WIP: The Impact of Formative Assessment on Students' Attitude, Anticipated Academic Performance, and Design Skills: Insights from Three Design-Oriented Electrical Engineering Courses

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Abstract:

In teaching and learning, assessment plays a crucial role for both educators and students. It serves as a fundamental tool used to provide learners with essential feedback for adapting and enhancing their ongoing learning processes. Simultaneously, it enables instructors to make necessary adjustments in their teaching methods to align with their predefined educational objectives. Formative assessment is a term that describes the regular assessment of students' progress and comprehension. Its purpose is to identify the specific needs of students and make adjustments in teaching methods accordingly. In essence, formative assessment is designed to offer feedback that enhances the learning experience, while summative assessment is primarily focused on measuring the extent of learning achieved. In this study, we aim to examine the effects of formative assessment practices on students' attitude toward learning, grade achievement and design skills from three design-based courses offered at different levels of the electrical engineering curriculum.

The study involved participants who were students enrolled in various levels of Electrical and Computer Engineering courses: junior level (Electronics, and Computer Architecture and Design), and senior level (Medical Instrumentation: Application and Design). Each of these courses spanned a duration of 14 weeks and was divided into three to four distinct modules, with each module taking 3-5 weeks to complete. Notably, nearly half of these modules underwent weekly formative assessment practices. Following the completion of each module, students were requested to complete self-assessed learning skill assessments, observation forms, and participated in several semi-structured interviews. In the context of this study, the responses obtained from students in modules that did not include formative assessments were used as a point of reference, akin to responses from a control group.

Preliminary analysis of data from modules incorporating formative assessments, as opposed to those without them, reveals favorable outcomes associated with the utilization of formative assessments in terms of students' learning, academic performance, and design skills. It is worth noting that students exhibit a preference for specific formative assessment methods in distinct modules. This variation underscores the importance of tailoring the choice of formative assessments to the specific course content. Formative assessments offer educators the valuable ability to deliver continuous feedback to their students. This engagement makes students an integral part of the learning process and enhances their self-assessment skills, ultimately aiding in their comprehension of their own cognitive processes. As a result, we strongly encourage instructors to incorporate formative assessments into their teaching methodologies to assist students in honing their skills in the realm of system design.

Introduction

In the realm of education, assessment plays a pivotal role, serving as a fundamental tool employed by both educators and students. It functions as a means to provide essential feedback that guides the ongoing learning process, enabling instructors to tailor their teaching methods to achieve the planned educational objectives [1] - [5]. Formative assessment, a concept central to

this study, entails the frequent evaluation of students' development and comprehension, with the primary aim of identifying their specific needs and adjusting instructional strategies accordingly [1], [6].

Traditionally, assessments are often perceived as tools for measuring learning outcomes, conducted at the culmination of lessons or units. However, their potential as teaching instruments often remains underutilized, as educators can leverage assessments to diagnose student misconceptions and bridge learning gaps through meaningful feedback [7]. The study by Black and colleagues [8] underscores the importance of employing formative tests for their intended purpose, enhancing classroom practices by encouraging students to engage with course content actively and reflectively. In essence, formative assessment is fundamentally concerned with nurturing students' learning and development [9], rendering it a vital component in the fusion of assessment and teaching [3], [10].

Brown [11] describes the formative assessment as the evaluation of learners in the process of "forming" their skills and competencies, facilitating their continuous growth. It encompasses all activities conducted by instructors and learners alike, supplying information that can be harnessed as feedback to refine ongoing learning and teaching practices [12]. Importantly, this definition underscores the active involvement of both students and teachers, making formative assessment an integral component for enhancing students' performance.

Assessment for learning, predicated on its underlying purpose, centers on tracking learners' progress [13]. Its essence lies in the collection of data pertaining to learners' achievements, allowing for the identification of strengths and weaknesses in skills, requirements, and capabilities before, during, and after educational courses. Ultimately, the goal is to foster the improvement of students' learning and academic achievements [14], [15]. Regular feedback and recognition of progress can motivate students to stay engaged and take ownership of their learning.

