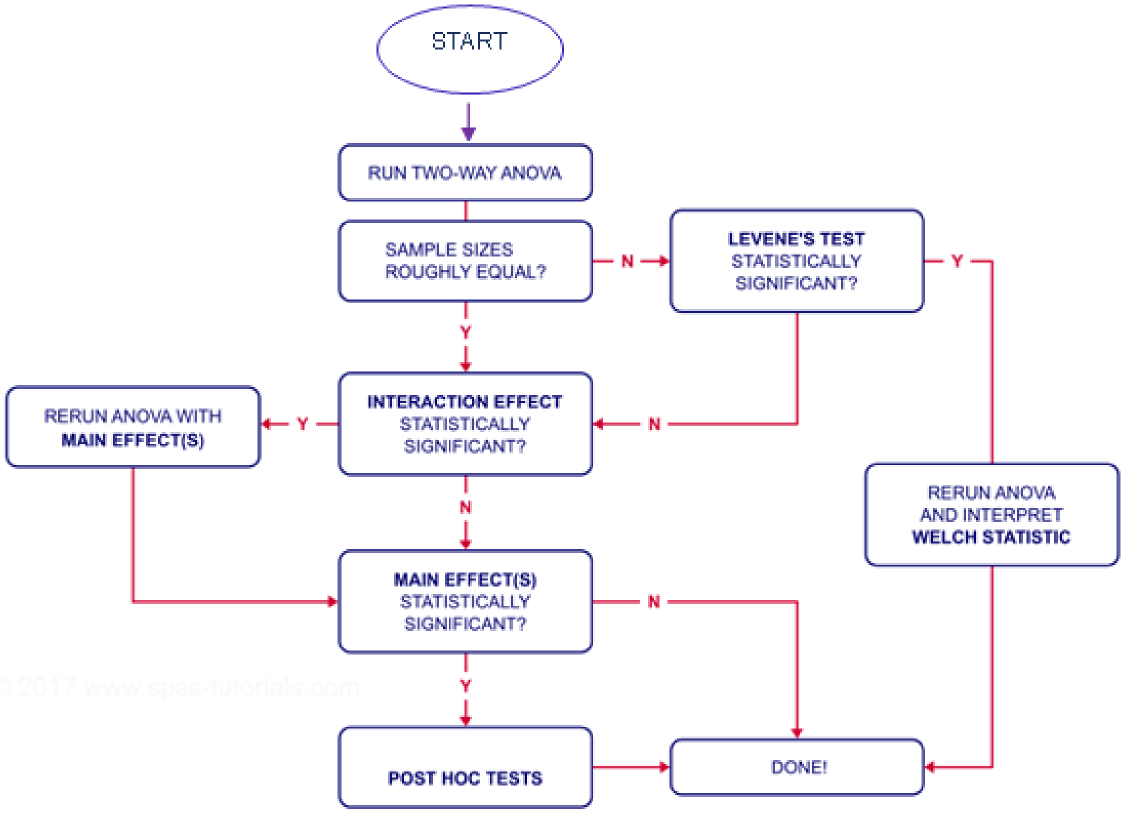

Figure 3.2: ANOVA Flowchart

Qualitative Data Analysis

The aim of the qualitative strand of the research was to identify common themes and patterns in qualitative data which might help explain identified trends in students' formative assessment participation, their relationships with summative achievements and reasons behind those trends using iterative and emerging coding process (Creswell, 2007). More specifically, thematic analysis was used to identify, analyze, and report themes and patterns in the interview data (Braun & Clarke, 2006, p.79). Thematic analysis is flexible because it "matches what the researcher wants to know" (Braun & Clarke, 2006, p.80) rather than depending upon any particular epistemological or theoretical perspective which provide a framework to predict, describe, or deconstruct population world view. According to Maguire and Dlahunt (2017), the flexibility of thematic analysis advantages the diverse work in teaching and learning.

Data collected using semi-structured interviews (audio-recordings) were first transcribed using zoom transcription feature and then manually verified by the researcher for any errors. All data were then de-identified using unique alphanumeric codes so that none of the responses can be traced back to the original interviewee (participant). The data were also cleaned to remove any unnecessary information. Unnecessary information excluded from the transcripts included personal introduction, introduction to the research topic, any explanations about the process or purpose of the interview, and any other information that was considered as irrelevant in terms of its contribution to explain students' reasons and motivations to participate in formative assessment. Interview data were organized such that all participant responses were listed together for each interview question for ease of analysis.

Thematic Analysis Process

Six-phased thematic analysis framework (Braun & Clarke, 2006) was followed sequentially. As shown in figure 3.3, Braun and Clarke (2006) thematic analysis framework consists of (a) Familiarization with data, (b) generation of initial codes, (c) searching for themes, (d) review of themes, (e) defining/naming themes, and (f) and reporting the analysis. Thematic analysis was done from an inductive perspective for themes to emerge from qualitative data.

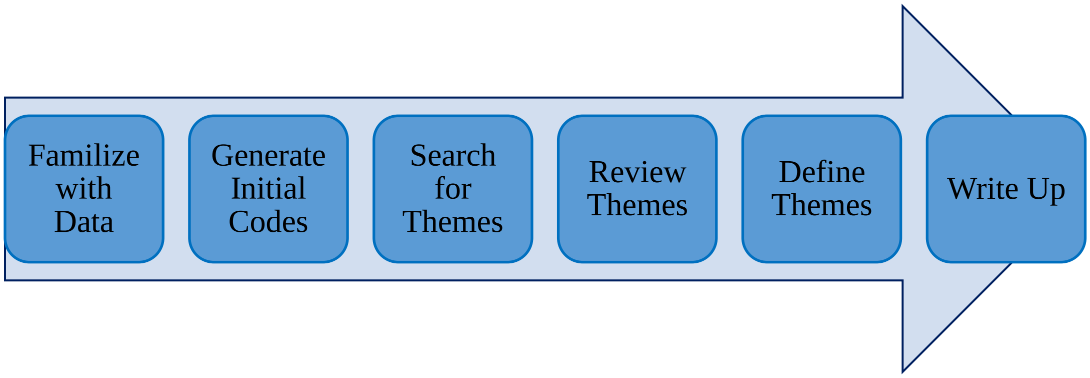

Figure 3.3: Braun & Clarke's Six-Phase Framework for Thematic Analysis

The researcher and another graduate student in engineering education independently conducted the three phases (b, c, &d) of thematic analysis for two participants and discussed their findings to reach a consensus. Following the same pattern, researcher completed coding and theming for the rest of the participants. After all the coding and theming was complete, researcher and fellow graduate students again thoroughly reviewed the themes to establish a shared meaning reflecting participants' narratives more accurately. Thus, 100% inter-coder agreement (consensus) was established in the qualitative data analysis. Finally, themes and findings were interpreted with equal focus on common as well as exceptional or divergent cases in integration with quantitative results.

Table 3.2 shows how the research questions, data collection, and data analysis methods align in the research design to answer the research questions and achieve the aims of the study.

Table 3.2: Summary of Research Design

Research Question	Data Collection	Participants	Data Analysis Methods
RQ#1	Existing quantitative data on Formative Assessment Participation, their Learning Achievement (exam scores, grades), Task Value Beliefs	All students enrolled in ENGR 2210 course (spring 2018 – fall 2021)	Quantitative Data analysis Descriptive Statistics (Mean, Median, Standard Deviation, Frequencies, percentages) Inferential Statistics (*t-Tests, ANOVA, correlational analysis)*
RQ#2	New Data collected through semi-structured interviews from 8 participants selected through criteria informed by qualitative analysis trends	8 students purposively sampled from Fall 2021 cohort of the course ENGR 2210	Qualitative Data analysis Thematic analysis framework (Braun & Clarke, 2006)
Mixing of the Results from Quantitative and Qualitative Strands of the Study Explanatory sequential Mixed Method Design was followed with analysis flowing from RQ#1 towards RQ#2. The emerging themes in qualitative data analysis strand were interpreted in conjunction with results of the quantitative strand of the study.			

CHAPTER 4

RESULTS

Aligned with the aims of the study and research questions guiding this research, this chapter presents the results of data analysis. Results have been organized into 3 main sections as described below.

The chapter starts with first section presenting summarized analysis results of demographic information of study participants. Demographic information includes students' backgrounds in terms of gender, ethnicity, national and international student status, first generation status, and semester/year when they completed the course.

Next section provides results of quantitative data analysis to answer first research question (i.e., relationships between students' formative assessment participation, their achievement on summative exams and their task value beliefs). This section presents an independent analysis of student's formative assessment participation, their achievement on summative examinations, and their task value beliefs to give an overview of trends in students' formative assessment participation, their summative achievement and their task value beliefs (interest, usefulness, and importance) about the course materials using descriptive statistics (e.g., frequency distributions, Means and Standard Deviations). Then correlational and inferential statistical analysis results are presented to show how formative assessment participation is related to students' achievement on summative exams and how their task value beliefs (importance, usefulness, interest) about the course materials may moderate this relationship (moderation effects' analysis).

The third and last section of this chapter presents results of qualitative analysis of semi-structured interviews conducted with a purposive sample to see how they explain different trends of participation as observed in quantitative strand of the study and what are the reasons and motivations behinds students' decisions to participate or not to participate in formative assessment quizzes.

QUANTITATIVE ANALYSIS RESULTS

Formative Assessment Participation, Summative Achievement, and Task Values

This section presents results of analysis of formative assessment participation using four different measures (i.e., total quizzes done, total attempts, total time spent, and total achievement on quizzes), students' achievement on summative exams, and their task value beliefs. Following descriptive analysis of these variables, relationships among them are presented. Demographic differences (particularly based on gender) in formative assessment participation, summative achievement and task value beliefs are also presented in this section. Before the results are reported, it must be noted that data on dependent variable was not perfectly normal but a little skewed towards right.

Formative Assessment Participation

This section provides results of analysis about students' participation in formative assessments and differences in participation based on participants' demographics. Literature on formative assessment participation most commonly uses number of assessments completed by students and their achievement on these assessments as a measure of participation in formative assessments (Adesope et. al, 2017). The researcher takes this as an opportunity to consider multiple variables (i.e., number of quizzes, number of attempts on each quiz, time spent on each quiz, and scores on each quiz) to measure formative assessment participation. The researcher hopes that this will contribute to research literature in terms of recommendations on what factor(s) represent a better measure of participation in formative assessments.

There were total 12 formative assessment quizzes corresponding to 12 different modules in the course to help students prepare for different summative exams. Table 4.1 below shows how different sets of formative assessment quizzes covering different course modules correspond to different summative examinations.

Table 4.1: Formative Assessment Quizzes, Modules and Exams

Formative Assessments	**Course Modules**	**Summative Exam**
Quizzes 1 – 4	Module 1 – 4	Mid Term Exam 1
Quizzes 5 – 8	Module 5 – 8	Mid Term Exam 2
Quizzes 9 – 11	Module 9 – 11	Mid Term Exam 3
Quizzes 1 – 12	Module 1 – 12	Final Examination

Semester-wise Formative Assessment Participation

Analysis of students’ formative assessment participation over eight (08) different semesters shows mixed trends with different levels of participation in different sets of formative assessments and in different semesters (see Table 4.2).

Lowest participation (12%) is observed for exam 1 in spring 2018 semester while highest participation (77.1%) is found in formative assessments for exam 1 in fall 2021 semester. Aggregate participation in all formative assessments for all four summative exams over the course of semester is almost 50% or more. It is also interesting to note that participation in formative assessments has an increasing trend moving from spring 2018 towards fall 2021 (with some exceptions).

Table 4.2: Semester-wise analysis of students' FAP

Semester	**Participation**	**FAP Exam1**	**FAP Exam2**	**FAP Exam3**	**FAP Final**	**Overall Semt.**
Spring 2018	Not Participated	88.0%	47.0%	34.0%	24.0%	48.3%
	Participated	12.0%	53.0%	66.0%	76.0%	51.8%
Fall 2018	Not Participated	65.2%	50.0%	51.9%	54.4%	55.4%
	Participated	34.8%	50.0%	48.1%	45.6%	44.6%
Spring 2019	Not Participated	71.4%	53.6%	51.8%	41.1%	54.5%
	Participated	28.6%	46.4%	48.2%	58.9%	45.5%
Fall 2019	Not Participated	48.4%	32.8%	35.2%	42.6%	39.8%
	Participated	51.6%	67.2%	64.8%	57.4%	60.3%
Spring 2020	Not Participated	25.5%	42.2%	93.1%	43.1%	51.0%
	Participated	74.5%	57.8%	6.9%	56.9%	49.0%
Fall 2020	Not Participated	26.5%	34.6%	37.5%	44.9%	35.9%
	Participated	73.5%	65.4%	62.5%	55.1%	64.1%
Spring 2021	Not Participated	50.0%	65.7%	69.4%	61.1%	61.6%
	Participated	50.0%	34.3%	30.6%	38.9%	38.5%
Fall 2021	Not Participated	22.9%	40.0%	40.7%	45.0%	37.2%
	Participated	77.1%	60.0%	59.3%	55.0%	62.9%
Overall Sample	Not Participated	49.7%	45.7%	51.7%	44.5%	
	Participated	50.3%	54.3%	48.3%	55.5%	

Quiz-wise Formative Assessment Participation

An analysis of means of students' formative assessment participation in terms of number of attempts per quiz, time spent on quizzes, and achievement scores on quizzes, and scores per attempt is presented Tables 4.3 (a, b, c, & d) below. Each table shows details of students' participation in a particular set of quizzes corresponding to specific summative exams.

Table 4.3a: Quiz-wise Participation before Midterm Exam 1 (Means)

Quiz#	Participants	Attempts	Time/Quiz	Time/Attempt	Score/Quiz	Score/Attempt
1	474 (48.5%)	1.88	30min	18min	8.1	5.9
2	415 (42.4%)	1.6	24min	16min	8.5	6.8
3	397 (40.6%)	2.3	35min	17min	7.3	4.6
4	372 (38.0%)	2.1	31min	17min	7.2	5

Table 4.3b: Quiz-wise participation between Midterm Exam 1 & 2 (Means)

Quiz#	Participants	Attempts	Time/Quiz	Time/Attempt	Score/Quiz	Score/Attempt
5	507 (51.8%)	3.4	43min	14min	7.2	3.5
6	473 (48.4%)	2.6	33min	14min	8	4.8
7	452 (46.2%)	2.2	27min	14min	8.3	5.7
8	431 (44.1%)	2.2	27min	14min	8.4	5.8

Table 4.3c: Quiz-wise participation between Midterm Exam 2 & 3 (Means)

Quiz#	Participants	Attempts	Time/Quiz	Time/Attempt	Score/Quiz	Score/Attempt
9	477 (45.7%)	2.6	34min	15min	8	4.7
10	427 (43.7%)	2.2	42min	22min	8.1	5.3
11	408 (41.7%)	2.7	58min	24min	7	4

Table 4.3d: Quiz-wise participation between Midterm Exam 3 and Final Exam (Means)

Quiz#	Participants	Attempts	Time/Quiz	Time/Attempt	Score/Quiz	Score/Attempt
1	284 (29%)	1.52	24min	18min	8.2	7
2	251 (25.7%)	1.4	20min	15min	8.5	7.4
3	247 (25.3%)	1.8	27min	17min	7.5	6
4	227 (23.2%)	1.6	25min	17min	7.7	6.2
5	211 (21.6%)	1.9	21min	12min	7.4	5.6
6	187 (19.1%)	1.5	19min	13min	8.4	6.8
7	181 (18.5%)	1.4	19min	13min	8.4	7.1
8	174 (17.8%)	1.4	18min	13min	8.6	7.4
9	243 (24.8%)	1.8	22min	14min	8.5	6.7
10	236 (24.1%)	1.6	27min	18min	8.4	6.8
11	282 (28.8%)	2	41min	24min	7.2	5.3
12	442 (45.2%)	2	36min	21min	8.2	5.9

Table 4.3a shows that students' participation ranged between 38% (in quiz 4) and 48.5% (in quiz1) corresponding to summative exam 1. Students spent an average of 24 to 35 minutes on these quizzes. Average score of participants ranged between 7.2 (quiz4) to 8.5 (quiz 2) out of total 10. Students quiz scores were also adjusted for number of attempts and average scores per attempt are also given in the table. Results also indicate that although time spent on individual quizzes appears to vary considerably between quizzes in a particular set. However, when adjusted for number of attempts made on each quiz, the variability in average time spent per attempt on different quizzes reduced. Similarly, Tables 4.3b and 4.3c show participation details of students in formative assessment quizzes corresponding to midterm exam 2 and 3 respectively.

Table 4.3d shows participation details of students in individual quizzes after midterm exam 3 and before final exam. Students' participation in any of the formative assessment quizzes 1 through 12 after exam 3 is assumed to be done to prepare for final exam.

Participation trends show that relatively less number of students participated in individual quizzes in preparation for final examination. Low participation might be attributed to the fact that they had already participated in these quizzes for midterm exams 1, 2, and 3 and hence did not feel the need to repeat the same quizzes again. This is also evident from students' participation in Quiz#12. A total of 45.2% ($N = 442$) students participated in quiz#12 because the corresponding module was not tested on midterm exams and was new to be tested in final exam.

On average, students who participated in quizzes before final exam, made 1.4 to 2 attempts on each quiz in preparation for final exam. Average time spent on each quiz ranged from 19 minutes (quiz#8) to 41 minutes (quiz#11), while average time spent on a single attempt ranged between 12 minutes (quiz#5) to 24 minutes (quiz#11). In terms of average achievement, students scored between 8.6 to 7.2 out of total 10 points on each quiz and 5.3 to 7.4 points on each attempt.

Cumulative Quiz-wise Formative Assessment Participation in Sets of Quizzes Corresponding to each Exam

Students' overall formative assessment participation in set of quizzes corresponding to three midterm examinations and one final examination was analyzed. Results of the analysis are summarized in Table 4.3e.

