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The Perception of Engineering Undergraduates Towards an Active-Learning Pedagogy at a Minority Serving Institution.

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Title: *A Journey in Data Science and Risk Analysis*

Biography:

A graduate student at Morgan State University, with a background in mathematics from Mountain Top University, embarked on a remarkable journey. Fueled by a deep interest in data science, I secured an internship at KPMG as a financial risk analyst. There, I made impactful contributions by analyzing data and managing risks for clients.

My academic pursuit at Morgan State University further enriched their passion for data science. This individual's journey showcases the power of determination and dedication in the realm of data analysis, data science and risk management, inspiring others to follow their own paths to success.

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Abstract

Experimental centric pedagogy (ECP) which is an active learning approach has been reported to increase student engagement, critical thinking, peer collaboration, as well as motivation in engineering related courses. However, little is known on the perception of students about this Active Learning Pedagogy (ALP). This study aims to investigate the perception of minority serving institutions (MSI) engineering undergraduates on the use of ALP as an active agent during instruction. This study adopted a quantitative approach in a pre-post-test design. The engineering modules where experiment centric pedagogy was implemented span across industrial engineering, civil engineering, and transportation engineering. A Likert scales was employed to collect the perception of the undergraduates towards the impact of the pedagogy on the learning instrument, the learning process, and the overall learning achievements. Data was collected electronically and then collated, cleaned, and analyzed using statistical package for social scientists (SPSS v25.0). The Cronbach-alpha for the instrument was range 0.85 - 0.96. The average mean score of the perception on the instrument range from 3.84 – 3.92 among the undergraduates out of a total of 5. The use of both analogues devices and mobile devices created more positive perception among the students than the use of phone devices only. More so, the correlation result revealed that there is a strong relationship between the perception on the instrument and the overall perception of the pedagogy. The findings also underscore the importance of aligning pedagogical strategies with the diverse student populations found in MSI, promoting more inclusive and effective educational practices.

In summary, this study reinforces the value of ALP in enhancing student engagement and learning outcomes and emphasizes its adaptability and relevance in MSI engineering programs. It provides a foundation for future research and pedagogical development aimed at optimizing the benefits of active learning in diverse educational settings.

Introduction

The traditional lecture style that is used in most engineering courses has several difficulties that affect the processes of teaching and learning. Although many students can be efficiently taught a significant amount of knowledge using this method, its one-way nature encourages passive and superficial learning and does not stimulate students' motivation, confidence, or excitement. As a result, graduates of traditional lecture models frequently lack the fundamental abilities needed for success in the workplace [1], [2]. The goal of engineering education research is to pinpoint the information and abilities that aspiring engineers must gain both in the classroom and in their career.

Students' learning and engagement in a classroom environment may be enhanced by non-traditional learning approaches. The chances of increasing students' understanding of and interest in engineering subjects, thereby reducing the shortcomings of traditional educational environments [3]. When students are taught in a more stimulating and engaging approach, there are evidence that the students who struggle in traditional, standard engineering courses tend to be more interested and driven [4]. The active learning strategy therefore improves student understanding of ideas and recall of information [5].

In several academic fields, active learning has been shown to improve student learning when compared to traditional lecture-based instruction [6] ,[4]. Like the experimental-centric pedagogy (ECP), it promotes students' participation in meaningful learning by having them read, write, discuss, and actively solve problems in addition to listening in class [7] . Active learning strategies can be applied to the experimental activities utilized in the classroom to engage these learning characteristics. Since learning is ultimately a student's responsibility, it is imperative to gain understanding and the receiver’s perspective on how they see active learning as an essential strategy for learning tactics that work. Although there is evidence that ECP is an improved approached to teaching and learning than standard lectures [8], little is known about how individual students perceive their level of engagement and efficacy of the ECP.

Welsh [9] examined the differing opinions that students had about the application of active learning strategies in science courses for undergraduates. More than 250 students' written responses provided a comprehensive understanding of the reasons behind their perceptions of these strategies' benefits or drawbacks for their learning process. According to the study, third-year students and female students saw in-class active learning strategies as crucial to enhancing their comprehension and interactions with peers and professors, while fourth and fifth-year students were more likely to consider these strategies as a waste of lecture time. Self-efficacy, experience, and motivation are key constructs that active learning strategies are recognized to improve among students [10]. Social and intellectual experiences are equally important. Whether students' perceptions of active learning have a meaningful impact on the design of this learning, however, itis still up for debate. A study by Hsieh and Knudson [11] expected that students who felt their instructor performed no active learning activity in class at all would have inadequate learning compared to students who perceived more active learning during the class.

As efforts in developing frameworks and strategies for active learning in different STEM fields, it is imperative to incorporate the voices of the receivers of the pedagogy The purpose of this study was to ascertain how engineering students that have been taught using an active learning pedagogy called the experiment-centric pedagogy perceived the approach. This study was also intended to contribute to the body of knowledge on the perspectives of historically black college and university engineering learning.