Students’ attitudes toward learning encompass both positive and negative dimensions [4]. Positive attitudes have the potential to enhance learning experiences, while negative attitudes can serve as impediments, often arising from learning difficulties or perceived boredom with course content [16]. This research aims to explore the effects of incorporating formative assessments within three electrical engineering design-based courses on students’ attitudes towards learning, anticipated academic achievement, and the development of design skills. From this point of view, it is expected that this study will contribute to the related literature. The sub-problems that have been identified for this purpose are presented below:

(i) Is there a significant difference between modules with and without formative assessment techniques towards students’ self-assessed/perceived attitude towards learning experiences and anticipated academic achievement after the practices?

(ii) Is there a significant difference between modules with and without formative assessment techniques towards students’ development of design-skills after the practices?

(iii) What are the overall views of students on formative assessment practices and their relative influences in design-based courses in electrical engineering field?

Methodology

Participants are students enrolled in Electrical and Computer Engineering junior and senior-level courses (ECEN 325: Electronics, ECEN 350: Computer Architecture and Design, ECEN 489: special topic in Medical Instrumentation: Application and Design). The course which spans 14 weeks is divided into three/four distinct modules, and each module takes 3-5 weeks to complete. Notably, nearly half of these modules underwent weekly formative assessment practices. Following the completion of each module, students were requested to complete self-assessed learning skill assessments, observation forms, and participated in several semi-structured interviews. In the context of this study, the responses obtained from students in modules that did not include formative assessments were used as a point of reference, i.e., a control group.

Out of three/four modules, at least two modules underwent extensive formative assessment practices such as active class activities in group, class quizzes and polls, homework assignments, lab activities, peer assessment. When students are required to write reports or design circuits, instructors provide formative feedback on early drafts to help students improve their understanding of the subject matter. Also, a software tool and relevant simulations specific to medical instrumentation or electronics circuit design were used for formative assessment. Students can interact with virtual circuits or design simulations to practice and receive feedback. For the remaining modules, no/minimal formative assessment practices were applied.

The research was conducted in the junior and senior year electrical engineering classes over two semesters (and ongoing). The same instructor lectured in all the courses. There was a good overlap among the students taking the junior level courses (ECEN 325 and 350), whereas a completely different cohort of students took the senior-level course (ECEN 489). Lessons that include formative assessment practices conducted within the scope of the learning-teaching process in the current program. To get students accustomed to the formative assessment techniques, the following strategy had been adopted: explaining learning objectives and success criteria, increasing the quality of inquiry/dialogue, increasing the quality of marking/ feedback/recordkeeping, and using self and peer assessment.

After each module, students were asked to fill out self-assessed learning skill scales and some observation forms. The survey contains ~10 questions related to different aspect of students' performances: attitude toward learning, anticipated academic achievement, and design skills. Also, the survey questions were adapted according to the learning outcome of the relevant modules. Likert scale was utilized in the questionnaire to show the amount of disagreement and agreement from 1 to 5 that were highly disagree, disagree, no idea/neutral, agree, and highly agree. The observation form was developed to support the data obtained from the quantitative method and open-ended questions to qualitatively examine the effects of formative assessment practices on students' attitudes toward the class, anticipated academic achievement, and design skills. The observation form was also used to monitor whether the experimental procedures progressed in accordance with formative assessment principles and characteristics.

At the end of each module, a formal quiz/exam was conducted and graded after the survey to relate the findings (triangulation) with their counterparts before the survey. These data will also be used to identify the learning deficits of the students so that lessons could be adjusted in future. The graded exam/quizzes were distributed to the students and feedback was given to them about their deficiencies for each module.

Data analysis

After data collection, some statistical steps were taken to provide answers to the questions raised in this study. In the quantitative data analysis, it was examined whether the data obtained corresponded with the assumptions of parametric tests. First, the data were analyzed descriptively to compute the means of the groups. Second, some one-way ANOVA F-tests were used for analyzing the data inferentially. In the statistical analysis, the level of significance was accepted as 0.05. In the qualitative data analysis, a descriptive analysis approach was used, and an overall observation was made from the direct quotes.