Table 4.3e shows that formative assessment participation in terms of number of students for females ranged between a minimum of 61% for exam 3 and a maximum of 68% for exam 2 and final examination. For male students, participation ranged between a minimum of 47% for exam 3 and a maximum of 52% for exam 2 and final exam.

With respect to total number of formative assessment quizzes done out of total quizzes required for a particular exam, female students' participation was lowest (i.e., 7 out of 12 quizzes or 52%) for final exam and highest (i.e., 2.7 of 3 quizzes or 90%) for Exam 3. Among male students, this participation was lowest (i.e., 5 out of 12 quizzes or 42%) for final examination and highest (i.e., 2.6 out of 3 quizzes or 87%) for exam 3.

Female students made more attempts and spent more time on formative assessment quizzes corresponding to each summative exam compared to male students (Table 4.3e). On the average among students who participated in formative assessments female students achieved higher scores on formative assessment quizzes compared to male students for all sets of quizzes.

Table 4.3e: Overall Formative Assessment Participation for each Exam (Means)

Exam#	Gender	Students Participated	#Quizzes Done	#Attempts	Time Spent	Quizzes Score
Exam 1 (Quiz 1-4)	F	61%	3.4/4	7.5	110min	66%
	M	49%	3.3/4	6	97min	64%
Exam 2 (Quiz 5-8)	F	68%	3.5/4	10	121min	68%
	M	52%	3.4/4	9	112min	69%
Exam 3 (Quiz 9-11)	F	63%	2.7/3	7	123min	69%
	M	47%	2.6/3	6	116min	67%
Final Exam (Quiz 1-12)	F	68%	7/12	12	172min	46%
	M	52%	5/12	9	137min	35%

Formative Assessment Participation - Total Quizzes Done (TQD)

Students were grouped in four (4) different categories based on their levels of participation in terms of number of quizzes done corresponding to a particular exam. Table 4.4a below defines different levels of formative assessment participation (FAP) in terms of number of quizzes done corresponding to a particular midterm or final examination.

Table 4.4a: Grouping based on Total Quizzes Done (TQD)

Group	**TQD (Exam 1&2)**	**TQD (Exam3)**	**TQD (Final)**
No Participation	None	None	None
Low Participation	1	1	1 – 4
Moderate Participation	2 – 3	2	5 – 8
High Participation	4	3	9 - 12

Analysis of students' FAP in terms of TQD are shown in Table 4.4.b below. Results show that more than half of the students participated in one or more quizzes corresponding to each summative examination except for Exam 3. Further distribution of students into different categories based on levels of participation yielded encouraging results.

Results show that majority of participating students fall in high participation category based on TQD corresponding to all midterm examinations. However, students' TQD-based formative assessment participation corresponding to final examination does not seem encouraging. Most of the students fall in no participation and low participation category in this case. One of the major reasons might be the fact that most of participating students had already covered quizzes 1 – 11 in preparation for midterm examinations and only quiz 12 was new for them.

Table 4.4b: TQD-based Formative Assessment Participation (TQD)

Group	TQD Exam1	TQD Exam2	TQD Exam3	TQD Final
No Participation	49%	45%	51%	45%
Low Participation	7%	6%	6%	29%
Moderate Participation	10%	8%	6%	11%
High Participation	34%	41%	38%	16%

Gender differences in TQD-based FAP

Analysis of gender-based differences in TQD-based formative assessment participation shows that more female students participated in formative assessment quizzes than males. Table 4.4c shows that almost 50% of male students did not participate in any formative assessment quizzes while female students who did not participate in formative assessment quizzes corresponding to different midterms and final exam, ranged between 33% and 39%. On the contrary, more of the female students participated in formative assessment quizzes corresponding different summative examinations compared to males. Table 4.4c shows that around 50% of male students participated in formative assessments while percentages of female students participating in these assessments range between 61% and 67%.

Table 4.4c: Gender differences in TQD-based Formative Assessment Participation

Group	Gender	TQD Exam1	TQD Exam2	TQD Exam3	TQD Final
Non-Participants	F	39%	33%	38%	33%
	M	51%	48%	53%	48%
Participants	F	61%	67%	62%	67%
	M	49%	52%	47%	52%

Table 4.4d shows students' distribution in to different TQD-based formative assessment participation categories.

Table 4.4d: Gender differences in TQD-based Formative Assessment Participation levels

Group	Gender	TQD Exam1	TQD Exam2	TQD Exam3	TQD Final
Low Participation	F	8%	4%	4%	25%
	M	6%	6%	6%	29%
Moderate Participation	F	9%	13%	9%	14%
	M	10%	8%	5%	10%
High Participation	F	44%	50%	49%	28%
	M	33%	39%	36%	13%

Distribution of male and female students into participation-based categories (defined by TQD) reveals that percentage of male students is almost always greater than female students in low participation categories. As we move from low towards higher participation categories, the percentage of female student participants grows higher than percentage of male participants. Hence it is safe to say that more female students participated in formative assessments and at higher levels than male students.

Independent sample *t*-Test was conducted to find mean differences in total quizzes done between male and female students. Results indicated that female students on average participated in statistically significantly ($p < .05$) more quizzes than male students in preparation for final exam. However, differences in TQD-based participation were not statistically significant for any of the midterm exams. This indicates that not only more females participated in formative assessment quizzes for final exam (i.e., 67%) as per Table 4.5c, but also that females who participated attempted more quizzes than male students to prepare for final exam (see Table 4.4e).

Table 4.4e: Gender differences in TQD-based Formative Assessment Participation

Participation	**Female Mean (*N*)**	**Male Mean (*N*)**	**Mean Differences**
TQD before Exam1	3.43 *(98)*	3.29 *(402)*	0.14
TQD before Exam2	3.53 *(108)*	3.47 *(427)*	0.06
TQD before Exam3	2.84 *(100)*	2.87 *(383)*	0.07
TQD before Final	6.7 *(108)*	5.2 *(428)*	1.5*

**Mean difference was statistically significant at p < .05*

Achievement-based Formative Assessment Participation (Ac_FAP)

Differences in achievement on formative assessment quizzes might define participation level differently than merely using number of quizzes done. Therefore, students' achievement on formative assessment quizzes has been used as measure of formative assessment participation. Students' percent achievement scores on different sets of quizzes corresponding to each summative examination were pooled together to define total achievement for each set of quizzes. An interval of 33% was used to define students' participation levels as below:

Table 4.5a: Grouping based on achievement on formative assessments

Group	**Pooled Score (FA)**
No Participation	0%
Low Participation	(0.1 – 33)%
Moderate Participation	(33.1 – 66)%
High Participation	(66.1 – 100)%

Analysis of achievement based formative assessment participation are shown in Table 4.5b below. Results indicate that 46% - 51% students did not participate in formative assessments at all. Out of the remaining students who participated in one or more formative assessments a majority of 31% to 38% fall in higher participation category (formative assessment scores higher than 66%) in preparation for midterm exam 1, 2, and 3.

Achievement based formative assessment participation for final examination however, showed an opposite trend with more participants in lower participation groups. As explained earlier, 11 out of total 12 quizzes were already corresponding to midterm exams 1, 2, and 3 and that students may have already covered those quizzes in preparation for midterm exams.

Table 4.5b: Achievement-based Formative Assessment Participation (Ac_FAP)

Group	**Ac_FAP Exam1**	**Ac_FAP Exam2**	**Ac_FAP Exam3**	**Ac_FAP Final**
No Participation	49%	46%	51%	46%
Low Participation	8%	7%	6%	30%
Moderate Participation	12%	10%	11%	10%
High Participation	31%	38%	32%	13%

Gender Differences in Achievement-based FAP (Ac_FAP)

An analysis of gender-based differences in achievement-based formative assessment participation reveals similar trends (as in TQD-based FAP) with more females falling in higher participation categories compared to males (Table 4.5c). Similarly, distribution into different participation levels based students' scores on formative assessment quizzes (Table 4.5d) shows that female students outperformed male students in formative assessment quizzes. More of the female students are included in higher and moderate participation categories based on formative assessment scores compared to proportions of males in these categories. Based on these results, it can be inferred that female students not only participated in more formative assessment quizzes compared to males, but they also performed better on these practice quizzes.

Table 4.5c: Gender differences in Achievement-based FAP

Group	**Gender**	**AcFAP Exam1**	**AcFAP Exam2**	**AcFAP Exam3**	**AcFAP Final**
No Participation	F	39%	33%	38%	34%
	M	51%	48%	53%	49%
Low Participation	F	61%	67%	62%	66%
	M	49%	52%	7%	51%

Table 4.5d: Gender differences in Ac_FAP Levels

Group	**Gender**	**Ac_FAP Exam1**	**Ac_FAP Exam2**	**Ac_FAP Exam3**	**Ac_FAP Final**
Low Participation	F	8%	7%	5%	31%
	M	8%	7%	7%	30%
Moderate Participation	F	14%	16%	19%	11%
	M	12%	9%	10%	10%
High Participation	F	39%	45%	39%	25%
	M	29%	36%	30%	11%

Attempt-based Formative Assessment Participation (At_FAP)

There is a great variability in the number of attempts that students made on different formative assessment quizzes. Multiple attempts on one hand might mean that students repeated these formative assessment quizzes in an attempt to recheck the concepts they learnt. However, on the other hand, frequent attempts with less time spent may also mean that students just wanted to check the correct answers and did not use these quizzes effectively to check their concepts.

Due to great variability in number of attempts that students made on different formative assessment quizzes percentile-split method was used to group students into different categories based on number of attempts they made on formative assessment quizzes (see Table 4.6a). Students were assigned percentile ranks based on the number of attempts they made on different sets of formative assessment quizzes corresponding to different summative exams. Then participation levels were defined based on percentile ranges. For example, students who fall between 1^{st} to 33^{rd} percentile based on their number of attempts made on formative assessments were grouped into low participation group. Table 4.6a shows all the percentile ranges (column 2) corresponding to each participation level (column 1) based on their attempts on various sets of quizzes (columns 3 – 6).

Table 4.6a: Grouping based on attempts on formative assessment quizzes

Group	Percentile Range	Attempts Q#(1 – 4)	Attempts Q#(5 – 8)	Attempts Q#(9 – 11)	Attempts Q#(1 – 12)
No Participation	0	0	0	0	0
Low Participation	1 – 33	1 – 4	1 – 5	1 – 4	1 – 3
Moderate Participation	34 – 66	5 – 7	6 – 9	5 – 7	4 – 10
High Participation	67+	8+	10+	8+	11+

Percentile split method helps retain all the cases of participation while providing close group sizes for comparison purposes. Table 4.6a shows distribution of students into 3 different participation categories based on percentile-split method. The table shows number of attempts students in different participation categories made on formative assessment quizzes for each exam.

Table 4.6b below shows percentages of students falling in different participation categories based on their number of attempts on formative assessment quizzes. The percentages as such do not represent comparative differences because percentile split method splits sample into almost equivalent size groups. However, this splitting provides grounds for gender-based differences (discussed next).

Table 4.6b: Attempt-based Formative Assessment Participation (At_FAP)

Group	At_FAP Exam1	At_FAP Exam2	At_FAP Exam3	At_FAP Final
No Participation	49%	45%	51%	45%
Low Participation	23%	23%	22%	19%
Moderate Participation	12%	14%	12%	18%
High Participation	16%	18%	15%	18%
Total	100%	100%	100%	100%

Gender Differences in Attempts-based FAP (At_FAP)

Gender differences in At_FAP (Table 4.6c) shows mixed trends in participation levels in terms of attempts on formative assessment quizzes corresponding to midterm exam1. However, as we move down towards higher participation categories, percentages of female participants increase compared to males for all exams. Cumulatively, more of female participants fall in moderate and high participation categories compared to males based on At_FAP. This means that female students made more attempts on formative assessment quizzes compared to male students.

Table 4.6c: Gender differences in At_FAP Levels

Group	**Gender**	**At_FAP Exam1**	**At_FAP Exam2**	**At_FAP Exam3**	**At_FAP Final**
Low Participation	F	23.8%	28.1%	26.9%	16.9%
	M	22.2%%	21.3%	21%	18.8%
Moderate Participation	F	13.8%	15.6%	13.8%	20%
	M	11.9%	14.1%	11.6%	17.6%
High Participation	F	23.8%	23.8%	21.9%	30.6%
	M	15%	16.9%	14.2%	15.9%

Time-Spent-based Formative Assessment Participation (TS_FAP)

Due to similar reason as for *attempt-based formative assessment participation*, percentile split method was also employed to group students into 3 different participation categories based on total time spent on different sets of formative assessments. Table 4.7a below presents grouping criteria for time spent-based formative assessment participation (TS_FAP) using percentile split-method. Again column 1 and 2 show participation levels and percentile ranges corresponding to each participation level. Column 3 to 6 show range of time spent on all attempts made on each set of formative assessment quizzes.

Table 4.7a: Grouping based on time-spent on formative assessment quizzes

Group	Percentile Range	Time Spent Q#(1-4)	Time Spent Q#(5-8)	Time Spent Q#(9 – 11)	Time Spent Q#(1 – 12)
No Participation	0	0	0	0	0
Low Participation	1 – 33	0.1 – 52	0.1 – 56	0.1 – 58	0.1 – 62
Moderate Participation	34 – 66	52.1 – 108	56.1 – 118	58.1– 127	62.1 – 159
High Participation	66+	108+	118+	127+	159+

Table 4.7b shows distribution of all students into 3 different participation categories of comparable sizes. As can be seen, percentile split method helps split participants' sample in to 3 comparable size groups based on time spent on quizzes using an interval of 33 percentile.

Table 4.7b: Time Spent-based Formative Assessment Participation (TS_FAP)

Group	TS_FAP Exam1	TS_FAP Exam2	TS_FAP Exam3	TS_FAP Final
No Participation	49%	45%	51%	45%
Low Participation	17%	18%	16%	18%
Moderate Participation	17%	18%	16%	18%
High Participation	17%	19%	17%	19%
Total	100%	100%	100%	100%

Gender Differences in Time Spent-based FAP (TS_FAP)

Distribution in time spent based participation categories repeats similar trends as more of female students appear in moderate and high-level participation categories determining that more female students on average spent more time on formative assessment quizzes compared to male students.

Table 4.7c: Gender differences in TS_FAP Levels

Group	**Gender**	**TS_FAP Exam1**	**TS_FAP Exam2**	**TS_FAP Exam3**	**TS_FAP Final**
Low Participation	F	17.5%	18.9%	17%	15.6%
	M	16.6%	18.5%	15.9%	18.5%
Moderate Participation	F	22.3%	23.9%	21.4%	24.4%
	M	16.3%	16.4%	15.3%	17%
High Participation	F	21.5%	24.5%	23.9%	27.5%
	M	16.3%	17.4%	15.6%	16.9%

Students' Task Value Beliefs & Gender Differences

This section presents results of analysis on students' task value beliefs in terms of the extent to which they find course materials in the course interesting, important and useful. Self-report data collected on a 3-items Likert-scale, each item with 4 levels has been analyzed. For ease of presentation 4 levels of responses to each item have been combined into two groups. For example, "Very Important" and "Important" both have been counted in one category "Important" representing students who found course materials as important. Similarly, "Very Unimportant" and "Unimportant" have been counted in another category representing students who found course material to be unimportant to them. Results are presented in Table 4.9a below:

Table 4.8: Students' Task Value Beliefs (Importance, Usefulness, Interest)

Task Value Belief	Gender	Gender-based Responses	Total Participant Responses
Important	F	79.4%	78.4%
	M	78.2%	
Useful	F	81.3%	79.6%
	M	79.2%	
Interesting	F	71.3%	73.3%
	M	73.7%	

As shown in Table 4.8 above, overall, a majority of the students reported the course materials taught in this course as important (78.4%) and useful (79.6%). Comparatively lesser portion (73.3%) of students reported the course material as interesting. In terms of gender differences, more females considered the course materials as important and useful compared to male students. However, proportion of male students who reported the course material as interesting was higher than female students.

Students' Achievement on Summative Exams

This section provides a descriptive analysis of students' achievement on 3 midterm examinations and one final comprehensive examination and gender-based differences. All scores on midterm and final examinations are presented in percentages. Students' overall mean exam scores and standard deviations are presented in Table 4.9a.

Results show highest mean score on midterm exam 3 followed by exam 2 and final examination for overall sample. Moreover, students had lowest mean scores on midterm exam 1.

Table 4.9a: Gender Differences in Summative Achievement

Examination	**Female** ***(N=160)*** **Mean (SD)**	**Male** ***(N=818)*** **Mean (SD)**	**Mean Differences**	**Overall** ***(N=978)*** **Mean (SD)**
Midterm Exam 1	67.88 (16.3)	72.12 (16.8)	-4.25*	71.4 (16.7)
Midterm Exam 2	78.5 (16.8)	79.16 (16.9)	0.66	79.1 (16.9)
Midterm Exam 3	88.25 (14.5)	85.99 (16.1)	2.26*	86.4 (15.9)
Final Examination	76.64 (15.6)	74.86 (16.5)	1.78	75.2 (16.4)

Mean difference was statistically significant at p < .05

Gender Differences in Summative Achievement

Analysis of gender differences in exam scores revealed that on average male students, outperformed female students on midterm exam 1 and 3. Female students on the other hand achieved higher mean scores on exam 3 and final exam (see Table 4.9a).

Although students' summative achievement (outcome variable) data was not completely normally distributed (skewed to right), however (as discussed in methods section), robustness of ANOVA and *t*-Tests allow these tests to be used with non-normal data without affecting the results. Levene's tests of equality of variances between gender groups for all exam scores were non-significant (passing assumption to consider using parametric ANOVA test results). Results of *t-Test* showed that on average males performed statistically significantly (4.25%) higher than females on midterm exam1. Similarly, female students performed on average 2.26% higher than male students on midterm exam3 compared to males. These differences were statistically significant at $p < .05$. Results also show that female students outperformed male students by 0.66% in midterm exam2 and 1.78% on final examination. However, these differences in exam 2 and final exam scores were not statistically significant.