Theoretical Framework

To examine how participation in an active learning environment influences students' perceptions of learning, this study adopted the situated learning theory. Situated learning and related theoretical perspectives have been utilized in investigating the connection between active learning and STEM education [12]. Situated learning has been used to study learning and attitudes towards science from the learners or novice perspective [13].

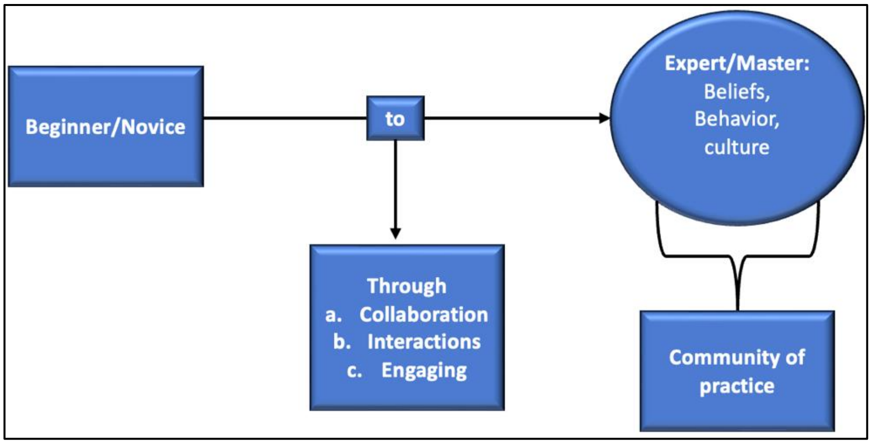

Figure 1: Model of situated learning showing legitimate peripheral participation as newcomers become experienced members [14].

The learning that that occurs arises from legitimate peripheral participation in authentic activity [15]. Through opportunities to acquire and apply knowledge and practice skills, learners develop deeper understandings from meaningful context in which those opportunities exist [15], [16]. Active learning promotes access and opportunities to participate in learning, and therefore influences perceptions. Employing a situative perspective in this study provides a context for broadening understanding of how authentic experiences and participation in an active learning environment can transform students' perceptions towards learning.

Methodology

This quantitative descriptive study was carried out in one of the nations' historically black colleges and universities after the use of experimental centric pedagogy (ECP). The self-developed quantitative instrument consisted of three subscales which are 4-point Likert scale, designed to measure students' perceptions of the impact of experimental-centric pedagogy on various aspects of their learning. The scale ranged from strongly disagree to strongly agree with numerical values assigned to each response (1-5). The 19 items in the questionnaire were strategically formulated to assess the students' perceptions of the experimental centric pedagogy in terms of its impact (i) of the learning instrument; (ii) on the learning process, and (iii) on the overall learning achievements.

The data collected, spanned from the academic terms from spring 2021 to fall 2023. The participants include 269 engineering undergraduate's students from industrial engineering, civil engineering, and transportation engineering departments, all of whom were exposed to the experimental centric pedagogy. These students were enrolled in various courses and were expected to have used phone devices, analog or digital devices in their studies, such as the M1K and Arduino, or both. The description of the experiments and impact on motivation have been published by authors [8], [7].

To analyze the collected data, this study employed the statistical package for social scientist (SPSS v25.0). The data was first collated and cleaned to ensure accuracy and reliability test was done using random 10% of the data. The reliability result showed Cronbach alpha of range 0.85-0.95. The students' perceptions across the three engineering disciplines were investigated and results were presented together. Overall perception scores were found for each subscale. Using the analysis of variance (ANOVA), the differences in the perception scores of the students by gender and academic level was found at confidence interval of 95.0%. The Turkey post-hoc test was conducted to understand the significant differences. Results were presented using bar charts, frequency, and simple percentages.

Results

The result presented in Figure 1 showed that 79.9% of learners have heard of analogue devices as tool for learning. However, 64.7% of learners have used analogue devices during the implementation. The result also showed that 50.2% of the learners have used phone apps as a hands-on device during the implementation of this module. The diagram shows that a higher percentage of students have heard of analog devices than have seen them. This also shows that many students are using analog devices without realizing it.