Results and Discussions

After checking about the normality distribution of the data by using the Kolmogorov-Smirnov test, we used one-way ANOVA F-tests and reported their results in the following Tables:

The Effects of Formative Assessment Practices on Students' Attitudes toward the Lesson:

Table 1 Descriptive statistics of the modules with and without formative assessments towards student's attitude/learning experience

	N	Means	Std. deviations	Std. errors	95% C.I. for Means		Minimum	Maximum
					Lower Bound	Upper Bound		
Modules without FA	114	37.15	10.99	4.28	33.6	40.7	24	51.6
Modules with FA	114	51.13	6.51	2.55	49.54	53.24	40	60

Table 2 Inferential statistics of the modules with and without formative assessments towards student's attitude/learning experience

	Sum of Square	df	Mean Squares	F	Sig
Between Groups	6055.08	2	3027.63	29.1	0.00
Within Groups	7173.2	111	103.97		

As shown in the Table 1, the mean scores of the module with and without formative assessment are 51.13 and 37.15, respectively, on the attitude/learning experience towards electrical

engineering design-based courses. It is clear that students prefer modules with formative assessment practices over modules with no practices in these courses. In Table 2, the inferential statistics of modules with and without formative assessment practices on the attitude/learning experience are revealed. The sig value (0.00) is less than 0.05; therefore, the differences between the groups are significant. This implies that students held positive attitudes towards the effectiveness of formative assessments on their attitude toward learning experiences in electrical engineering design-based courses.

In the study, the attitudes of the students toward design-based electrical engineering classes in the experimental group where the formative assessment practices were applied were significantly higher than the ones in the control group where no formative assessment practices were applied. Similar research results were found in the literature [4]. When the effect of formative assessment practices on students' attitudes toward class is evaluated in conjunction with the results obtained from the present research and the results in the literature, formative assessment significantly improves students' attitudes toward the class. One can infer that the elements applied in formative assessment practices, including prioritizing the learning and making up of deficiencies instead of grading, teaching groups requiring sharing and cooperation instead of individual efforts, and assessing students in accordance with individual development levels instead of comparing them to each other, all help students develop positive attitudes toward class.

The Effects of Formative Assessment on Students' Anticipated Academic Achievement:

As shown in Table 3, the mean scores of the module with and without formative assessment are 146.51 and 78.12, respectively, on the anticipated academic achievement. It appears that students reported positively of achieving higher grades in the modules with formative assessment practices compared to modules with no formative assessment practices in these courses. In Table 4, the inferential statistics of modules with and without formative assessment practices are also calculated. There exists a significant difference between the modules (experimental vs. control). This implies that students are more confident to attain higher grades in modules with formative assessment practices compared to the performance in modules with no or minimal formative assessment techniques in these design-based electrical engineering courses.

Table 3 Descriptive statistics of the modules with and without formative assessments towards student's anticipated academic achievement

	N	Means	Std. deviations	Std. errors	95% C.I. for Means		Minimum	Maximum
					Lower Bound	Upper Bound		
Modules without FA	114	78.12	18.13	3.5	62.88	102.79	42	115
Modules with FA	114	146.51	26.15	4.55	135.76	152.75	49	163

Table 4 Inferential statistics of the modules with and without formative assessments towards student's anticipated academic achievement

	Sum of Square	df	Mean Squares	F	Sig
Between Groups	23339.41	2	5834.85	71.13	0.00
Within Groups	10511.23	111	82.03		

In the study, the academic achievements of the students in the experimental group where the formative assessment practices were applied were significantly higher than the ones in the control group where no formative assessment practices were applied. This result also coincides with the results of studies in the literature examining the effect of formative assessment on academic achievement. Meta-analysis of many studies has also shown that formative assessment raises standards and increases students' achievement [17] - [19]. In the present study, data from the observations forms and semi-structured interviews also support the results in the literature. Such characteristics of formative assessment as no comparison of the students, assessment of the students according to their own development levels, and prioritizing learning rather than grades have more influence, especially on students with low academic achievement, by enabling them to participate in the lesson and increase their success accordingly.