Differences in Summative Achievement based on Task Values

Students' summative achievement when analyzed against students' task value beliefs returned very interesting results. Independent sample *t*-Test revealed that there were statistically significant mean differences in students' exam scores based on their task value beliefs. For example, students who reported the course materials as important, useful, and/or interesting, on the average performed statistically significantly better that other students who reported negative beliefs in terms of importance and usefulness of the course material and their interest in it (see Table 4.9 b, c, d).

Table 4.9b: Summative Achievement and Task Value Beliefs (Importance)

Score	Task Value	*N*	Mean	SD	Mean Difference
Exam 1	Important	*767*	72.2	16.8	3.4*
	Unimportant	*211*	68.8	16.2	
Exam 2	Important	*767*	80.0	17.0	4.2*
	Unimportant	*211*	75.8	16.2	
Exam 3	Important	*767*	86.7	16.6	1.5
	Unimportant	*211*	85.2	12.7	
Final Exam	Important	*767*	76.0	16.7	4.1*
	Unimportant	*211*	71.9	14.7	

Mean difference was statistically significant at p < .05

Table 4.9c: Summative Achievement and Task Value Beliefs (Usefulness)

Score	Task Value	N	Mean	SD	Mean Difference
Exam 1	Useful	*778*	72.2	16.7	3.8*
	Useless	*200*	68.4	16.7	
Exam 2	Useful	*778*	79.8	17.3	3.8*
	Useless	*200*	76.0	15.2	
Exam 3	Useful	*778*	86.5	16.8	0.7
	Useless	*200*	85.8	11.7	
Final Exam	Useful	*778*	75.8	16.6	3.0*
	Useless	*200*	72.7	15.4	

Mean difference was statistically significant at p < .05

Table 4.9d: Summative Achievement and Task Value Beliefs (Interest)

Score	Task Value	N	Mean	SD	Mean Difference
Exam 1	Interesting	717	72.7	16.9	5.0*
	Uninteresting	261	67.8	15.8	
Exam 2	Interesting	717	80.2	17.4	4.2*
	Uninteresting	261	75.9	15.1	
Exam 3	Interesting	717	86.6	17.2	0.9
	Uninteresting	261	85.7	11.5	
Final Exam	Interesting	717	76.3	16.9	4.2*
	Uninteresting	261	72.1	14.5	

Mean difference was statistically significant at p < .05

Effect of Gender on Relationship between Task Values and Summative Achievement

In order to see if there are any gender differences in relationship between students' different task value beliefs and their summative achievement, two-way analysis of variance (ANOVA) test was conducted. Despite all groups demonstrating equal variances as evidenced by non-significant Levene's test, there were no statistically significant interaction effects of gender on relationship between students' achievement on summative exams and their task value beliefs.

Analysis of Relationships between Formative Assessment Participation, Summative Achievement: Moderation Effects of Gender, Task Values, and Prior CGPA

Correlational Analysis (FAP vs. Summative Achievement)

To identify strengths and directions of relationships between students' formative assessment participation and summative achievement, an analysis of correlations between the two variables is presented. Pearson correlation coefficients were calculated. Significance of the correlations was determined using a p value of less than .05 (i.e., $p < .05$). This must be noted that when it comes to statistical benchmarks, acceptable ranges consistent in engineering research differ from those in behavioral research. This research sought for a Pearson correlation between 0.04 and 0.6 as suggested by Ruesch et al. (2017) review of behavioral research literature.

As shown in table 4.10, there were statistically significant correlations ($p < .05$) between students' achievement on summative examinations and their participation in corresponding formative assessments. The table shows that these correlations were statistically significant irrespective of the measure (i.e., number of quizzes, time spent, attempts and achievement on formative assessments) of participation used. However, it is worth noting that students' achievement on summative exams had strongest correlations with their (pooled) scores on formative assessments followed by total number of quizzes done. There were comparatively weaker correlations of students' exam scores with formative assessment participation in terms of time spent on quizzes and attempts made on these quizzes.

Table 4.10: Correlations between FAP and Summative Achievement

	Total Quizzes	**Time Spent**	**Total Attempts**	**Pooled Score**
Exam 1 Score	.21**	.12**	.18**	.27**
Exam 2 Score	.24**	.09**	.16**	.30**
Exam 3 Score	.26**	.18**	.22**	.29**
Final Exam Score	.15**	.06*	.12**	.18**

*****Correlations were statistically significant at p < .05***
****Correlations were statistically significant at p < .10***

Gender Differences in Correlations

Gender-based differences in correlations between formative assessment participation and summative achievements were measured to see how these two variables relate to each other within different gender groups. Pearson's correlation coefficients as listed in Table 4.11 showed mixed trends.

Table 4.11: Gender-based differences in correlations between FAP and Summative Achievement

	Gender	Total Quizzes	Time Spent	Total Attempts	Pooled Score
Exam 1 Score	F	.28**	.25**	.27**	.34**
	M	.21**	.11**	.17**	.27**
Exam 2 Score	F	.25**	0.15	.23**	.32**
	M	.24**	.08*	.15**	.29**
Exam 3 Score	F	.17*	0.15	.16*	.23**
	M	.27**	.19**	.22**	.30**
Final Exam Score	F	0.08	0.02	0.10	0.12
	M	.16**	0.07	.12**	.19**

*****Correlations were statistically significant at p < .05***
****Correlations were statistically significant at p < .10***

Correlations between formative assessment participation and summative achievement were stronger within female students compared to male students in case of exam 1 and exam 2. However, for exam 3 and final examination there was an opposite trend. Male students showed stronger positive correlations between scores on exam 3 and final exam and participation in formative assessments corresponding to these exams. Moreover, some of correlations for female students were not even statistically significant in the latter case.

Differences in Correlations based on Task Values

To see how task value beliefs might moderate these correlations, all three constructs of task value beliefs were used as categorical variables and correlations between formative assessment participation and summative achievement were compared between groups with negative and positive task value beliefs for each construct of task values.

Table 4.12a shows differences in correlations between students' formative assessment participation (TQD, time spent, attempts, and pooled scores) and summative achievements based on the intrinsic value (importance) they found in course materials.

Table 4.12a: Correlations between FAP vs. Summative Achievement (Task Value Belief – Importance)

	Task Value	Total Quizzes	Time Spent	Total Attempts	Pooled Score
Exam1 Score	Important	.28**	.18**	.24**	.33**
	Unimportant	-0.13	-.15	-.14*	-0.08
Exam2 Score	Important	.31**	.11**	.20**	.35**
	Unimportant	-0.07	-0.05	-0.05	-0.01
Exam3 Score	Important	.34**	.25**	.27**	.35**
	Unimportant	-.18*	-.17	-.15*	-0.09
Final Exam Score	Important	.19**	.09*	.15**	.21**
	Unimportant	-0.10	-0.10	-0.04	-0.08

*****Correlations were statistically significant at $p < .05$***
****Correlations were statistically significant at $p < .10$***

Statistically significant positive correlations were found for students' who thought the course material was important. There were either no or very small negative correlations between formative assessment participation and summative achievements for students who found course material to be unimportant. Similar trends in correlation differences were also found based on students' differential task value beliefs in terms of usefulness and interest in the course materials.

Students' positive task value beliefs in terms of usefulness and interest in course material were also found to be positively associated with statistically significant positive correlations between their formative assessment participation and their achievement on summative exams. On the other hand, for students who thought the course material was useless or uninteresting, there were no significant positive correlations between their participation in formative assessments and achievement on summative exams (see Table 4.12b, and 4.12c).

Table 4.12b: Correlations between FAP vs. Summative Achievement (Task Value Belief – Usefulness)

	Task Value	**Total Quizzes**	**Time Spent**	**Total Attempts**	**Pooled Score**
Exam1 Score	Useful	.26**	.18**	.23**	.32**
	Useless	-0.07	-0.12	-0.11	-0.02
Exam2 Score	Useful	.30**	.11**	.20**	.35**
	Useless	-0.09	-0.08	-0.08	-0.03
Exam3 Score	Useful	.35**	.26**	.27**	.36**
	Useless	-.16	-.50	-.11*	-.10
Final Exam Score	Useful	.19**	.09*	.15**	.21**
	Useless	-0.11	-0.10	-0.06	-0.09

*****Correlations were statistically significant at p < .05***
****Correlations were statistically significant at p < .10***

Table 4.12b shows that there were statistically significant positive correlations between formative assessment participation and achievements on all summative exams for those students who believed that course material was useful for them. However, for the students who believed that course material was useless, there were no statistically significant correlations between formative assessment participation and summative achievement. Comparison of correlations based on students' beliefs about interest in the course materials also show similar results (see Table 4.12c).

Table 4.12c: Correlations between FAP and Summative Achievement (Task Value Belief – Interest)

	Task Value	**Total Quizzes**	**Time Spent**	**Total Attempts**	**Pooled Score**
Exam1 Score	Interesting	.27**	.17**	.24**	.33**
	Uninteresting	-0.07	-0.08	-0.11	-0.02
Exam2 Score	Interesting	.33**	.11**	.21**	.37**
	Uninteresting	-0.09	-0.07	-0.10	-0.04
Exam3 Score	Interesting	.37**	.26**	.28**	.38**
	Uninteresting	-.11	-.17	-.17	-.14
Final Exam Score	Interesting	.19**	.10**	.15**	.21**
	Uninteresting	0.07	-0.08	0.03	0.04

*****Correlations were statistically significant at p < .05***
****Correlations were statistically significant at p < .10***

These findings suggest that task value beliefs (i.e., perceived importance, usefulness and interest) about course materials might act as motivational constructs to moderate the effect for formative assessment participation on students' achievement in summative examinations. More specifically, formative assessment participation might help enhance summative achievement for students who have positive task value beliefs.

Students with negative task value beliefs do not benefit from formative assessments despite participation. However, these results require further analysis in terms of identifying significant mean differences and significant interaction effects of gender, task values and prior CGPA on relationships between formative assessment participation and summative achievement.

FAP-based Mean Differences in Summative Achievement and Moderation Effects of Gender, Task Values and Prior CGPA

As discussed earlier, two-way ANOVA was used to determine if gender, task values, and prior CGPA of students have any interaction/moderation effects on relationship between formative assessment participation and students' achievement on summative exam scores. Then one-way ANOVA was used to see main effects of gender, task values and prior CGPAs of students on these relationships.

Assumption of homogeneity of variance for both two-way and one-way ANOVA was tested using Levene's test. Significance of two-way ANOVA results was used to determine interaction effects of gender, task values and CGPA. One-way ANOVA test significance was used to determine statistically significant mean differences between groups with homogenous variances. If variances were not homogenous, Welch's test was used to determine significant mean differences. Finally, Post hoc multiple group comparison table with Tuckey HSD (Honest Significant Difference) test was used to find exactly which comparison groups have statistically significant mean differences and what the directions of these differences are.

Interaction effects and main effects of gender, task values and prior CGPA on relationship between formative assessment participation and summative achievement were assessed using two main measurement models (i.e., TQD-FAP and Ac_FAP) which showed higher and statistically significant correlations (discussed above).

TQD-based FAP and Summative Achievement

One way ANOVA results for overall sample showed statistically significant mean differences in achievement scores on summative exam 1, 2, 3, and final exam between high-low, high-moderate, and high-no participation groups (as shown Table 4.13a). Highest mean differences were found between high participation and no-participation categories for all summative examinations followed by high vs. low and then high vs. moderate participation groups. It can be inferred that higher the differences in participation level in the sample, higher are the mean differences in summative achievement always favoring participation in formative assessments.

Table 4.13a: Mean differences in Exam Scores based on TQD-FAP

	TQD-FAP		Mean Difference
Exam1	High	No	8.4*
		Low	7.3*
		Moderate	6.8*
Exam2	High	No	8.8*
		Low	7.0*
		Moderate	4.7*
Exam3	High	No	9.1*
		Low	4.1*
		Moderate	5.8
Final	High	No	7.4*
		Low	5.0*
		Moderate	5.8*

**Mean difference is significant at* $p < .05$

Interaction Effects of Gender on relationship between TQD-FAP and Summative Achievement

Two-way ANOVA tests were conducted to examine the interaction effects between gender and TQD-FAP on students' achievement in 3 midterm and one final comprehensive examination. Results showed no significant interaction effects of gender and TQD-FAP on students' summative achievement for any of the exams. Hence relationship between TQD-FAP and summative achievement does not depend on gender or more specifically the relationship holds similar for males and females.

Figure 4.1 (a, b, c, d) show interaction effects of gender with TQD-based formative assessment participation. As can be seen all the figures show almost similar trends of changes in summative achievement means with respect to formative assessment participation levels for both males and females.

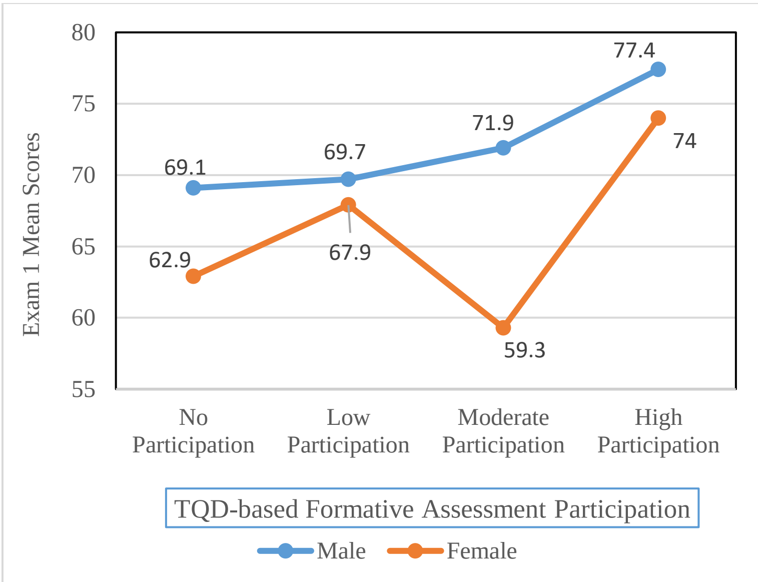

Figure 4.1a: Interaction of Gender with TQD-FAP (Exam 1)

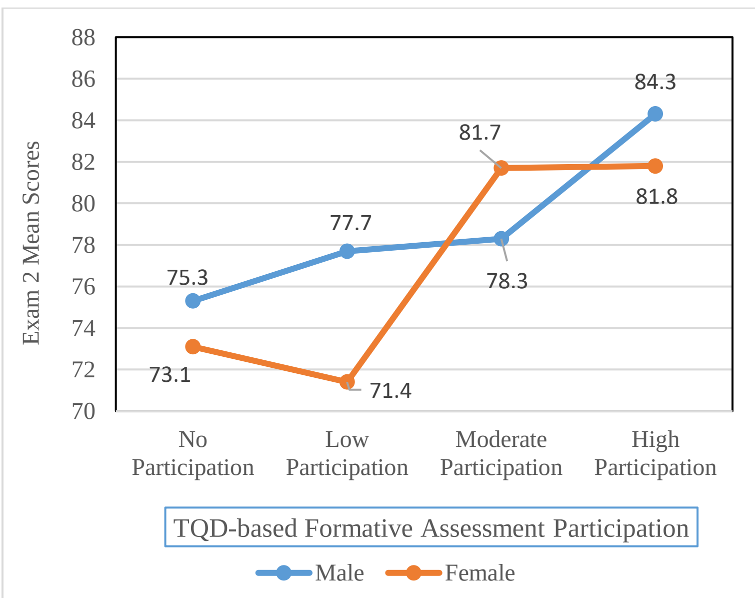

Figure 4.1b: Interaction of Gender with TQD-FAP (Exam 2)

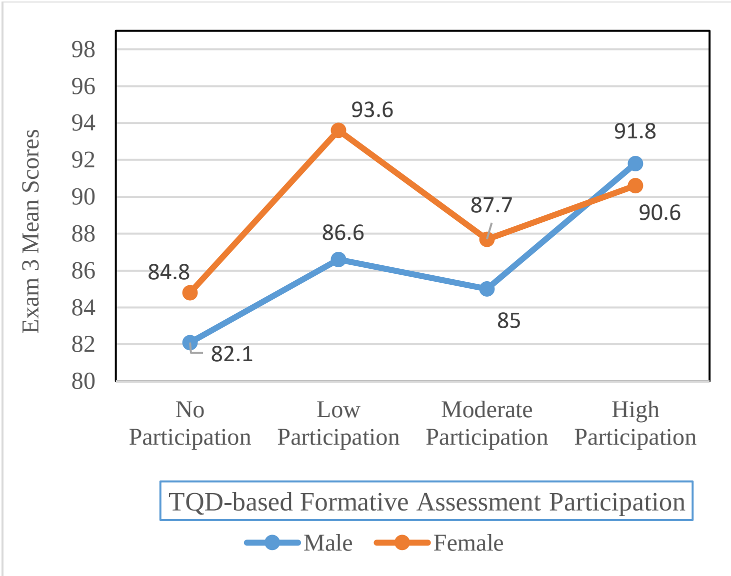

Figure 4.1c: Interaction of Gender with TQD-FAP (Exam 3)

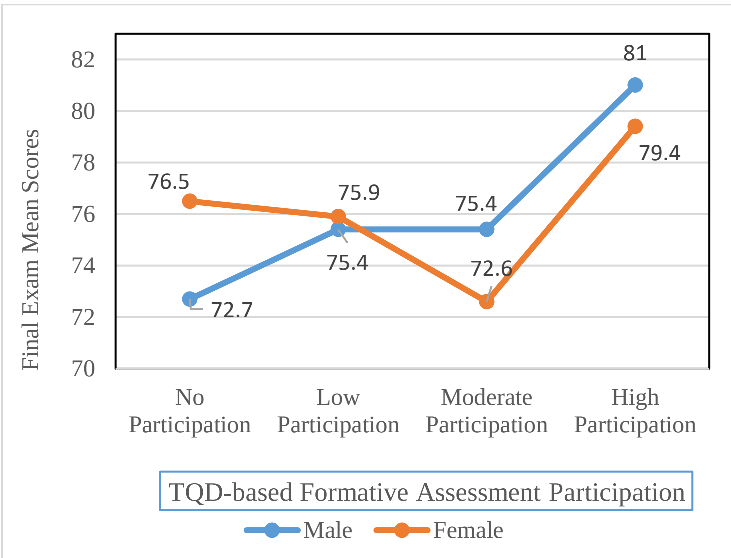

Figure 4.1d: Interaction of Gender with TQD-FAP (Final Exam)

Main Effects of Gender on relationship between TQD-FAP and Summative Achievement

One-way ANOVA was conducted to find mean differences in exam scores based on different levels of TQD-FAP separately for males and females. Table 4.13b summarizes the results. One-way ANOVA showed statistically significant mean differences in all exam scores based on different levels of participation for males.