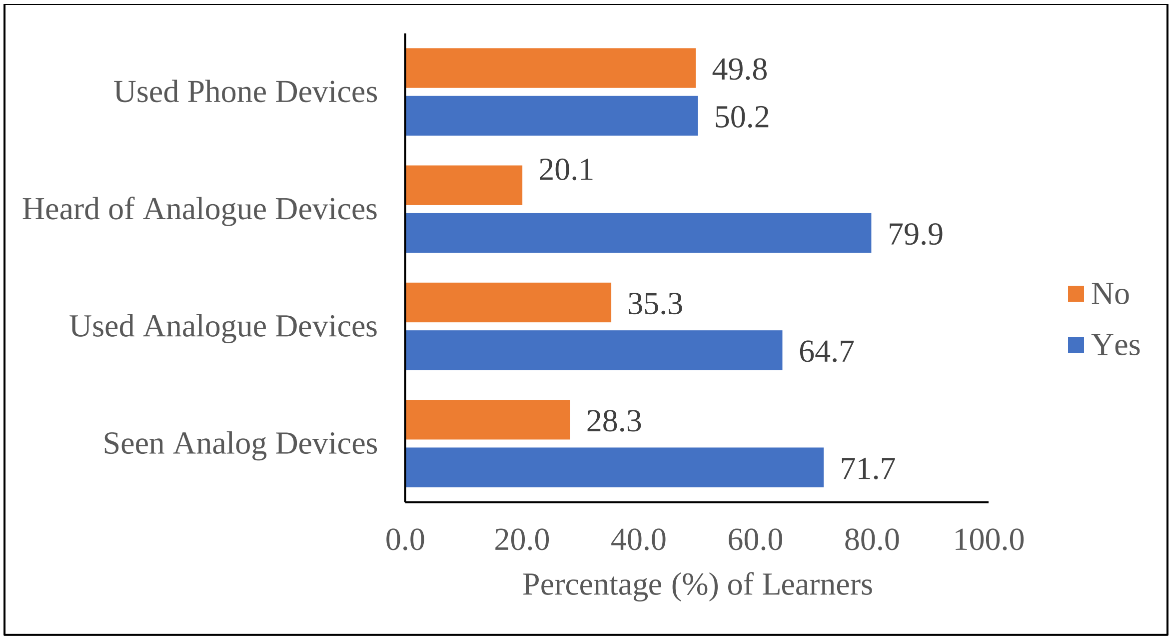

Figure 2: Student that have used phone devices, heard of Analogue devices, used analogue devices, and have seen analogue devices.

The provided pie chart illustrates data regarding the utilization of various tools for the aim of active learning. The data reveals that 32% of students utilize both analogue and phone apps, 18% exclusively rely on phone apps, 33% solely use analogue methods, and 17% do not employ either. Hence, their responses were ultimately excluded from the subsequent study (previously = 269, currently = 224).

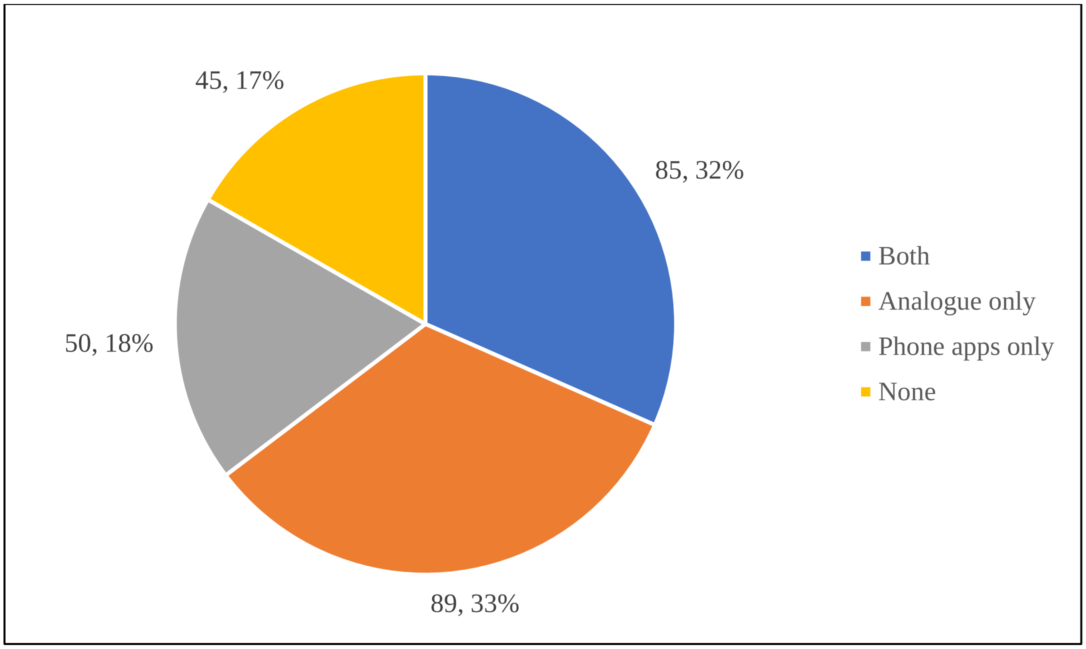

Figure 3: Student with either both device (digital or analogue) or heard of both devices.

The graph depicted above illustrates the frequencies of responses for six different perception items, labeled as P1 to P6 in Figure 4. Based on the example, 36% of students agree with P1, whereas 37% of students agree with P2, demonstrating its connection to their material. In addition, 36% of students consider P3 to be pertinent to their academic field. P4 provides evidence that the instrument is in accordance with real-world application for a total of 37% of students. P5 shows the highest frequency, with 37% of students, which represents the majority, believe that the allocated time for the instrument is adequate. Lastly, P6 signifies that the instrument corresponds to the educational objectives of 35% of students. 28% of students strongly agree with P1, 23% with P2, 21.2% with P3, 23.4% with P4, 21% with P5, and 21% with P6.