The Effects of Formative Assessment Practices on Students' Design Skills:

As reported in Table 5, the mean scores of the module with and without formative assessment are 49.50 and 29.95, respectively, on the students' development of design skills. Students prefer the modules with formative assessment practices compared to no practices for their development of design skills in these courses. In Table 6, the inferential statistics of modules with and without formative assessment practices on the development of design skills are reported. The sig value (.01) is less than 0.05; therefore, the difference in modules with and without formative assessment practices is significant.

Table 5 Descriptive statistics of the modules with and without formative assessments towards students' development of design skills

	N	Means	Std. deviations	Std. errors	95% C.I. for Means		Minimum	Maximum
					Lower Bound	Upper Bound		
Modules without FA	114	29.95	11.08	2.26	25.27	34.63	14	51
Modules with FA	114	49.50	10.37	2.11	45.11	53.88	23	62

Table 6 Inferential statistics of the modules with and without formative assessments towards students' development of design skills

	Sum of Square	df	Mean Squares	F	Sig
Between Groups	4253.17	2	2117.65	19.2	0.01
Within Groups	7566.82	111	110.29		

However, in this study, the design skills of the students in one of the three electrical engineering design-based courses for modules where the formative assessment practices were applied did not significantly differ from the ones in the control group where no formative assessment practices were applied (data not shown). This exception could be attributed to that particular course content and the relevant design requirement for that course. Although there was no statistically significant difference, it is expected that formative assessment practices increased self-regulation skills of students providing a continuous and purposeful interaction between instructor and students, which was learning effort and performance directed.

Briefly, the results indicate that experimental groups (i.e., modules with formative assessment) had better attitudes/learning experiences, higher anticipated grade achievements, and better design skills. Their higher performances are also informally (not properly analyzed yet) confirmed through tests/exams for each module that were graded by the instructor in those courses. The overall better performance of the students in modules with formative assessments compared to no formative assessment practices could be attributed to the fact that they received much more input. They were provided with different kinds of feedback and took more tests during the semester. These tests and feedback can be the reasons for their successes in grade achievement and development of design skills. This is in line with Krashen's [20] input theory stating that if students are exposed to more input, they can learn more.

Findings Related to Views on Formative Assessment Practices

To address the question related to the overall views and relative influences of different formative assessment techniques, students' views on formative assessments practices for different modules in each design-based courses and their attitudes toward instructors, class activities, group works, quizzes, self and peer assessments were collected in observation forms and semi-structured interviews. Informal analysis shows that students had overall positive attitude towards these courses when modules are covered with different formative assessment techniques. Although students mostly preferred class activities in group, they also showed inclination to a variety of formative assessment practices for different modules, which could be attributed to the contents and design requirements of the modules itself.

Limitations of this study: A few aspects of our research study limit the generalizability of our findings. First, although formative assessment increases achievement supporting the students' development of self-regulation and metacognitive skills and their development through educational standards [21], we have not explicitly designed survey to measure the metacognitive improvements over control groups. Please note that the same students underwent modules with

and without formative assessment practices, making it difficult to disentangle this long-term effect. Second, the study was based on self-report measures, which could be less reliable than non-self-reported measures [22], [23]. Nonetheless, survey-based studies are deemed credible if they are based on instruments that have been validated in the contexts in which they are used [24]. We are cautiously confident in our findings because the measurement scales used in this study had strong psychometric properties to support their reliable and valid use in this context. Third, inferences based on this data analysis are also limited by the fact that the modules are of short duration and the same students are subjected to formative or no formative assessment practices within the same course which might affect their abilities in design-skills from one module to another.

Conclusions

Preliminary analysis of data from modules incorporating formative assessments, as opposed to those without them, reveals favorable outcomes associated with the utilization of formative assessments in terms of students' learning, academic performance, and design skills. It is worth noting that students exhibit a preference for specific formative assessment methods in distinct modules. This variation underscores the importance of tailoring the choice of formative assessments to the specific course content. Formative assessments offer educators the valuable ability to deliver continuous feedback to their students. This engagement makes students an integral part of the learning process and enhances their self-assessment skills, ultimately aiding in their comprehension of their own cognitive processes. As a result, we strongly encourage instructors to incorporate formative assessments into their teaching methodologies to assist students in honing their skills in the realm of system design.

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