Although analysis also found some significant mean differences based on TQD for female students, but due to low number of females in the sample, and further splitting of the sample in high, moderate, low, and no participation categories (see descriptive tables above), most of participation-based differences exam scores were not statistically significant. It is safe to infer that testing with larger sample sizes might give significant mean differences in achievement comparable to male participants.

Overall results showed positive mean differences in summative exams scores attributed to formative assessment participation in terms of TQD.

Table 4.13b: Mean differences in Exam Scores based on TQD

	TQD-FAP (High vs. others)		Mean Differences	
			Female	**Male**
Exam1	High	No	11.1*	8.4*
		Low	6.1	7.7*
		Moderate	14.7*	5.5*
Exam2	High	No	8.7*	9.1*
		Low	10.2	6.7*
		Moderate	.15	6.0*
Exam3	High	No	5.8	9.6*
		Low	-2.9	5.2
		Moderate	2.9	6.8*
Final	High	No	2.9	8.3*
		Low	3.5	5.6*
		Moderate	6.9	5.6

Interaction Effects of Task Values on relationship between TQD-FAP and Summative Achievement

Two-way ANOVA results showed that there were statistically significant interaction effects between students' task values beliefs in the course materials and their TQD-based FAP on students' achievement in summative exams. These interaction effects were statistically significant ($p<.05$) for all midterm and final exams. Moreover, interaction effects were significant for all the constructs of task values (i.e., importance, usefulness, and interest).

As can be seen in figures below, students' task value beliefs moderate the relationship between their formative assessment participation and their summative achievement. For instance, figure 4.2a shows that students who believed the course material to be important, their summative achievement mean scores on midterm exam1 are showing an upward trend as we move from no participation category towards high participation category in terms of TQD-based formative assessment participation. On the contrary, students who believed course materials to be unimportant, their mean summative achievement either follows a random trend or goes downward towards higher level of formative assessment participation.

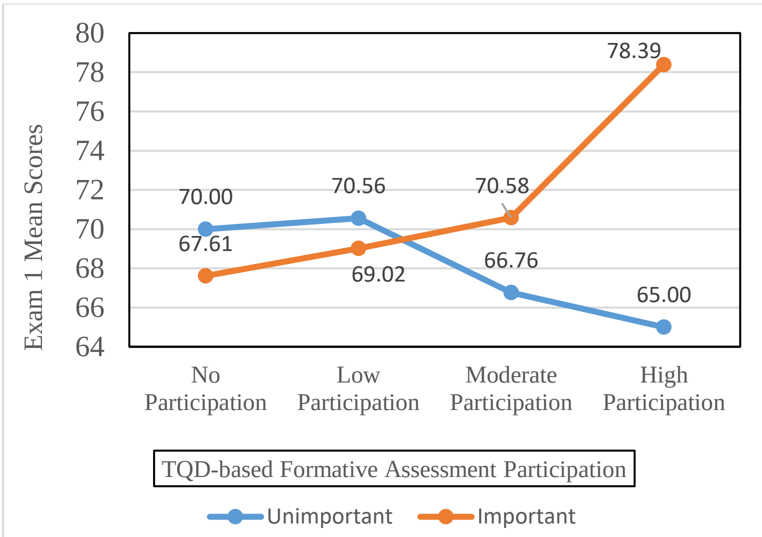

Figure 4.2a: Interaction of Importance with TQD-FAP (Exam1)

Similar trends can be observed for all exams and all three constructs of task values (see following figures). These interactions reveal that students' task value beliefs moderate the relationship between their formative assessment participation and their summative achievement scores.

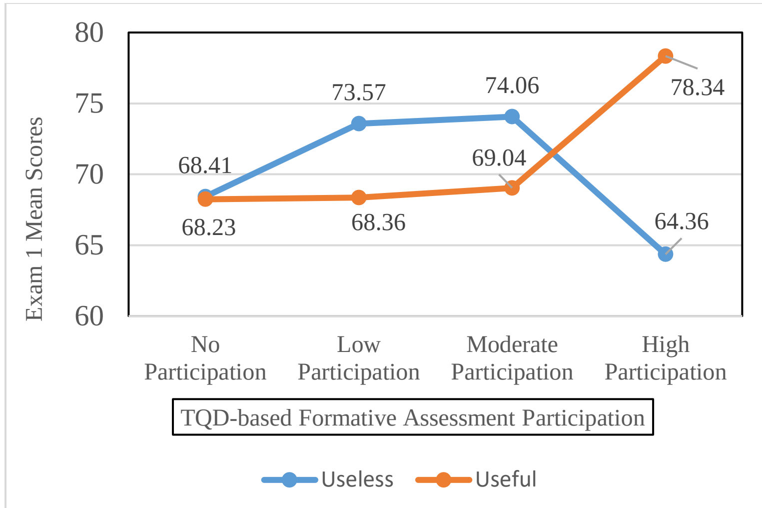

Figure 4.2b: Interaction of Usefulness with TQD-FAP (Exam1)

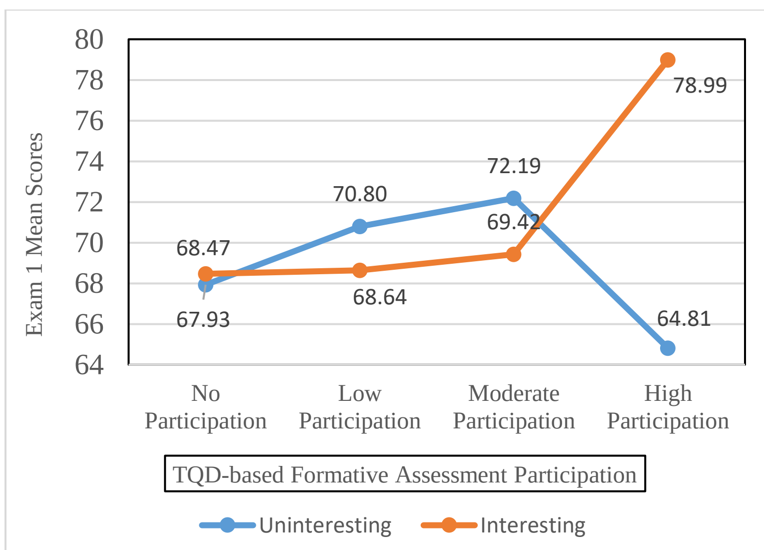

Figure 4.2c: Interaction of Importance with TQD-FAP (Exam1)

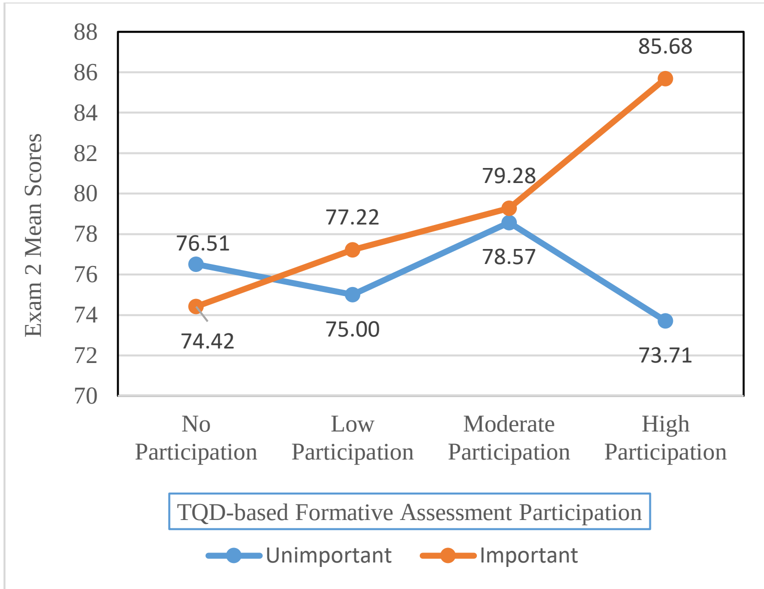

Figure 4.3a: Interaction of Importance with TQD-FAP (Exam2)

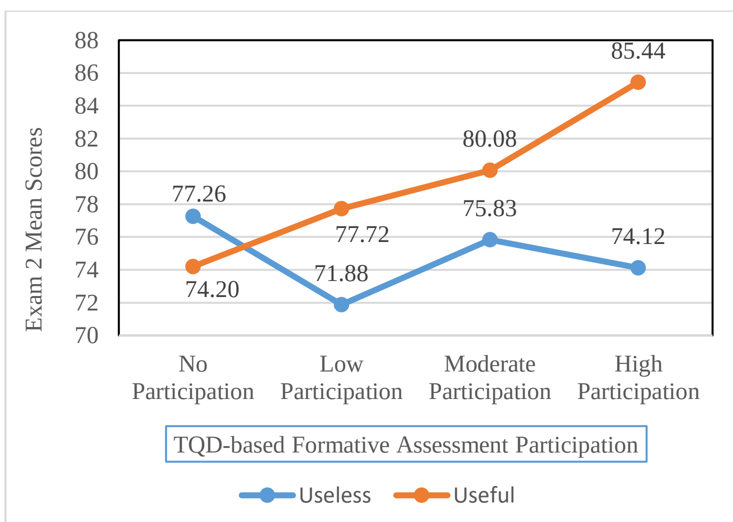

Figure 4.3b: Interaction of Usefulness with TQD-FAP (Exam2)

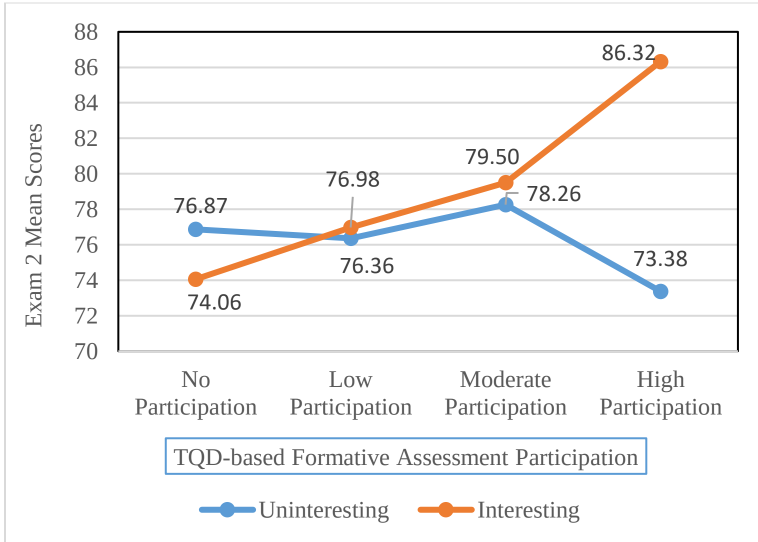

Figure 4.3c: Interaction of Interest with TQD-FAP (Exam2)

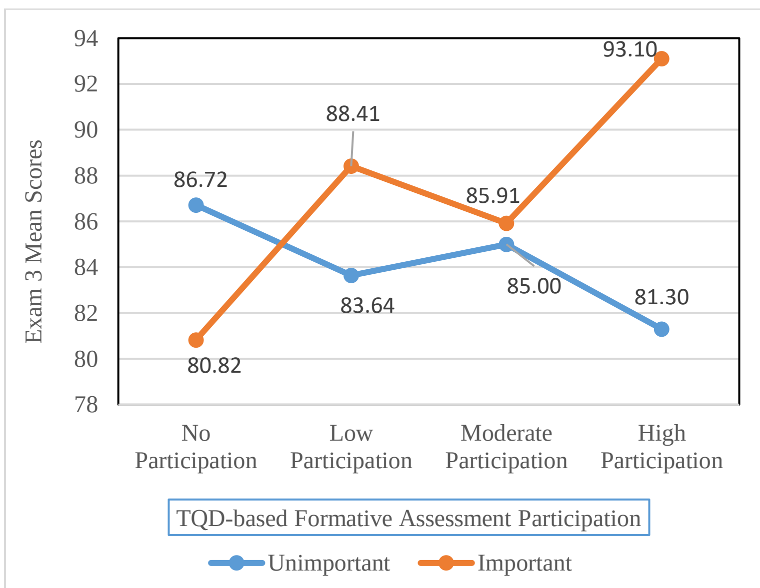

Figure 4.4a: Interaction of Importance with TQD-FAP (Exam3)

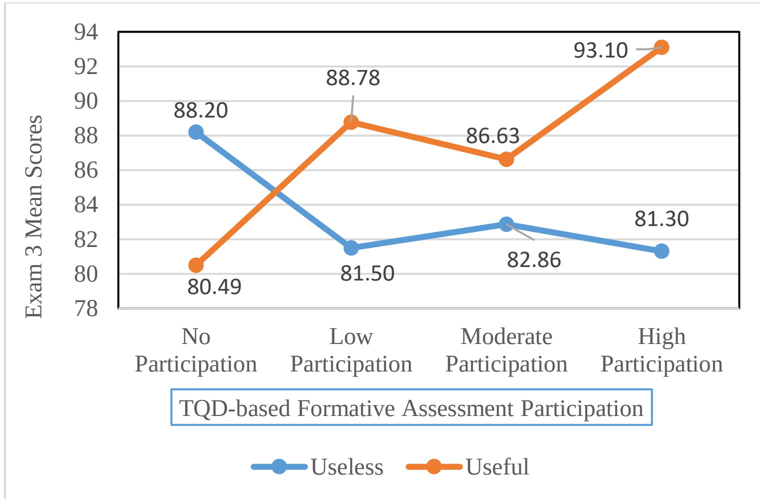

Figure 4.4b: Interaction of Usefulness with TQD-FAP (Exam3)

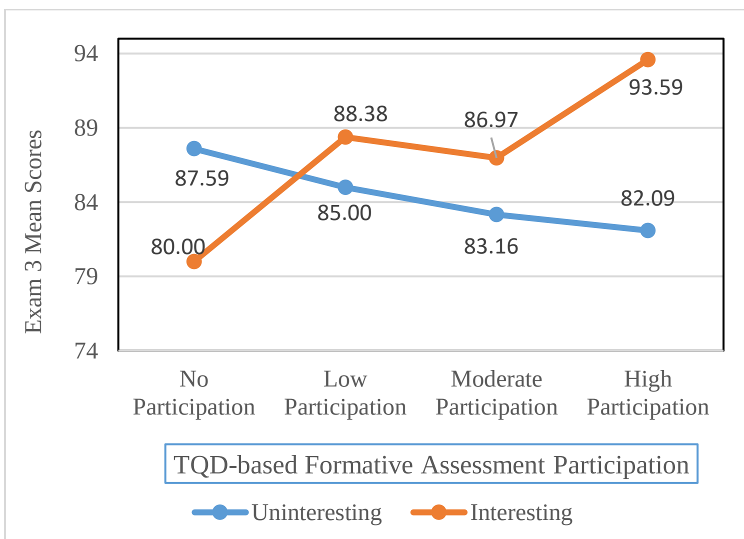

Figure 4.4c: Interaction of Interest with TQD-FAP (Exam3)

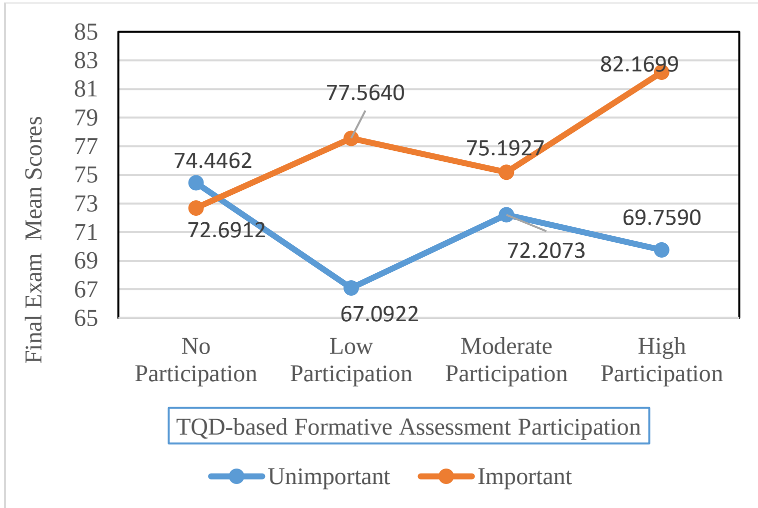

Figure 4.5a: Interaction of Importance with TQD-FAP (Final Exam)

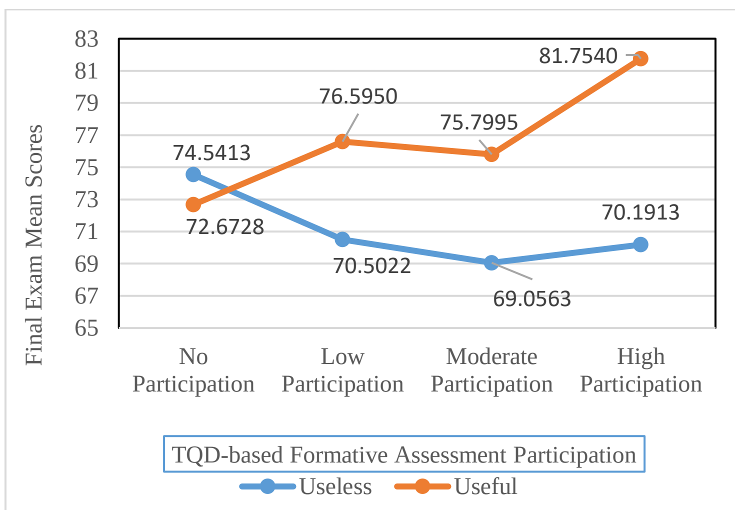

Figure 4.5b: Interaction of Usefulness with TQD-FAP (Final Exam)

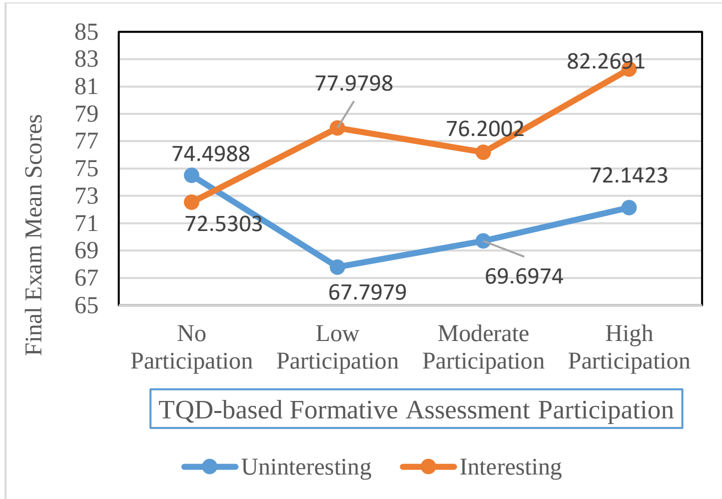

Figure 4.5c: Interaction of Interest with TQD-FAP (Final Exam)

Main Effects of Task Values on relationship between TQD-FAP and Summative Achievement

To assess main effects of task values (i.e., importance, usefulness, interest), One-way ANOVA was conducted separately for positive and negative task value groups and results were compared (see Table 4.14a). Results showed that statistically significant mean differences between groups with different levels of formative assessment participation were found for those students who believed that course material was important, useful, or interesting to them. On the contrary, no significant mean differences (with few exceptions) in summative achievements associated with formative assessment participation were observed for students' who believed that course materials were unimportant, uninteresting, or useless. Highest mean differences were found between high participation and no/low participation groups.