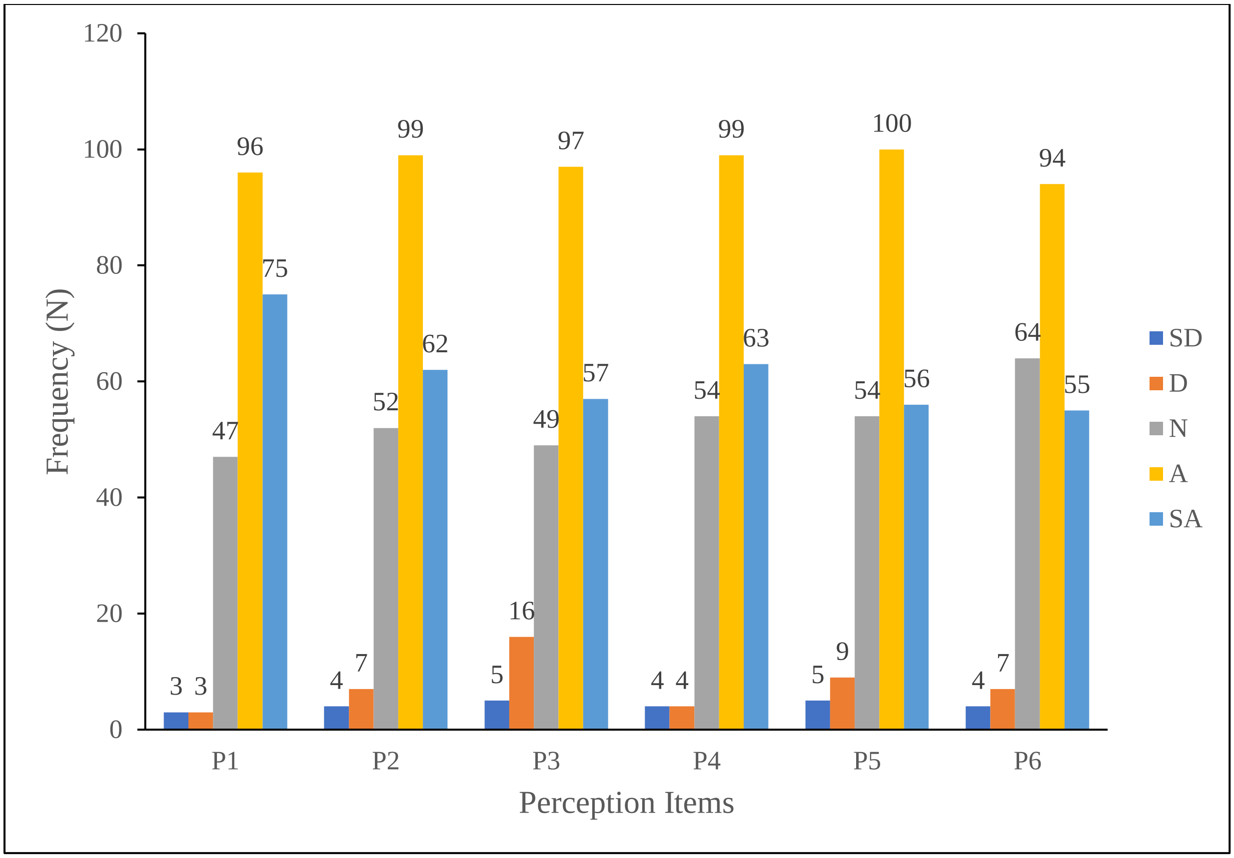

Figure 4: Bar graph representing the frequency of responses of the six perceptions. P1-The Arduino, M1K, M2k or others provided opportunities to practice content; P2 - The use of Arduino, M1K, M2k or others reflected course content; P3 - The use of Arduino, M1K, M2k or others was relevant to my academic area; P4 - The use of Arduino, M1K, M2k or others reflected real practice; P5 - The time allotted for Arduino, M1K, M2k or others use was adequate; P6 - The use of Arduino, M1K, M2k or others suited my learning goals