Table 4.14a: Mean differences in Exam Scores with respect to TQD-FAP and Task Values

			Mean Differences based on Task Value Beliefs					
Scores	**TQD- FAP**		**Important**	**Unimportant**	**Useful**	**Useless**	**Interesting**	**Uninteresting**
Exam1	High vs.	No	10.8*	-5.0	10.1*	-4.1	10.5*	-3.1
		Low	9.4*	-5.6	10.0*	-9.2	10.4*	-6.0
		Moderate	7.8*	-1.8	9.3*	-9.7	9.6*	-7.4
Exam2	High vs.	No	11.3*	-2.8	11.2*	-3.1	12.3*	-3.5
		Low	8.5*	-1.3	7.7*	2.2	9.3*	-3.0
		Moderate	6.4*	-4.9	5.4	-1.7	6.8*	-4.9
Exam3	High vs.	No	12.3*	-5.4*	12.6*	-6.9	13.6*	-5.5*
		Low	4.7*	-2.3	4.3	-.2	5.2	-2.9
		Moderate	7.2*	-3.7	6.4	-1.6	6.6	-1.1
Final	High vs.	No	9.5*	-4.7	9.1*	-4.4	9.7*	-2.4
		Low	4.6*	2.7	5.2*	-.31	4.3*	4.3
		Moderate	7.0*	-2.5	6.0*	1.1	6.7*	2.4

*Mean differences were statistically significant at $p < .05$

Interaction Effects of Prior CGPA on relationship between TQD-FAP and Summative Achievement

Two-way ANOVA results showed that there were no statistically significant interaction effects between students' prior CGPA in their program of study and their TQD-based FAP on students' achievement in summative exams. This indicates that prior CGPA did not affect the relationships between students' formative assessment participation and their summative achievement differently for different groups. More specifically, main effects of CGPA (if any) on the relationship between formative assessment participation and summative achievement were similar across different CGPA based groups of students as shown in figures 4.6 (a, b, c, d).

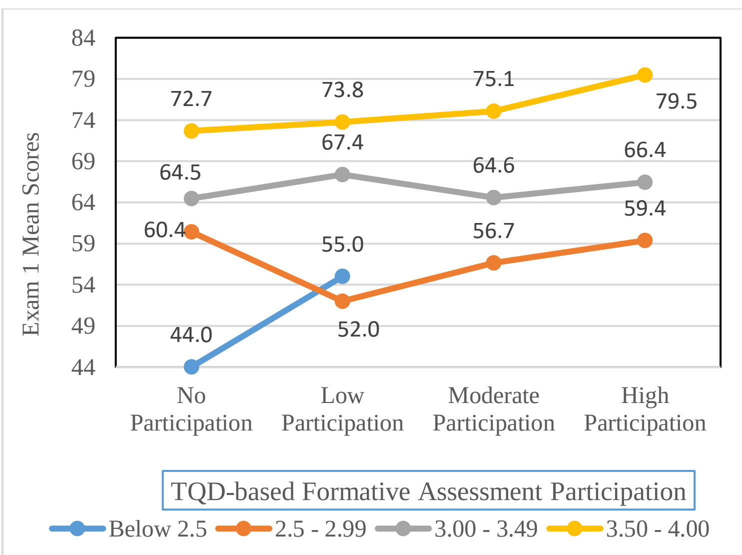

Figure 4.6a: Interaction of Prior CGPA with TQD-FAP (Exam 1)

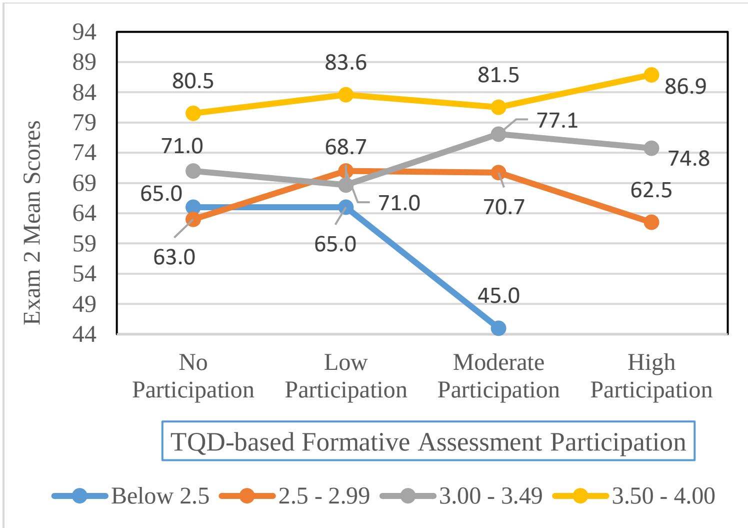

Figure 4.6b: Interaction of Prior CGPA with TQD-FAP (Exam 2)

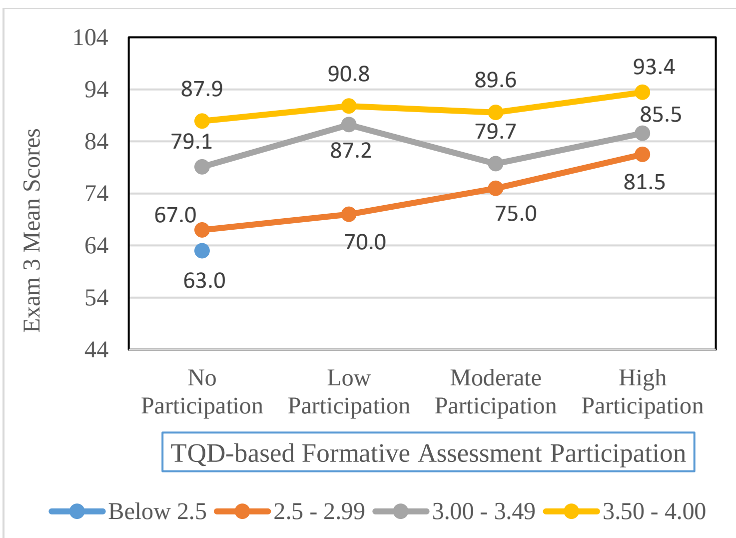

Figure 4.6c: Interaction of Prior CGPA with TQD-FAP (Exam 3)

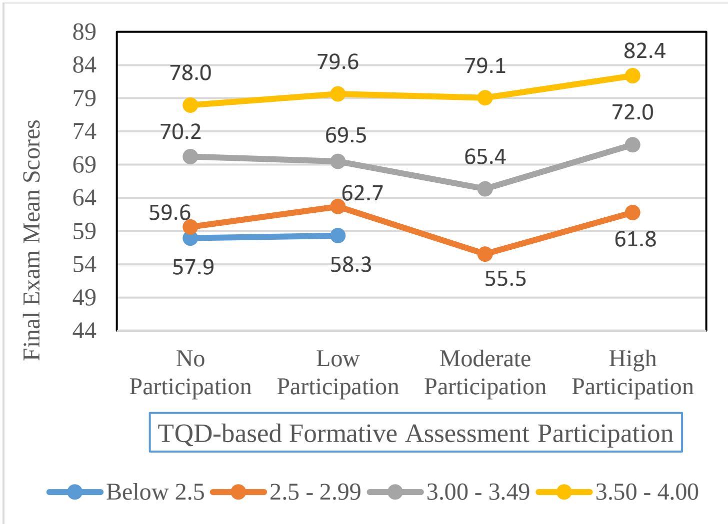

Figure 4.6d: Interaction of Prior CGPA with TQD-FAP (Final Exam)

Main Effects of Prior CGPA on relationship between FAP and Summative Achievement

One-way ANOVA was conducted to compare mean differences in exam scores based on different levels of formative assessment participation (TQD-FAP) within different groups based on prior CGPA. Results showed that there were no statistically significant mean differences in summative achievement based on formative assessment participation among various prior CGPA-based groups. Hypothetically it was expected that if there are no significant interaction effects of CGPA, formative assessment participation should have positive relationships with summative achievement for all CGPA based groups. However, due to CGPAs highly skewed towards higher level and very few participants in some of CGPA based groups who participated in formative assessments at different levels, no significant relationships were found.

Achievement-based FAP (Ac_FAP) and Summative Achievement

One way ANOVA results for overall sample showed statistically significant mean differences in achievement scores on summative exams 1, 2, 3, and final examination between high-low, high-moderate, and high-no formative assessment participation groups (as shown in right column of Table 4.15a).

Highest overall mean differences were found between high participation and no-participation categories for all summative examinations followed by high participation vs. low participation and then high participation vs. moderate participation groups. It can be inferred that higher the differences in participation level, higher are the mean difference in summative achievement always favoring participation in formative assessments.

Table 4.15a: Mean differences in Exam Scores based on Ac_FAP

	Ac_FAP		**Mean Difference**
Exam1	High	No	10.1*
		Low	9.9*
		Moderate	10.9*
Exam2	High	No	10.3*
		Low	10.3*
		Moderate	8.7*
Exam3	High	No	10.6*
		Low	6.8*
		Moderate	7.4*
Final	High	No	8.9*
		Low	6.8*
		Moderate	6.6*

**Mean differences were significant at $p < .05$*

Interaction Effects of Gender on relationship between TQD-FAP and Summative Achievement

Two-way ANOVA results showed no interaction effect of gender with achievement-based formative assessment participation (Ac_FAP) on students' summative achievement. Therefore, it can be inferred that (like TQD-based FAP), gender did not affect the relationship between Ac_FAP and students' summative achievement. In other words, any differences in relationships between Ac_FAP and summative achievement cannot be attributed to gender differences.

Main Effects of Gender on relationship between TQD-FAP and Summative Achievement

Results of one-way ANOVA showed statistically significant mean differences in all exam scores for male students at different levels of Ac_FAP. For example, male students in high Ac_FAP group on average performed better than male students in low, moderate and no Ac_FAP groups. In case of female students, these differences were only significant for exam 1 and exam 2 mean scores.

Further analysis reveals that females showed relatively higher mean differences in exam 1 and 2 scores that might be attributed to Ac_FAP compared to male students. However as defined by interaction effect of gender, these differences between male and female students were not statistically significant. Moreover, non-significant mean differences associated with Ac_FAP for females might be attributed to smaller sample size which is further divided into smaller subgroups based on Ac_FAP levels.

Table 4.15b: Mean differences in Exam Scores based on Ac_FAP (Gender)

			Mean Differences	
	Ac_FAP		**Female**	**Male**
Exam1	High	No	13.1*	10.0*
		Low	9.5	10.2*
		Moderate	16.0*	9.6*
Exam2	High	No	11.5*	10.2*
		Low	14.1*	9.6*
		Moderate	8.8*	8.6*
Exam3	High	No	7.3*	11.1*
		Low	3.3	7.4*
		Moderate	5.0	8.2*
Final	High	No	4.2	9.9*
		Low	5.3	7.4*
		Moderate	9.3	6.4

**Mean differences were statistically significant at $p < .05$*

Interaction Effects of Task Values on relationship between TQD-FAP and Summative Achievement

Two-way ANOVA to find statistically significant interaction effect of task values on relationship between Ac_FAP and summative achievement replicated similar results as for TQD-FAP. Similar to TQD-FAP, students showed statistically significant positive mean differences at different levels of Ac_FAP for positive task values. On the contrary, there were no statistically significant mean differences in summative achievement based on Ac_FAP for students with negative task values.

Main Effects of Task Values on relationship between Ac_FAP and Summative Achievement

Table 4.15c shows one-way ANOVA results to compare mean differences in summative achievement at different levels of Ac_FAP separately for students with positive and negative task value beliefs. Results show that students' who believed the course material to be important, useful, and interesting, showed statistically significant mean differences in summative exam achievements attributed to different levels of Ac_FAP. On the contrary, no significant mean differences in summative achievements based on Ac_FAP levels were observed for students who reported the course materials as unimportant, useless, and uninteresting (with some exceptions). However, students with moderate level of Ac_FAP participation in quizzes corresponding to exam 3 showed statistically significant mean differences in exam3 scores despite reporting course material as unimportant, useless, and uninteresting.

Highest mean differences were found between high participation and no and/or low participation groups for students with positive task value beliefs. It might be inferred that students' interest in the course material and their belief that the course material is useful and important moderate the relationship between Ac_FAP and summative exam achievement as well.

Table 4.15c: Mean differences in Exams Scores with respect to Ac_FAP and Task Value Beliefs

Exam Scores	**Comparison Groups (Ac_FAP Participation)**		**Comparison of Ac_FAP – based Mean Differences in Exam Scores and role of Task Value Beliefs**					
	Group A	**Group B**	**Important**	**Unimportant**	**Useful**	**Useless**	**Interesting**	**Uninteresting**
Exam 1	High	No	12.0*	-1.2	11.3*	0.02	11.7*	0.1
		Low	11.9*	-1.9	12.4*	-5.0	13.2*	-3.4
		Moderate	10.2*	8.4	11.4*	3.7	11.3*	5.5
Exam 2	High	No	12.3*	0.4	12.3*	-0.1	13.0*	-0.1
		Low	11.6*	2.5	10.9*	5.7	12.2*	1.4
		Moderate	7.8*	7.6	7.4*	7.2	7.1*	6.3
Exam 3	High	No	12.6*	1.9	13.3*	-1.6	14.0*	-0.9
		Low	6.6*	4.7	6.5*	5.6	6.9*	2.8
		Moderate	4.2	10.6*	4.2*	8.7*	3.7*	8.1*
Final	High	No	10.8*	-4.8	10.3*	-4.2	10.9*	-1.1
		Low	6.3*	2.5	6.7*	0.2	5.7*	6.0
		Moderate	7.7*	-3.5	6.7*	-0.9	6.8*	2.2

*Mean differences were statistically significant at $p < .05$

Interaction Effects of Prior CGPA on relationship between Ac_FAP and Summative Achievement

Analysis of interaction effect of prior CGPA of students on relationship between Ac_FAP and their summative achievement (two-way ANOVA) also replicated similar results as for TQD-FAP. Prior CGPA did not affect relationship between Ac_FAP and summative achievement.

Main Effects of Prior CGPA on relationship between Ac_FAP and Summative Achievement

One-way ANOVA results showed no statistically significant mean differences in students' achievement based on Ac_FAP within different groups of students based on prior CGPA.

Qualitative Analysis Results

Explanation of Different Trends in Formative Assessment Participation vs. Summative Achievement

Quantitative analysis (presented earlier) already determined different trends in formative assessment participation and its relationships with student's achievement on summative examinations. The analysis showed mixed trends which can be summarized as four major takeaways listed below:

Trend 1: Students with ***high*** formative assessment participation achieved ***high*** scores on summative exams.

Trend 2: Students with ***low*** formative assessment participation achieved ***low*** scores on summative examinations.

Trend 3: Students with ***high*** formative assessment participation achieved ***low*** scores on summative examinations.

Trend 4: Students with ***low*** formative assessment participation achieved ***high*** scores on summative examinations.

The first two trends are simple to conclude the findings of the research that formative assessment participation is positively correlated with students' achievement on summative examinations. However, the other two trends challenge this argument. Since quantitative analysis also found that students showed high achievement despite low or no formative assessment participation on one hand and low achievement despite high formative assessment participation on the other hand, it is worth further qualitative investigation to dig deeper into the reasons and motivations behind these differential participation and achievement trends.

The overall goal of this qualitative analysis is therefore to find and understand reasons and motivations behind students' differential formative assessment participation trends and how these reasons and motivation might play a role in relationships between formative assessment participation and students' achievement on summative examinations. Moreover, this analysis will also help to identify potential approaches and strategies that students used in formative assessment participation to explain its differential relationship with students' achievement on summative examinations.

Reasons and Motivations behind Differential Formative Assessment Participation Decisions

A major higher order theme emerged out of data collected via semi-structured qualitative interviews was at least partially dictated by *framework of achievement goal orientation (i.e., mastery, performance, and performance-avoidance goal orientations)*. It is worth mentioning here that the optional nature of formative assessments supported participation from performance-avoidance goal-oriented participants because these types of assessments are not graded, and results are not shared with anyone. This provides such students an opportunity to participate in these quizzes, assess and reflect on their learning, and use feedback to improve their learning. Results of the qualitative analysis here are presented intertwined with distinctive quotes referring to various achievement goal orientation constructs to substantiate the arguments.