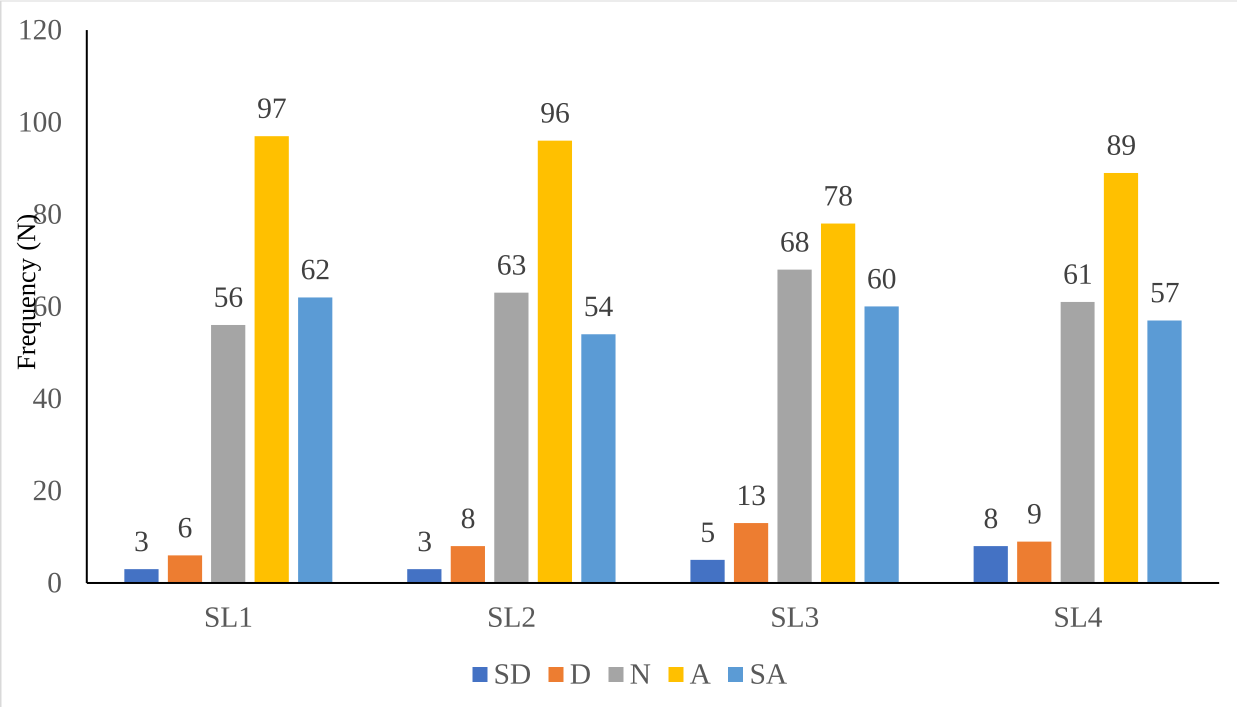

Figure 5: Perception of students on the impact of ECP on the learning process. SL1 - My knowledge has increased as a result of the use of devices (Arduino, M1K, M2k or others; SL2 - My confidence in the content area has increased because of the use of devices (Arduino, M1K, M2k or others); SL3 - The hands-on devices (Arduino, M1K, M2k or others) is important in my preparation for my future career; SL4 - Using the devices (Arduino, M1K, M2k or others) motivated me to learn the content.

The above diagram illustrates the impact of ECP-supported learning. In Figure 6, IP1 reveals that ECP assisted 109 students in honing problem-solving skills within the subject. Examining the graph, IP2, boasting the highest participation with 119 students, indicates unanimous agreement that ECP enhanced their ability to approach problems in a visual manner. Moving on to IP3 in Fig 6, 100 students acknowledged that ECP facilitated their understanding of practical applications of electric circuits. IP4, portrayed in the graph, highlights those 113 students found ECP beneficial in recalling course content. Additionally, IP5 demonstrates that 91 students concurred that utilizing the device led to improved grades. Moreover, IP6 indicates that 109 students affirmed the development of confidence in the content area. Furthermore, both IP7 and IP8 depict student consensus on being motivated to learn course content and cultivating an interest in the subject area, respectively. Notably, IP9 in which 106 students agreed that incorporating the device in ECP aided them in completing their lab assignments.