Mastery goal-oriented students tend to self-assess and reflect on their learning and feedback to improve their learning. High participation students in this research indicated that formative assessments helped them self-assess their learning progress, identify learning gaps, and use the feedback and other learning resources (textbook, video lectures) to fill those gaps. For example, one participant pointed out the purpose of participation in formative assessments as;

> *"…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"*

Another respondent specifically mentioned how voluntary and optional nature of these assessments helped reduce performance-avoidance orientation and learn the concepts well without worrying about the grades as in summative exams.

> *"yes they 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."*

Similarly, another participant referred to the fact that formative assessment participation helped him self-regulate and verify their learning. Participant responded to the question of "*what was the purpose behind participating in formative assessment?"* 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 goal-oriented students, performance goal-oriented students tend to show competence assessed against pre-defined standards and hence prefer graded academic activities (e.g., high stake summative assessments, activities with extra credit rewards etc.). As indicated by one of the research participants, one reason for no or low formative assessment participation is that there are no extra credits or stakes associated with these assessments. For example, the participant responding with reason for not participating in practice quizzes justified it 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”.*

However, performance goal orientation was also found to help one participant decide to participate despite no stakes associated with formative assessments. This response came from a participant with high formative assessment participation and high exam achievement. The participant justified how formative assessment participation helped improve his summative exam grades as below:

> *“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.”*

Other reasons identified in the interview transcripts were tough schedules due to family commitments, full course loads, and/or fulltime work while studying. Yet some others mentioned relying more on video lectures, revisiting homework problems and solutions, and textbook being more helpful compared to formative assessments.

Participants, irrespective of their participation level, were asked if something could be changed about formative assessment quizzes to motivate and enhance participation in these quizzes. Responses were again directly or indirectly dictated by achievement goal orientation. Mastery oriented responses suggested providing more detailed feedback and step by step guidance to solve more difficult problems.

Performance oriented responses on the other hand emphasized associating some stakes with these assessments for final grades, aligning formative assessment problems with exam problems, and repeating some formative assessment problems on the exams to enhance participation in formative assessments.

As qualitative analysis results show, quantitative results are pre-dominantly explained by students' goal orientations. Emerging themes in the qualitative data supported by excerpts from students' responses to semi-structured interview questions clearly show that students' different decisions to participate or not to participate in formative assessment quizzes and the relationship of their participation levels with their summative achievement were driven by their differential goal-orientations. Table 4.16 below provides an overview of the mixing of the quantitative and qualitative results to provide a clear picture of how the selected research design helped in answer the research questions. First column in the table shows observed quantitative result (trend), while second and third column shows results of qualitative analysis which explain the identified quantitative results.

Table 4.16: Mixing of Quantitative and Qualitative Analysis Results

Quantitative Results	**Qualitative Explanations (Reasons, Motivations)**		
	Emerging Theme	**Reasons/motivation dictating participation**	**Example Excerpt**
High Formative Assessment Participation, **High** Summative Achievement	Mastery Goal Orientation	Self-assessment, reflection on learning, using feedback to improve learning, identifying learning gaps	*…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"*
	Reduce Performance Avoidance Orientation	Learning without being judged, use tests without worrying about grades	*"yes they 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."*
	Self-Regulation	Help self-regulate learning, verify learning, identify/address misconceptions	*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."*
	Performance Goal Orientation	Know format of questions, perform better on exam, get good grades	*"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."*

Quantitative Results	Qualitative Explanations (Reasons, Motivations)		
	Emerging Theme	**Reasons/motivation dictating participation**	**Example Excerpt**
High Formative Assessment Participation, **Low** Summative Achievement	Performance Goal Orientation	To know the answers, know the format of questions, get good grades	*"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."*
Low/No Formative Assessment Participation, **High** Summative Achievement	Mastery Goal Orientation	No detailed feedback, focus on other learning resources (videos, homework, labs, book)	*"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."*
	Performance Goal Orientation	No extra credit, not graded, lack of incentive	*"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."*

Quantitative Results	Qualitative Explanations (Reasons, Motivations)		
	Emerging Theme	**Reasons/motivation dictating participation**	**Example Excerpt**
Low/No Formative Assessment Participation**, Low** Summative Achievement	Performance Goal Orientation & Workload	No extra credit, not graded, lack of incentive, full time job, no feedback	*"they were not graded and it was hard to find time to do extra stuff."* *"with so many courses and full time job, I couldn't manage to do extra quizzes. If they had some extra credit like homework and other assignments, I would have done them"*

Strategies used in formative Assessment Participation

Students who participated in formative assessments were also asked to comment on the approaches they used to participate in formative assessments and associated feedback to achieve their learning goals. Analysis of students' responses revealed several strategies which can be associated with differential relationships between formative assessment participation and achievement on summative examinations.

Participants (both male and female) with high participation and high achievement perceived formative assessments as an extra resource to assess their learning progress, reflect on their learning, and use the feedback to revisit the relevant concepts. These participants indicated to participate in formative assessment quizzes in a more systematic way reflecting several components of self-regulation in learning. For example, one such participant mentioned.

> *"Mostly on weekends, I will watch the video lectures and complete reading topic in textbook and homework. then I will do the quiz……….if I do bad on the quiz, I will go back to relevant concepts and try to understand them. Then after I am ready, I ll do quiz again. I also note mistakes in my first attempt and try to understand them."*

This excerpt from participant's response indicates use of a good self-regulated learning strategy where the participants monitor their learning progress, evaluate and reflect on their learning. This may also better explain the positive relationship between formative assessment participation and students' achievement on summative exams.

Participants also mentioned repeating the quizzes, however the pattern of repetition was different between different participants. Some participants continued to use the quizzes during the learning process and then repeated the set of quizzes close to exams. On the other hand, some other participants attempted the quizzes repeatedly right before exams.

> *"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."*

> *"I usually attempted them close to exams… the day of exam sometimes."*

These different patterns in repeated participation might explain why number of attempts on quizzes and total quizzes done were not as strongly associated as hypothetically expected.

CHAPTER 5

DISCUSSION

Purpose of this chapter is to discuss implications to quantitative analysis results, emerging themes in qualitative analysis and the integration of the two to the research questions guiding this dissertation research. The study was guided by two major research questions answers. First research question looked for relationships among students' formative assessment participation and their achievement on summative exam scores, and investigate if their task value beliefs (i.e., importance, interest, and usefulness of course materials) moderate or mediate these relationships. Second research question specifically aimed at qualitative investigation to explain different trends and relationships identified in quantitative strand of the study.

Although optional online formative assessments as an additional help and assessment resource with no bearing on final grades come with a natural advantage of allowing to adequately deduce on students' natural choice of participation, generalizability of findings might be limited by specific teaching and learning contexts. Therefore, it is necessary to start the discussion with clarifying the limitations of the study and hence the specific context where the implications might be valid, and the study outcomes be generalized.

The first limitation of the study design is the lack of randomization in the sample under study and that there was no intentional assignment of participants into control and intervention groups that could help identify and control for confounding variables like differences in study strategies, preferred learning styles, motivations, and learning resource usage. Such confounding factors when included in the study might help partly explain participants' reasons for participation in the formative assessments more clearly. Thus, control of confounding variables and other personal information was sacrificed when refraining from explicit experimental setting for this study.

Secondly, there were no incentives (extra credits, weights in final grading) offered for students to participate to justify a pure natural and volunteer participation in these assessments. The researcher believed that any controlled conditions would hurt the findings and implications of the study in an actual course to deduce about individuals who voluntarily participate in these quizzes. Moreover, any incentives associated with these assessments will contaminate their formative nature and hence their definitional validity to be no stake assessments.

Randomized assignment and incentivized participation within large enrolment courses advances concerns of differential didactic setups among students and is susceptible to spillover effects of the intended intervention. Lastly, the more natural design in terms of completely optional offer to participate in formative assessments also tends to compromise the internal validity of relationships between formative assessment participation and summative achievement. Differential learning opportunities offered to control and experimental groups and attitudinal factors may partly explain the correlations between students' formative assessment participation and their learning achievement and may be considered in future experimental studies.

Relationships between Formative Assessment Participation, Summative Achievement, and Task Value Beliefs

A sample size of 978 participants for this study included 160 (16.4%) females and 818 (83.6%) males which is close in representation to National Science Board (2018) statistics. National Science Board reported an average enrollment of 20% women in undergraduate engineering programs between 2010 and 2018. Although the portion of females (i.e., 16.4% or 160) in the sample closely represents national average, however, further distribution of this sample size into comparison-groups results in considerably small samples compared to males. For example, out of 160 female students, 98 (61%) students participated in one or more formative assessment quizzes and 62 (39%) did not participate in any quizzes (see Table 4.4c). However, further breakdown of the female participant group based on participation levels shows that there were only 13 (8%) female students in low participation group, and 15 female students in moderate participation group. The group sizes of low and moderate participation groups within females are not only considerably smaller compared to male groups, but they are also smaller compared to high and no-participation groups within female sample itself. The smaller sized comparison groups within female participants and higher differences between male and female groups for comparative analysis might impact the significance of the results (Peto et al. 1976, p. 593, Lindley & Scott 1984, p. 3) in the context of this study.

Overall results of voluntary participation in formative assessment are encouraging considering the fact that the assessments were completely optional, and no rewards were associated with them. As can be seen in Table 4.2, overall participation in every set of formative assessment quizzes averaged to between a minimum of 48.3% for exam 3 and a maximum of 55.5% for final exam. Similarly, cumulative participation for all sets of formative assessments averaged for each semester ranged from a minimum of 38.5% for spring 2021 and a maximum of 64.1% for fall 2020. Similarly, quiz-wise participation also showed similar trends with each quiz having a participation from almost 50% of the students (Table 4.3 a, b, c, & d). Prior studies (Kibble, 2007, 2011) have shown similar participation trends (50% - 60%) when no rewards were associated with formative assessments. Kibble (2011) further added that adding extra credit rewards increased students' participation in formative assessments in subsequent studies, however it also caused a dissociation between formative assessment participation and achievement on summative exams, and the dissociation increased as the rewards were increased. Therefore, the researcher believes that in the light of Kibble (2011) findings, with existing participation being completely voluntary, the further analysis results will be free from dissociation effects of rewards.

Gender-based comparative analysis of formative assessment participation shows that female students on average participated more than male students. The differences were reflected both in terms of participant vs. non-participant comparison, but also in categories based on participation levels. As shown in Table 4.4c, students who had at least some participation in formative assessments (TQD) comprised between 61% - 67% females, and 47% - 52% males. Similarly, high and moderate participation groups had more females than males and low participation groups had more males than females. Similar trends appear in achievement-based formative assessment participation (Ac_FAP) as shown in Table 4.5c. Analysis of mean differences in total quizzes done

(TQD) based formative assessment participation also showed higher participation among females in terms of mean TQD compared to males. However, the only difference that was statistically significant was for TQD before final exam. These findings contradict with some empirical research findings (Hoskins & Van Hoof, 2005; Angus & Watson, 2009) that gender has no significance and does not play any part in differential participation of individuals in optional online quizzes. However, Forster, Weiser, and Maur (2018) found statistically significant gender based mean differences in optional online formative assessments with an effect size Cohen's d of 0.27. Their findings provide empirical evidence of gender differences with females showing higher participation in optional formative assessments compared to males. Similarly, other studies in STEM education also found that female students put in extra time and effort to complete bonus exercises (Fischer, Schult, & Hell, 2013; Macher, Paechter, Papousek, & Ruggeri, 2012; Ramirez et al., 2012, Tempelaar, Schim van der Loeff, Gijselaers, & Nijhuis, 2011, as cited in Forser, Weiser, & Maur, 2018). Although research findings are not clearly decisive about the reasons for differences in formative assessment participation based on gender, the differences might be partially attributed to lower self-concept and higher anxiety among female students in traditionally masculine STEM education (OECD, 2015; Chiesi & Primi, 2010; Forser & Maur, 2015), which pushes them to use supplemental help resources more than male students.

Analysis of students' task value beliefs (see Table 4.8) showed overall higher tendencies among students to value the course materials in terms of importance (78.4%), usefulness (79.6%), and interest (73.3%). In terms of gender differences, more females (79.4%) than males (78.2%) perceived the course materials to be important. Similarly, more females (81.3%) considered course material to be useful compared to males (79.2%). However, in case of interest, more males (73.7%) reported the course materials to be interesting than females (71.3%). These findings support the notion that students' task value beliefs are expected to influence students' willingness to invest more efforts in formative assessment participation (Timmers, Braber-Van Den Broek, & Van Den Berg, 2013), because gender-based differences in formative assessment participation discussed earlier already indicated more female participation in formative assessments compared to males.

Students' overall achievement scores on summative exams were found to be skewed towards higher achievement. Analysis of gender differences in summative achievement showed mixed results with males outperforming female students in midterm exam 1 and 2, while females achieving higher exam scores compared to males in midterm exam 3 and final examination. Although the only mean difference that is statistically significant is for midterm exam 1, however, the insignificant mean differences in summative achievement favoring female students might be attributed to smaller sample size as discussed earlier. When students' achievement on summative exams was analyzed based on task value beliefs, it was found that positive task value beliefs always favored higher summative achievement (see Tables 4.9 b, c, & d). For example, students who considered course materials as important, useful and/or interesting always performed better than those who reported the materials to be unimportant, useless, and/or uninteresting to them. All the differences in mean achievements based on task value beliefs were statistically significant except for midterm exam 3. These results support already established research findings (Lawanto et al., 2014; Pintrich, 1999; Yoon et al., 1996) of positive relationships between students' task value beliefs and their academic performance (summative achievement in this case). This relationship might be justified by association between task value beliefs and students' self-regulated learning behaviors (Lawanto et al., 2014; Metallidou & Vlachou, 2010; Pintrich, 2000, 2003). Lawanto et al. (2014) explained that students with high task value beliefs are more self-regulated learners with skills in effective goal setting, task strategies, help-seeking, and self-evaluation. It might be safe to conclude that students with high task value beliefs put effort and time in using formative assessments as an extra help resource to self-evaluate their learning to achieve their set learning goals.

An extensive analysis of relationships between students' formative assessment participation, using different measures, and their summative exam achievement indicated that students' formative assessment participation has statistically significant positive correlations with their summative achievements. Different measures of participation included total formative quizzes done, scores on quizzes, attempts made on quizzes and total time spent on quizzes. Formative assessment participation was found to be positively associated with summative achievement irrespective of measure of participation used. However, total quizzes done and scores on formative assessment quizzes were found to be correlated with summative achievement stronger compared other measures.

These relationships were further explored by measuring mean differences in summative achievement that might be attributed to students' formative assessment participation using one-way analysis of variance (ANOVA). The results indicated that higher the difference in formative assessment participation, higher were the mean differences in students' summative achievement. Results coincide with findings from various studies (Cummings, 2020; Förster, Weiser, & Maur, 2018; O'Connell, 2015; Pick & Cole, 2021) exploring relationships between formative assessment participation and students' summative achievement. However, it is worth mentioning that participation measured as number quizzes done and scores on quizzes done corresponding to each exam had stronger associations with scores on summative exams as compared to participation in terms of number of attempts and time spent. The weak relationships using number of attempts as measure of participation might be hypothetically attributed to students making frequent attempts to know the answers rather than focusing on strategies to actually solve the problems, however further research with focus on cognitive engagement activities during participation might help explain this better.

Gender differences in summative achievement associated with differential participation in formative assessments were found to be significant only for exam 1. Mean differences in summative exam achievement based on different levels of formative assessment participation for exam 1 were much higher for females compared to mean differences for male students with different levels of participation. For midterm exam 2, 3 and final exam, male students showed statistically significant mean differences in exam scores based on levels of formative assessment participation. However, for females these differences were not statistically significant probably because of smaller sample size as discussed earlier. Findings that female participants benefited more from formative assessment participation compared to males (as in exam 1) partially contradict with prior research findings (Förster, Weiser, & Maur, 2018) that males benefit more from formative assessment participation than females. However, these differences need to be further studied with larger samples of females equitable in size as males.

Moderating role of gender, task values, and prior CGPA, in the relationship between formative assessment participation and students' summative achievement was explored by using two-way ANOVA. Two-way ANOVA results found statistically significant interaction effects of task value in this relationship. It was found that students who had positive task value beliefs (i.e., importance, interest, usefulness) about course materials showed statistically significant mean differences in their exam scores which can be attributed to their formative assessment participation. However, students who had negative task value beliefs, did not show any significant mean differences in exam scores associated with formative assessment participation. One-way ANOVA was conducted on the sample splitting based on task value beliefs to explore main effects of negative and positive task values on students' FAP and summative achievement (see Tables 4.13a, 4.14c). Irrespective of measure of formative assessment participation used, students with positive task value beliefs (importance, usefulness, and interest) showed statistically significant mean differences in summative achievement based on levels of formative assessment participation. On the other hand, students with negative task value beliefs (unimportant, useless, and uninteresting) showed no statistically significant differences (with few exceptions) in summative achievement based on no, low, moderate and high level of participation in formative assessments. Interaction effects of prior CGPA and gender were not found to be statistically significant. Which means relationship between formative assessment participation and summative achievement had no differences based on students' prior CGPA or gender. This may also encourage the researcher to hypothesize that students irrespective of gender identity and prior CGPA might equally benefit from formative assessments. Moreover, students' cumulative grade point average (CGPA) represents students' overall performance on all previously studied courses which may or may not relate to their performance on "Fundamentals of Electronics for Engineers" course. This means, students' CGPA does not necessarily represent students' level of familiarity with and understanding of concepts that may or may not help their performance on the course under consideration. Future research may consider students' performance on the courses that may conceptually relate to this course as a confounding variable.