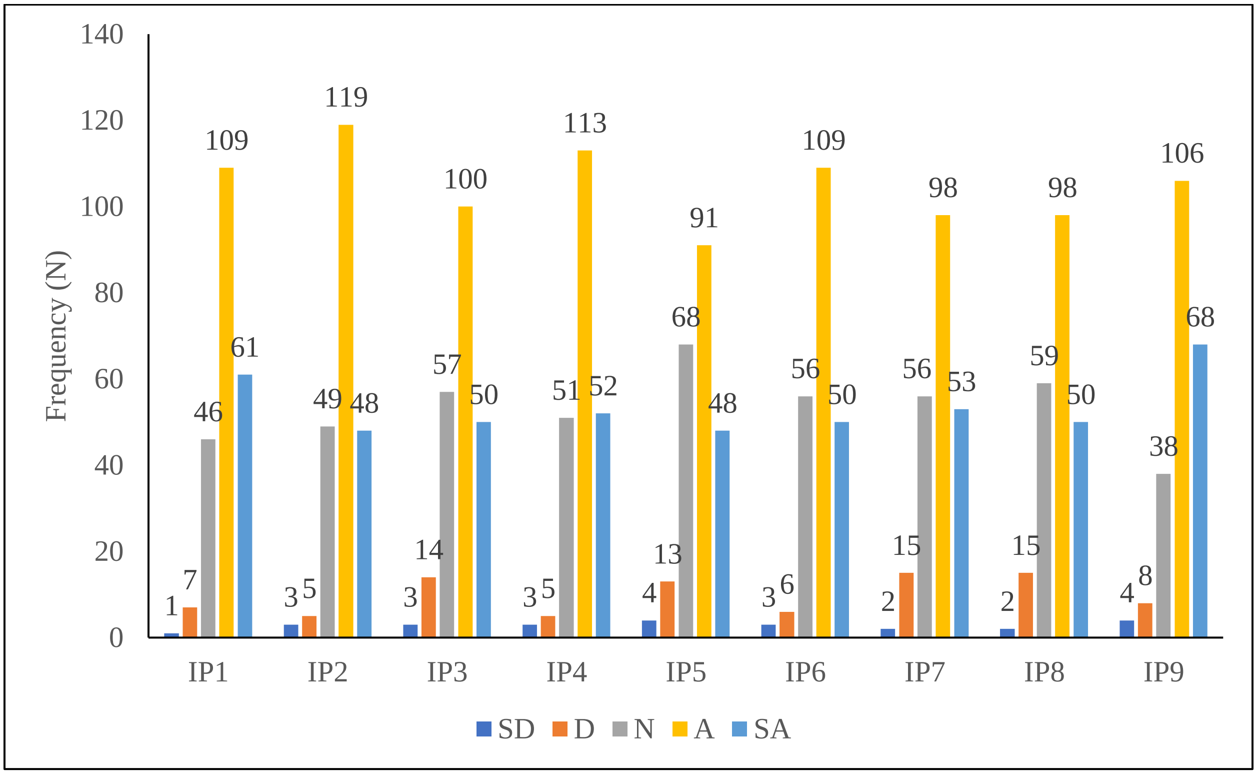

Figure 6: IP - Perception of students on how ECP Supported learning/Area of Growth. IP1- Helped me to develop skills in problem solving in this subject area; IP2 - Think about problems in graphical/pictorial or practical ways; IP3 - Learn how electric circuits are used in practical applications; IP4 - Recall course content; IP5 - Using such devices help improve grades; IP6 - Develop confidence in content area; IP7 - Become motivated to learn course content; IP8 - Develop interest in the subject area; IP9 - Using such devices help complete lab assignments.

Result presented in Table 1 revealed the mean score of the perception on the three areas of investigation. The result showed that the student had the most positive rating on the use of the instrument, followed by their perceptions on the impact of ECP on the learning / areas of growth. The result clearly revealed that there was a positive impact of ECP on the three constructs of investigation.

Table 1: Mean of perception scores of students

Subscales	Mean	Standard Deviation
Use of the instrument	3.92	0.79
Student learning process	3.84	0.84
ECP impact on learning /Area of Growth	3.88	0.72

The analysis of variance (ANOVA) conducted on students' perception gives substantial results regarding the influence on the three different scales on their perceptions (table 2). Firstly, the study revealed that there is a significant difference between the perceptions of the students on based on the type of instrument that they used among their different use of instrument ($F(2,221) = 20.010$, $p < 0.05$). This demonstrates that the variability in the utilization of the instrument results in substantial differences in student perspectives. These findings emphasize the significance of considering the way the ECP instrument is utilized in the classroom environment. Furthermore, the analysis assesses the influence of the use of different digital devices on the perception of the student on the learning process. There was a statistically significant ($F(2,221) = 11.181$, $p < 0.05$) in their perceptions. Therefore, the ECP experience across the different dialogue devices has a substantial impact on students' perspectives toward the learning process. In addition, the analysis of variance (ANOVA) used to assess the influence of the use of different devices during the ECP experience affected their perception of the pedagogical. There was a statistically significant difference across the different usage ($F(2,221) = 9.717$, $p < 0.05$). This shows the substantial impact of the ECP experience on students' evaluation of learning outcomes and areas of development. The ANOVA analysis shows statistically significant differences in students' perspective due to their experience with ECP (usage of different digital devices). These findings emphasized the effectiveness of the program in influencing students' perceptions on instrument utilization, the process of learning, and overall educational achievements.

Table 2: Analysis of variance (ANOVA) on students' perception using the ECP experience

		Sum of Squares	df	Mean Square	F	Sig.
Use of the instrument	Between Groups	765.987	2	382.993	20.010	.000
	Within Groups	4230.009	221	19.140		
	Total	4995.996	223			
Student learning process	Between Groups	230.053	2	115.026	11.181	.000
	Within Groups	2273.657	221	10.288		
	Total	2503.710	223			
ECP impact on learning /Area of Growth	Between Groups	747.708	2	373.854	9.717	.000
	Within Groups	8502.930	221	38.475		
	Total	9250.638	223			

Table 3 included post-hoc tests to investigate the differences in students' perceptions based on the use of different devices (analogue, phone apps, or both) across dimensions involving instrument usage, student learning process, and the impact of ECP on learning area of growth. The post-hoc tests analyze the average difference between pairs of devices for each dimension, including their standard errors and degrees of significance. The 95% confidence interval is supplied to suggest the range in which the true mean difference is likely to decrease. Regarding the utilization of instruments, a notable difference of 4.3 ($p < 0.05$) shows a significant difference in students' perception while utilizing both devices as opposed to just depending on phone applications. When comparing the use of analog devices and phone apps only, there is a notable difference of 4.6 ($p < 0.05$), indicating that perceptions significantly vary between the two types of devices.