As discussed in the light of literature earlier this moderating relationship of task value beliefs might be attributed to association between task value beliefs and students' self-regulated learning behaviors (Lawanto et al., 2014; Metallidou & Vlachou, 2010; Pintrich, 2000, 2003). Positive task value beliefs as predictors of self-regulated learner characteristics may justify the argument that these students set clear goals for learning and employ effective self-regulated task strategies to self-evaluate their learning. They put more effort and time in formative assessments to self-evaluate their learning. Moreover they seek and use feedback effectively (Timmers, Braber-Van Den Broek, & Van Den Berg, 2013) to learn and hence achieve better scores on summative examinations.

Despite positive associations between formative assessment participation and achievement on summative exams, there were instances (anomalies) where students with high formative assessment participation achieved low scores on summative exams and vice versa. To explore students' reasons and motivations behind decisions to participate or not to participate in formative assessments and its association with different relationship between participation and achievement, a qualitative investigation into these anomaly cases was conducted. As presented earlier, emerging theme explaining students' reasons for differential formative assessment participation and summative achievements were found to be partially dictated by their achievement goal orientations and strategies influenced by these orientations. Students with mastery goal orientations tended to take advantage of formative assessments as supplemental help resources to self-assess and reflect on their learning and make use of 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 expecting to familiarize themselves with format of exam questions and be able to achieve better scores on exams. While some others with similar goal orientations did not participate because it was an extra time and effort with no extra rewards (credits) that might be counted towards final grades. Yet some other students explained that they used the assessments because they could assess their learning without being noticed by someone. In that sense, these assessments provided an opportunity for 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 purposive sample, students who employed self-regulated learning strategies and used the assessments systematically in their SRL helped them achieve higher achievement scores on exams. Similarly, students who used them effectively to improve their exam scores also benefited from these assessments. However, students' who participated in these assessments merely to see the type of questions and made multiple attempts to find the correct answers without putting time to seek and use the feedback, did not benefit from these assessments despite participation. These findings are in harmony with Dijksterhuis et al. (2013) who found connections between individuals' preferences for various types of assessments and their achievement goal orientation. More specifically, Dijksternuis et al (2013) states 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.

Conclusions, Implications, and Recommendations

The researcher would like to highlight the encouraging participation levels (around 50%) across all eight semesters in completely optional online formative assessments with minimal feedback. These levels were observed despite the absence of any explicit motivation or incentives in the form of extra credit rewards. Even when categorized based on levels of participation, most of the participants were falling into higher participation categories. These trends show that at least half of the students opted to participate in these assessments as their natural choice.

This dissertation research revealed that female students showed higher participation in formative assessments compared to male students. Despite mixed research findings about gender differences in formative assessment participation (see discussion), higher formative assessment participation from female students has implications for supporting this traditionally underrepresented population to excel in STEM disciplines. As discussed earlier, researchers attribute extra efforts and higher participation in supplemental help resources among female students to a possible lower self-concept and higher anxiety in traditionally masculine STEM disciplines. Therefore, higher formative assessment participation may be more effectively used to favor females in STEM. However, it is strongly recommended that future research further investigate into gender differences in FAP and specific reasons and motivations behind these differences. A qualitative investigation into why female students participate in formative assessments, how they approach them to self-evaluate their learning and use available feedback to identify and clear misconceptions (if any) will help improve assessment design to support women particularly in engineering.

Analysis of relationships between formative assessment participation and students' summative achievement showed statistically significant correlations and mean differences in summative achievement between no, low, moderate and high participation students. All these comparisons favored formative assessment participation towards higher summative achievement. It can be safely concluded that optional online formative assessment participation has statistically significant positive association with students' summative achievement. Moreover, weaker correlations and mean differences in case of attempt-based FAP and time spent-based FAP raise questions which might need future research.

Statistically significant interaction effects of students' task value beliefs (i.e., importance, usefulness, and interest) in defining relationship between formative assessment participation and achievement on summative exams have implications for enhancing students' formative assessment participation and hence their achievement. Research findings (Soltani & Askarizadeh, 2021) suggest that students' conceptions of learning positively affect their task value beliefs. Research also shows that task value beliefs and conceptions about learning affect students to practice higher levels of self-regulated learning strategies (Soltani & Askarizadeh, 2021; Lawanto et al., 2014; Metallidou & Vlachou, 2010; Pintrich, 2000, 2003). Hence curricula planners, instructional designers, and teachers may concentrate on promoting conceptions of learning to improve students' task value beliefs which in turn can affect their self-regulation to make the most out of formative assessment participation. All these factors ultimately enhance their achievement on summative examinations. It is worth mentioning, that this research used students' task value beliefs about the course material as a whole, and not specifically related to the task (formative assessment) at hand. Future research might consider students' conceptions of learning in combination with task values specifically regarding formative assessments at hand to further establish the interaction effects.

This research found no interaction effects of gender and prior CGPA in relationship between formative assessment participation and their summative achievement. It can be concluded that formative assessment may help improve students' achievement on summative exam irrespective of gender and prior performance on other subjects. However, these findings are limited by two factors. Firstly, considerably low number of female students (16%) compared to males might limit the generalization of these outcomes based on gender. Secondly, students' prior performance (CGPA) might not be very representative of their background, prior performance, and conceptions about learning related to fundamentals of electronics. Future research might consider students prior conceptions about learning related to this course, with samples including equitable number of females to see if these findings still hold.

Very interestingly, qualitative investigation into specific cases selected based on formative assessment participation and summative achievement connected another dot in this network of relationships. Analysis of qualitative data revealed students' learning goal orientation as a major theme explaining differences in relationships between FAP and summative achievement. As discussed earlier, both mastery and performance goal orientations seem to contribute to students' effective use of formative assessment participation and hence their summative achievement. Research findings (Soltani & Askarizadeh, 2021; Wolters et al., 1996) have already established the mediating role of learning goal orientations in relationship between self-efficacy, task values and students' self-regulated learning strategies. It can be confidently concluded that interaction effects of positive task values in relationship between FAP and summative achievement can be used to the benefit of students by identifying their learning goal orientations and enhancing their conceptions about learning in the course through motivational elements in instructional materials.

Although this study did not extensively focused on specific role of minimal feedback in guiding students' learning, however, availability of minimal feedback in the form of short and quick references to related concepts used to solve given formative assessment quiz questions may not be adequate to guide students' learning. Lawanto, Minichiello, Uziak, and Febrian (2018) in an investigation into gaps in instructors' and students' task interpretation found that students' task interpretation is usually limited to explicit interpretation (explicitly given information in problem statement). Moreover, there are gaps in task interpretation (both implicit and explicit) between students and instructors. It is recommended that students must be put into practice of understanding and interpreting problem-solving tasks with focus on both implicit and explicit task interpretation both in class and then in provided feedback to get the most out of automatic feedback integrated into optional online formative assessments.

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APPENDICES

APPENDIX A: IRB - CERTIFICATE OF EXEMPTION

OFFICE OF RESEARCH
UtahStateUniversity.

Institutional Review Board

Exemption #2, #4
Certificate of Exemption

From: Melanie Domenech Rodriguez, IRB Chair

Nicole Vouvalis, IRB Director

To: ***Oenardi Lawanto***

Date: ***November 10, 2021***

Protocol #: ***12377***

Title: ***FORMATIVE ASSESSMENT IN ENGINEERING EDUCATION: EXPLORING WAYS TO ENHANCE STUDENTS' LEARNING ACHIEVEMENT***

The Institutional Review Board has determined that the above-referenced study is exempt from review under federal guidelines 45 CFR Part 46.104(d) category #2 and #4:

> *Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met: (i) The information obtained is recorded in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subject; (ii) Any disclosure of the responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation, or (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and the IRB conducts a limited IRB review to make required determinations.*
>
> *Research Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met: (i) the identifiable private information or identifiable biospecimens are publicly available; (ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not have contact with the subjects, and the investigator will not re-identify subjects; or (iii) the research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under HIPAA*.*
>
> **All HIPAA requirements must be followed in obtaining the secondary data as set out in the approved protocol (including securing either HIPAA authorization or a Waiver of HIPAA authorization).*

This exemption is valid for five years from the date of this correspondence, after which the study will be closed. If the research will extend beyond five years, it is your responsibility as the Principal Investigator to notify the IRB before the study's expiration date and submit a new application to continue the research. Research activities that continue beyond the expiration date without new certification of exempt status will be in violation of those federal guidelines which permit the exempt status.

If this project involves Non-USU personnel, they may not begin work on it (regardless of the approval status at USU) until a Reliance Agreement, External Research Agreement, or separate protocol review has been completed with the appropriate external entity. Many schools will not engage in a Reliance Agreement for Exempt protocols, so the research team must determine what the appropriate approval mechanism is for their Non-USU colleagues. As part of the IRB's quality assurance procedures, this research may be randomly selected for audit during the five-year period of exemption. If so, you will receive a request for completion of an Audit Report form during the month of the anniversary date of this certification.

435.797.1821 | 1450 Old Main Hill | Logan, UT 84322 | MAIN 155 | irb@usu.edu | FWA#00003308

Institutional Review Board

Exemption #2, #4
Certificate of Exemption

In all cases, it is your responsibility to notify the IRB prior to making any changes to the study by submitting an Amendment request. This will document whether or not the study still meets the requirements for exempt status under federal regulations.

Upon receipt of this memo, you may begin your research. If you have questions, please call the IRB office at (435) 797-1821 or email to irb@usu.edu.

The IRB wishes you success with your research.

435.797.1821 | 1450 Old Main Hill | Logan, UT 84322 | MAIN 155 | irb@usu.edu | FWA#00003308

APPENDIX B: INFORMED CONSENT FORM

OFFICE OF RESEARCH
UtahStateUniversity

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Protocol #: 12377
IRB Exemption Date: November 10, 2021
Consent Document Expires: December 31, 2022
Amendment Approved (Version 8): December 2, 2021

Informed Consent

FORMATIVE ASSESSMENT IN ENGINEERING EDUCATION: EXPLORING WAYS TO ENHANCE STUDENTS' LEARNING ACHIEVEMENT

You are invited to participate in a research study by Dr. Oenardi Lawanto, a Professor in the Engineering Education Department at Utah State University, and Assad Iqbal, a Ph.D. Candidate in the Engineering Education Department at Utah State University. As part of the study, the researcher needs your permission to access your class records (i.e., No. of practice quizzes attempted, scores on practice quizzes, No. of attempts on each practice quiz, time spent on each quiz, scores for 3 midterm and final exam, and final grad) for ENGR 2210 course. The researcher will also request that you to provide some screening information through a short (about 5 minutes) survey. Based on class records, and screener survey information you provide, selected participants may be interviewed (20 – 30 min duration).

The purpose of this research is to investigate the relationship between students' participation in completely optional, online formative assessments (practice quizzes) with minimal feedback and their learning achievement (i.e., summative exam scores). Interview with the selected participants will provide information about their firsthand experience of participation or reasons for not participating in practice quizzes in ENGR 2210 course.

Your participation in this study is voluntary and you may withdraw your participation at any time for any reason. Your participation in this study will help enhance formative assessment practices in engineering education and improve the instructional design.

This is a minimal risk research study. The risks associated with participation in this study are no more likely or serious than those you encounter in everyday activities. The foreseeable risks or discomforts include loss of confidentiality. However the researchers guarantee to keep your responses confidential. To minimize the risks and discomforts regarding confidentiality, the researchers will keep the transcriptions of the interviews at the minimum length needed. Transcriptions will be phrased clearly and should not take a lot of time. Names in the interview transcripts data and class records will be replaced with unidentifiable alphanumeric codes and the recordings will be deleted immediately after the transcription process.

We will make every effort to ensure that the information you provided remains confidential. We will not reveal your identity in any publications, presentations, or reports resulting from this research study.

We will access your class records via Canvas and collect your information through recorded interviews and a screener survey. The researcher will collect the following class records via Canvas: number of practice quizzes attempted, scores on practice quizzes, number of attempts on each practice quiz, time spent on each quiz, scores for 3 midterm and final exam, and final grade or ENGR 2210 course. Online activities always carry a risk of a data breach, but we will use systems and processes that minimize breach opportunities. This data and screener survey information will be securely stored in a restricted-access folder on Box.com, an encrypted, cloud-based storage system and on a password-protected computer owned by Utah State University that only the researchers are allowed to access.

If selected for the interview part of the study, you will be offered an incentive of $25 Visa gift card.
You can decline to participate in any part of this study for any reason and can end your participation at any time.

If you have any questions about this study, you can contact Dr. Oenardi Lawanto at olawanto@usu.edu or Assad Iqbal at 435-754-8140 and assad.iqbal@usu.edu

Thank you again for your time and consideration. If you have any concerns about this study, please contact Utah State University's Human Research Protection Office at (435) 797-0567 or irb@usu.edu.

Department of Engineering Education | www.engineering.usu.edu | 4160 Old Main Hill | Logan, UT 84322

Office of Research
Utah State University

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Protocol #: 12377
IRB Exemption Date: November 10, 2021
Consent Document Expires: December 31, 2022
Amendment Approved (Version 8): December 2, 2021

By signing below, you agree that you are 18 years of age or older, and wish to participate in this study. You indicate that you understand the risks and benefits of participation, and that you know what you will be asked to do. You also agree that you have asked any questions you had and are clear on how to stop your participation in the study if you choose to do so. Please be sure to retain a copy of this form for your records.

______________________	______________________	__________
Participant's Signature	Participant's Name, Printed	Date

Department of Engineering Education | www.engineering.usu.edu | 4160 Old Main Hill | Logan, UT 84322

APPENDIX C: SCREENING SURVEY

General Demographics

1. **What is your age?**

- Under 18 years
- 18 – 20 years
- 21 – 24 years
- 25 – 29 years
- 30 – 39 years
- 40 – 49 years
- 50 – 64 years
- 65+ years

2. **What is your gender?**

- Male
- Female
- Others:
- Prefer not to disclose

3. **Your major or intended major as of today (Check one);**

- Computer Engineering
- Computer Science
- Electronic Engineering
- Aerospace Engineering
- Electrical & Aerospace Engineering
- Bioengineering
- Mechanical Engineering
- Civil Engineering
- Environmental Engineering
- Undecided
- Other (s):

4. Ethnicity (Please choose all that apply)

- Asian
- Black or African American
- Hispanic or Latinx
- Native American or Alaska Native
- Native Hawaiian or Other Pacific Islander
- White
- More than one race
- Other

5. My Academic Status is:

- Freshman
- Sophomore
- Junior
- Senior

<u>1st Generation Status</u>

6. Did your parents complete a degree from a 4-year college or university?

- Yes (One of them)
- Yes (Both of them)
- No

<u>Traditional – Non-traditional</u>

7. Did you enroll in college within 12 months of graduating from high school or earning high school equivalent certification?

- Yes
- No

8. What is the highest academic credential you have earned thus far?

- None
- High school diploma
- GED
- Vocational/technical associate degree
- Bachelor's degree
- Master's/doctoral/professional degree

9. Are you a single parent?

- Yes
- No

10. Have you received or are you currently eligible for financial assistance?

- Yes
- No
- I don't know

11. Do you have dependents other than spouse?

- Yes
- No

12. What is your current enrollment status?

- Full Time
- Part Time

13. Are you employed full time working 35 hours or more per week?

- Yes
- No

APPENDIX D: SEMI-STRUCTURED INTERVIEW PROTOCOL

Pre-Interview

- Contact participant to remind them of the interview time, and share the link to video conference (online meeting) or location of interview.
- Make sure audio-recording is working.
- Print out interview notes template and interview protocol.
- Arrive at interview location or join the video conference (online meeting) at least 10 minutes prior to scheduled time to set up interview space.

At the Time of Interview

[Participant enters the room or joins the online meeting]

[*Interviewer greets participant and engages in friendly conversation*.]

Interviewer: Do you have any questions about the study? Or would you like me to explain what is happening today?

[*Interviewer briefly outlines the interview protocol in various levels of detail based on the uncertainty of the participant's response*.]

Interviewer: Thank you for deciding to participate in this study. I appreciate you helping me with this research. If you could please complete the demographic survey before we begin. At any point during the interview you can decide not to answer a question. Let me know when you would like to skip a question. Also, please let me know if you need clarification on any of the questions?

[*Participant completes the following demographic survey. Researcher starts audio-recording contingent on response*.]

Demographic Information

Name: ____

Gender:____

Engineering Major:____

Ethnicity/Race: ____

Parents' Education:____

Current CGPA: ____

Non-Traditional Status: ____

Working (part/fulltime):____

Before we begin, I would like to remind you to please consider your responses in the context of the course, Fundamentals of Electronics for Engineers (ENGR 2210) that you recently studied (or currently studying).

1. What resources were available to you to help in learning the course concepts in ENGR 2210?
2. Which resources do you think were most helpful in learning the course concepts?
3. (if not mentioned earlier) – Do you know that there practice quizzes available to you in the course canvas? (Yes, Continue to Section A) (No, Jump to section B)

SECTION A

4. Did you participate in formative assessments (practice quizzes) in ENGR 2210?

   (Yes – Continue Section A – 1, No – Jump to Section A – 2)

SECTION A – 1

5. How often did you participate in practice quizzes?
6. When did you participate in the practice quizzes? (prior to exam, after exam, close to exam)
7. How much time did you spend on each practice quiz, each question?
8. What did you do if you scored low on the practice quizzes?
9. Was there any feedback available in practice quizzes?
10. How effective was that feedback in helping you solve the quizzes?
11. What was the purpose/goal in your mind when participating in the practice quizzes?
12. How did you use practice quizzes to achieve your learning goals?
13. Did the practice quizzes help you achieve that goal?
14. If Yes, How did practice quizzes help you achieve your goal? (if answer yes to question ix)

15. What in your opinion could be changed about practice quizzes to make them more effective in helping you achieve your learning goals?
16. What in your opinion could be changed about practice quizzes to enhance your motivation to participate in practice quizzes?

SECTION A – 2

17. What were the reasons you did not participate in practice quizzes? Explain
18. What in your opinion could be changed about practice quizzes to enhance your motivation to participate in practice quizzes?

SECTION B

19. If you were aware of the practice quiz resources, would you participate?
20. What in your opinion can motivate you to participate in practice quizzes?
21. What could have been done to make you aware about practice quizzes and other help resources in course canvas?

NOTE: Responses to the above questions may lead to follow up questions necessary to understand students' experiences completely and may provide valuable insights into the issue under study. Follow up questions may be asked as they emerge during the course of interview. However, all the questions will only be related to the topic under investigation with no privacy information. Also the interviewees will have a choice to skip any questions they don't want to answer at any stage of the interview

APPENDIX - E: CURRICULUM VITAE – ASSAD IQBAL

ASSAD IQBAL

735 E, 800 N, 1, Logan, Utah, 84321 | assad.iqbal@usu.edu | (435) 754 – 8140

PROFILE

- ✓ ***Extensive CE, EE, and CS teaching experience (13 years) in multi-cultural, multi-national contexts***
- ✓ Employed research-informed, continuous improvement instructional-interventions through integration of formative/summative assessment and feedback into instructional design
- ✓ Hands-on experience designing and developing research-informed curriculum and instruction incorporating information/educational technologies
- ✓ Extensive work experience developing and delivering face-to-face, online, and hybrid courses using CANVAS
- ✓ Extensive experience designing and developing online/offline resources to facilitate students' learning
- ✓ Mentoring and career advising experience with Undergraduate engineering students and teaching assistants
- ✓ Supervised undergraduate electrical, computer, and information system engineering capstone projects
- ✓ ***Hands-on experience designing/conducting quantitative, qualitative, and mixed-methods research studies***
- ✓ Hands on experience in qualitative and quantitative data collection, analysis, and reporting/scholarly writing
- ✓ Hands-on experience with SPSS, SPSS-AMOS, R, Python, MAXQDA, Excel for data analysis & management

EDUCATION

PhD in Engineering Education (expected graduation: July 2022) 2019 – Present
UTAH STATE UNIVERSITY, ENGINEERING EDUCATION DEPARTMENT

MS in Engineering Management 2010 – 2011

UNIVERSITY OF ENGINEERING & TECHNOLOGY, TAXILA PAKISTAN

Postgraduate Diploma in Professional Project Management 2010 – 2010

CENTER FOR ADVANCED STUDIES IN ENGINEERING (PDC-CASE), PAKISTAN

BS in Computer Information Systems Engineering 2000 – 2005

UNIVERSITY OF ENGINEERING & TECHNOLOGY, PESHAWAR PAKISTAN

TEACHING EXPERIENCE

ENGINEERING EDUCATION DEPARTMENT, UTAH STATE UNIVERSITY (2019 – PRESENT)

GRADUATE TEACHING ASSISTANT AND LAB COORDINATOR

Achievement & Awards:

- Named as, "*Graduate Student Teacher of the Year 2021*" for sustained excellence in teaching and learning facilitation, instructional design, and course and laboratory coordination in "*Fundamentals of Electronics for Engineers*" course for 3 consecutive years. This is a fundamental engineering course offered to all undergraduate engineering programs, enrolled by 120 – 180 students every fall & spring.

Activities & Responsibilities

- Helped develop and teach the course in traditional face-to-face, online, and hybrid formats
- Designed, developed, and facilitated synchronous/asynchronous online learning experiences during COVID-19
- Designed, developed and delivered simulation-based online laboratory experiences
- Trained/mentored/coached 5-6 undergraduate teaching assistants to facilitate students in the laboratory
- Trained/mentored/coached 5-6 undergraduate teaching assistants in conducting and facilitating online labs
- Analyzed students' and course canvas analytics for continuous instructional improvement
- Helped course facilitator in design of instruction and curriculum for semi-flipped classroom

BAHRIA UNIVERSITY ISLAMABAD, PAKISTAN (2008 – 2018)

ASSISTANT PROFESSOR, FACULTY OF ENGINEERING AND APPLIED SCIENCES

Achievement & Awards:

- Progressed from Lab Engineer to Assistant Professor based on performance over 10 years
- Named as "Best Teacher of the Year 2014" at the Department of Computer Science
- Named "Best Project Mentor of the Year 2017" at Department of Electrical Engineering supervising Electrical Engineering students' capstone design Project
- Students' capstone design project paper accepted/presented in 2017 IEEE Global Humanitarian Technology Conference (IEEE-GHTC), San Jose, CA.

Activities & Responsibilities

- Teaching undergraduate Computer Systems and Electrical Engineering courses

- Supervising/mentoring/advising undergraduate electrical/computer engineering capstone design projects
- Grading summative assessment activities (assignments, homework, projects, quizzes)

Curriculum Development

Developed new syllabi, instructional materials, classroom and lab learning experiences, summative and formative assessments, assignments and quizzes for Introduction to *Computers & Programming*, *Digital Logic Design, Advanced Digital Design, Microcontrollers & Applications, Technical Writing & Presentation Skills, Technology Management and Technology Entrepreneurship* courses.

Mentoring & Advising

- Worked one-on-one in office hours with students struggling with learning materials
- Advised students on their course/semester/degree plans, registrations, and potential careers paths
- Advised and mentored student groups in capstone design projects and report writing
- Delivered group mentoring and advising sessions for UG students, internees and teaching assistants
- Advised and facilitated new graduate teaching/research assistants and new faculty

Course	**Majors**
Digital Logic Design	Computer & Electrical Engineering
Advanced Digital Design with Verilog	Computer & Electrical Engineering
Microcontrollers & Applications	Computer Engineering (CE)
Microprocessor & Assembly Language	Computer Engineering (CE)
Intro. to Computers & Programming	CS, Computer & Electrical Engineering
Programming I & II	Computer Engineering (CE)
Data Communication & Computer Networks	Computer Science (CS)
System Analysis & Design	Computer & Software Engineering
Fundamentals of Electrical and Electronic circuits	CS, Computer & Electrical Engineering
Computer Aided Engineering Design	Computer & Electrical Engineering
Data Analysis with Python and R	Computer Science and Engineering
Technology Management	Information Technology
Technology Entrepreneurship	Information Technology
Technical Writing & Presentation Skills	CS, Computer & Electrical Engineering

UNIVERSITY OF ENGINEERING & TECHNOLOGY PESHAWAR, PAK (SEP 2005 – FEB 2006)

TEACHING ASSISTANT

- Design, develop, deliver practical laboratory learning experiences in digital and electronic circuits
- Assess, evaluate and provide feedback on students' laboratory learning experiences
- Facilitate students' learning through simulation and practical hands-on circuits design and analysis

TEACHING INTERESTS

- Digital Logic Design, Advanced Digital Design
- Assembly Language programming, Microprocessor-based System Design, Microcontroller & Applications
- Fundamental CS, EE, CE and other Engineering and Applied Science courses
- Design & Analysis of Algorithms, Artificial Intelligence and Machine Learning
- Statistical Analysis as it applies to behavioral research data
- Enthusiastic to learn and teach new courses of interest and as required/assigned
- Developing Online, Face-to-Face, Hybrid Engineering Education instruction & curriculum
- Quantitative, Qualitative, Mixed, and Multi-Methods Educational Research Design

AWARDS AND SCHOLARSHIPS

- Received "*Graduate Student Teacher of the Year 2021"* (Engineering Education Department, Utah State University)
- Nominated for *"Outstanding PhD Scholar of the Year 2022*" (College of Engineering, Utah State University)
- Received *"Bohne Memorial Scholarship*, Utah State University 2021 ($2,500 cash award)
- Named as "Best Teacher of the Year 2015", Department of Computer Science, Bahria University, Pakistan
- Named as "Best Project Mentor of the Year 2017" Department of Electrical Engineering, Bahria Univeristy, Pakistan

RESEARCH EXPERIENCE

ENGINEERING EDUCATION DEPARTMENT, UTAH STATE UNIVERSITY (2019 – PRESENT)

PHD CANDIDATE

Doctoral Dissertation: Designed and conducted a *Sequential Explanatory Mixed-method* research study to explore and understand the relationships between students' participation in completely optional, online formative assessments with automated feedback, their achievement on summative assessments, and their task value beliefs. Outcomes include a conference paper accepted in 2022 ASEE Annual Conference [1] and a journal paper under-review for publication in Advances in Engineering Education (AEE) (Advisor: Dr. Oenardi Lawanto)

GRADUATE RESEARCH ASSISTANT

NSF AWARD # 2110769: Currently working on NSF research project to understand and explore students' self-regulation of cognition and motivation during engineering and mathematics problem-solving activities using *Sequential Explanatory Mixed-method* design under the direction advisor/PI (Dr. Oenardi Lawanto).

- Designed, developed, pilot-tested, and refined interview and think-aloud protocols for data collection
- Led think-aloud, problem-solving, and semi-structured interview sessions for project data collection
- Tailored standardized surveys on self-regulation of cognition and motivation to our research context
- Leading/mentoring a team of undergraduates in transcription, coding and analysis of think-aloud data

NSF AWARD # 1950330: Will be mentoring and coaching a woman undergraduate research assistant from Utah State University, and a woman undergraduate research assistant from University of Delaware in the inductive and deductive coding and analysis of qualitative data as part of NSF funded multi-year project *"Research Experiences for Undergraduates (REU)"* in summer 2022 (PI: Dr. Oenardi Lawanto).

NSF AWARD # 1950330 (SUMMER 2021): Worked as graduate research mentor to coach and mentor two women undergraduate research assistants (a Hispanic from California State University and an African American from North Carolina Agricultural and Technical State University) in qualitative data coding, analysis and reporting, as part of NSF funded multi-year project *"Research Experiences for Undergraduates (REU)*" in summer 2021 (PI: Dr. Oenardi Lawanto)

- Guided and facilitated students to inductively code open-ended responses from 1237 respondents to explore and understand how these respondents adapted to unplanned transition to emergency remote teaching and learning environment imposed upon them in the wake of COVID-19 pandemic.
- This training led to a paper (under review) in Journal of Technology Education (JTE)

RESEARCH ON STUDENTS' ADAPTION TO UNPLANNED TRANSITION TO ONLINE LEARNING DUE TO COVID-19

- Prepared (qualitative and quantitative mixed response survey for data collection
- Collected data from 1237 students, studying 27 different courses in 7 US universities
- Analyzed quantitative data and reported findings as scholarly publication (IJEE under-review)
- Delivered a seminar on the findings of the quantitative part of the study
- Worked with research team to code, analyze, and publish findings of qualitative data (3 papers)

NSF AWARD # 2011926: Led and facilitated online survey development, administration, participant recruitment, and data collection for the NSF funded project, *"Broadening Participation Research: Testing the Efficacy of a Culturally Responsive Intervention to Broaden participation and Improve STEM Retention at HBCUs"* (Co-PI: Dr. Oenardi Lawanto)

CENTER FOR ADVANCED STUDIES IN ENGINEERING (CASE) ISLAMABAD, PAKISTAN (2011)

GRADUATE RESEARCH ASSISTANT (PART TIME)

Assisted Dr. Irfan Anjum Manarvi in mentoring and coaching MS Engineering Management students in their research projects and scholarly publications as part of the graduate course "Problem-Solving and Decision Making in Engineering". Activities included guiding students collecting data, selection of statistical analysis techniques and tests, making data driven decisions, and reporting the results.

RESEARCH GOALS/INTERESTS

I aim to pursue a career in engineering education research and teaching. Building upon my current research and teaching experience, I aim to explore and understand the possibilities of innovative and inclusive instructional design to promote self-directed, self-regulated, life-long learning among undergraduate engineering students through an integration of formative assessments and feedback. Specific subthemes to pursue in engineering education research include mixed and multi-methods in engineering education, online and hybrid learning, impact of formative assessments and feedback on students' self-regulated, self-directed learning, engineering problem solving, engineering design thinking, curriculum design and development, professional development of engineering students, and entrepreneurial and creative mindset.

PUBLICATIONS

JOURNAL PUBLICATIONS

[1] Minichiello, A., Lawanto, O., Goodridge, W., **Iqbal, A.**, & Asghar, M. (2022). Flipping the digital switch: Affective responses of STEM undergraduates to emergency remote teaching during the COVID-19 pandemic. *Project Leadership and Society*, 100043.

[2] **Iqbal, A.**, Lawanto, O. (under review). Participation in Online Formative Assessments with Minimal Feedback and Students' Learning Achievement in a Large Fundamental Engineering Class. *Advances in Engineering Education*

[3] Lawanto, O., **Iqbal, A**., Goodridge, W., Minichiello, A, , & Asghar, M. (in press). Unexpected and Unplanned Changes resultant to a shift from Traditional Face-to-face to Online Learning: Developing an understanding about online learning features and students' feelings. Special Edition of the *International Journal of Engineering Education (IJEE)*.

[4] Lawanto, O., **Iqbal, A.**, Goodridge, W., Minichiello, A., Galindo-Guerrero, C., & Sneed, A. (submitted). Adaptation in Unplanned and Unexpected Online Learning in Post-Secondary Education. *Project Leadership and Society, Special Paper Collection on Digital Learning and Education in a Project Society.*

[5] **Iqbal, A**., & Manarvi, I. A. (2011). Teachers' attitudes and perceptions for alternative assessment techniques: a case study of Pakistani universities. *International Journal of Teaching and Case Studies*, *3*(2-4), 131-146.

[6] Begum, Z., Khan, I., & **Iqbal, A.** (2011). Socioeconomic status of the girl students and their dropout rate at primary level in FR Kohat (FATA-Pakistan). *European Journal of Social Sciences*, *20*(2), 356-384.

CONFERENCE PRESENTATIONS/PUBLICATIONS

[7] **Iqbal, A.**, & Lawanto, O. (accepted). Work in Progress: Improving Students' Learning Achievement in Large Undergraduate Engineering Classes: Taking Advantage of Online Formative Assessments with Minimal Automatic Feedback submitted to 2022 ASEE Annual Conference

[8] Lawanto, O., & Minichiello, A., & **Iqbal, A.** (2019). *Work in Progress: Understanding Student Self-regulation during Engineering Problem Solving: A Preliminary Study*. In *2019 ASEE Annual Conference & Exposition, Tampa, Florida. 10.18260/1-2--33659.*

[9] **Iqbal, A.** & Khan, M. S. (2017). Customizable Timing Control Device for Home Gas Appliances. In *Global Humanitarian Technology Conference (GHTC), 2017 IEEE*.

[10] Shah, S. H., **Iqbal, A**., & Shah, S. S. A. (2013). Remote health monitoring through an integration of wireless sensor networks, mobile phones & Cloud Computing technologies. In *Global Humanitarian Technology Conference (GHTC), 2013 IEEE* (pp. 401-405). IEEE.

[11] **Iqbal, A.**, Ali, Q., & Pirzada, D. S. (2012). Productivity measurement issues in education sector of pakistan. In *Global Humanitarian Technology Conference (GHTC), 2012 IEEE* (pp. 398-402). IEEE.

[12] Siddiqui, M. H., **Iqbal, A**., & Manarvi, I. A. (2012). Maintenance Resource Management: A key process initiative to reduce human factors in aviation maintenance. In *Aerospace Conference, 2012 IEEE* (pp. 1-7). IEEE.

[13] **Iqbal, A**., Chishti, M. E. U. H., & Nisar, A. (2011) Reengineering the Undergraduate Engineering Final Year Projects Framework through an integration of Concurrent Engineering Principles. Presented in Asian Conference on Education, Osaka Japan (2011)

BOOK CHAPTERS

[14] Hussain, M., Manarvi, I. A., & **Iqbal, A**. (2013). Defect Trend Analysis of MI-172 Helicopters through Maintenance History. In *Business Strategies and Approaches for Effective Engineering Management* (pp. 111-126). IGI Global.

[15] Rafiq, H. A., Manarvi, I. A., & **Iqbal, A**. (2013). Identification of Major FOD Contributors in Aviation Industry. In *Business Strategies and Approaches for Effective Engineering Management* (pp. 237-250). IGI Global.

[16] Qazi, M. A., Manarvi, I., & **Iqbal, A**. (2013). Component Failure Analysis of J69-T-25A Engine. In *Business Strategies and Approaches for Effective Engineering Management* (pp. 128-141). IGI Global.

PROFESSIONAL MEMBERSHIPS, ACADEMIC SERVICES, LEADERSHIP/OUTREACH

Journal/conference Reviewer

- IEEE Transactions on Education Journal
- American Society of Engineering Education (ASEE) Annual Conferences (2020, 2021, 2022)
- IEEE Global Humanitarian Technology Conference (GHTC) 2012, 2013, 2014

Professional Memberships

- Student Member of American Society of Engineering Education
- Student Member of Institute of Electrical and Electronics Engineers (IEEE)

Committees (Bahria University Pakistan)

- Member industry-academia linkage committee
- Member curriculum development and revision committee
- Member, Departmental Self-Assessment Committee
- Member, Departmental Quality Assurance Committee
- Member, Admissions’ Committee

Leadership and Outreach

- President, International Students Council, Utah State University (summer 2021 – spring 2022)
- Vice President Finance, International Student Council, Utah State University (fall 2020 – spring 2021)
- Board Member, International Friends Program, Utah State University (Spring 2021 – spring 2022)
- Executive Secretary, International Student Council, Utah State University (Spring 2020)

- Coordinator, students' career and professional development, Bahria University, Pakistan (2016-2018)
- Faculty Advisor, Students' Resource Center and clubs, Bahria University, Pakistan (2014 – 2016)

REFERENCES

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APPENDIX F: GLOSSARY OF TERMS

ACRONYM	**Description**
FAP	Formative Assessment Participation
SA	Summative Achievement
TQD	Total Quizzes done
TQD-FAP	Total Quizzes Done-based Formative Assessment Participation
Ac_FAP	Achievement-based Formative Assessment Participation
At_FAP	Attempts-based Formative Assessment Achievement
TS_FAP	Time Spent-based Formative Assessment Participation
TVs	Task Values
SD	Standard Deviation
ANOVA	Analysis of Various
AIS	Academic and Instructional Services
USU	Utah State University
IRB	Institutional Review Board
FERPA	Family Educational Rights and Privacy Act