Table 3: Post-hoc test on the perception of impact of ECP based of digital devices.

Dependent Variable	(I) Device	(J) Device	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Use of the instrument	Both	Analogue only	-0.2	0.7	0.9	-1.8	1.3
		Phone apps only	4.3	0.8	0.0	2.5	6.2
	Analogue only	Both	0.2	0.7	0.9	-1.3	1.8
		Phone apps only	4.6	0.8	0.0	2.7	6.4
	Phone apps only	Both	-4.3	0.8	0.0	-6.2	-2.5
		Analogue only	-4.6	0.8	0.0	-6.4	-2.7
Student learning process	Both	Analogue only	-0.2	0.5	0.9	-1.4	0.9
		Phone apps only	2.3	0.6	0.0	1.0	3.7
	Analogue only	Both	0.2	0.5	0.9	-0.9	1.4
		Phone apps only	2.5	0.6	0.0	1.2	3.9
	Phone apps only	Both	-2.3	0.6	0.0	-3.7	-1.0
		Analogue only	-2.5	0.6	0.0	-3.9	-1.2
ECP impact on learning /Area of Growth	Both	Analogue only	0.6	0.9	0.8	-1.7	2.8
		Phone apps only	4.6	1.1	0.0	2.0	7.2
	Analogue only	Both	-0.6	0.9	0.8	-2.8	1.7
		Phone apps only	4.1	1.1	0.0	1.5	6.7
	Phone apps only	Both	-4.6	1.1	0.0	-7.2	-2.0
		Analogue only	-4.1	1.1	0.0	-6.7	-1.5

The analysis reveals a statistically significant mean difference of -4.3 ($p < 0.05$) between the impressions of utilizing phone apps only instead of analogue only. Furthermore, in terms of the student learning process, there is a significant average difference of 2.3 ($p < 0.05$) between the use of both analogue and phone devices and the use of phone applications only. This indicates a significant difference in students' perception when utilizing both devices instead of to only relying on phone apps. Regarding the use of analogue alone and phone apps only, there is a significant mean difference of 2.5 ($p < 0.05$), indicating significant differences in students' perception between both strategies. When comparing phone apps only and analogue only, there is a statistically significant negative mean difference (-2.3, $p < 0.05$). This indicates that there is a notable difference in student perceptions between utilizing phone apps only and analogue only.

Regarding the impact of ECP on learning and areas of growth, there is a significant difference of 4.6 ($p < 0.01$) between utilizing both analogue and phone devices compared to using phone apps alone. This shows that perception greatly varies depending on the type of device used. When comparing the use of analogue devices and phone apps, there is a substantial mean difference of 4.1 ($p < 0.001$). This suggests that there is a significant difference in perceptions when using both devices compared to using phone apps alone. The comparison between phone apps only and analogue only indicates significant differences in perceptions, with a negative difference of (-4.6, $p < 0.001$).

Table 4 presents an analysis of the difference between gender and other components of student perceptions. This research explicitly examines the usage of the instrument, the student learning process, and the perceived impact of ECP on learning or areas of growth. Among the female participants ($N = 73$), the average score for the usage of the instrument was 22.3973, with a standard deviation of 5.0076. This indicates their overall assessment of the instrument's usability and efficacy. The male participants ($N=150$) had a significantly higher mean score of 24 (standard deviation = 4.5035), indicating that, on average, they evaluated the instrument to be slightly more useful than the female participants. Furthermore, in the context of student learning, it is worth noting that among the female participants ($N = 73$), the average score for the student learning process was 14.7945, with a standard deviation of 3.4438.

Table 4: Perception difference based on gender of students.

	What is your gender?	N	Mean	Std. Deviation
Use of the instrument	Female	73	22.39	5.01
	Male	150	24.00	4.50
Student learning process	Female	73	14.79	3.44
	Male	150	15.60	3.27
ECP impact on learning /Area of Growth	Female	73	34.16	6.11
	Male	150	35.18	6.56

This demonstrates their impression of the efficacy and involvement in the educational process promoted by active learning. The male participant group, consisting of 150 individuals, had a slightly higher average score of 15.6967 (with a standard deviation of 3.2726). This suggests that male participants, on average, had a little more positive perception of the learning process compared to females.

Regarding the influence of ECP on learning or area of growth, female participants (N = 73) gave a mean score of 34.16 (standard deviation = 6.01) for their perceived impact of ECP on learning and growth. This underscores their comprehensive evaluation of the efficacy of ECP in promoting learning and personal growth. Regarding the male participants (N = 150), the data indicates a significantly higher mean score of 35.19 (standard deviation = 6.56). This indicates that, on average, male participants reported a somewhat greater impact of ECP on their learning and growth compared to females.

Table 5 shows the results of an independent sample test that examines the equality of means and variances across distinct dependent variables related to the impact of the active learning experience on various aspects of learning. The Levene's Test for Equality of Variances assesses whether the variances of the dependent variables are consistent across different groups. The 95% confidence interval of the difference provides a range that estimates the genuine difference in population means with 95% confidence.

Table 5: Independent Samples Test

Dependent Variables		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Use of the instrument	Equal variances assumed	.802	.371	-2.403	221	.017	-1.60	.66	-2.91	-.29
	Equal variances not assumed			-2.316	130.097	.022	-1.60	.69	-2.97	-.23
Student learning process	Equal variances assumed	.000	.983	-1.709	221	.089	-.81	.47	-1.74	.12
	Equal variances not assumed			-1.679	136.456	.095	-.81	.48	-1.77	.14
ECP impact on learning /Area of Growth	Equal variances assumed	1.359	.245	-1.117	221	.265	-1.02	.91	-2.83	.78
	Equal variances not assumed			-1.145	152.392	.254	-1.02	.89	-2.79	.74

Lenvene’s test indicates that there is no significant difference in variances among groups, as shown by a non-significant *p*-value of 0.371. The t-test demonstrates a statistically significant difference in averages between the groups (t = -2.40, $p = 0.017$), suggesting different perceptions of students. The mean difference offers an improved comprehension of the statistical difference between the means of different groups.

The Levene's test indicates a non-significant result ($p = 0.983$) for the student learning process, as does the ECP impact on learning ($p = 0.245$), suggesting that there are uniform variances among groups. The t-test conducted on the student learning process reveals a marginally significant disparity in means (t = -1709, $p = 0.089$), indicating a potential difference in learning experiences. The impact of ECP on learning was assessed using a t-test, which showed no significant difference in means between the groups (t = -1.117, $p = 0.265$). This suggests that both groups had a similar perception of the impact of ECP on learning.

Discussion

The current study aims to examine the impact of ECP on students' impressions of various aspects of their educational experience at a historically black institution and university (HBCU). The results of this study align with prior research that has shown the efficacy of active learning teaching methods in fostering student involvement and improving educational achievements [4]. More precisely, the findings revealed that students who were exposed to ECP demonstrated positive perceptions of their learning encounters, such as heightened motivation, involvement, and comprehension of the course material. The results are consistent with the ideas of active learning, which prioritize student-centered methods that promote critical thinking, problem-solving abilities, and an increased understanding of students [17].

Utilizing statistical methods like ANOVA and post-hoc tests to analyze gathered data yields significant insights into the differences in perception across students, considering characteristics such as gender and academic level. The findings demonstrated significant differences in perception ratings among several engineering disciplines, underscoring the significance of taking disciplinary context into account when conducting educational interventions [18].

Moreover, the examination of students' perspectives on the influence of ECP on learning demonstrated significant differences in perception scores depending on the usage of distinct learning instruments. The discovery highlights the significance of technology usage in influencing students' experiences and perception [19]. The findings also revealed subtle differences in the perception of the influence of ECP on learning across male and female students, with male students exhibiting somewhat higher perception ratings across all aspects in comparison to their female peers. The existence of differences in perception emphasizes the necessity for further research into the underlying mechanisms that contribute to the varied perception of active learning teaching methods among male and female students.

In summary, the results of this study add to the existing body of research on active learning teaching methods and their influence on students' educational experiences. This research highlights the significance of using innovative instructional methods, such as ECP, to improve students' perspective of learning in engineering education. It provides experimental proof that supports the effectiveness of ECP in encouraging student engagement and achievement.

Conclusion

This study utilized a comprehensive methodology that involved administering a survey to 269 engineering students from various disciplines. The purpose was to evaluate the impact of experimental centric pedagogy (ECP) on students' learning. The evaluation was done through pre- and post-tests, as well as questionnaire that assessed students' perception of how ECP influenced different aspects of their learning. Responses were captured using the Likert scale, and the data collected from spring 2021 to fall 2023 was examined using statistical methods. The examination of perception of educational tools, as depicted in Figure 4 and 5, provides insight into student attitudes towards the use of Arduino M1K, M2K, and other similar devices. Figure 6 illustrates the analysis of ECP-supported learning, revealing that students agree that it significantly benefits multiple aspects of their academic experience. The findings further emphasize the motivational and interest-inducing elements of ECP, as evidenced by students' heightened involvement with the course material.

The results of our study emphasize the efficacy of ECP in significantly impacting students' views and academic performance. Furthermore, it offers useful perspectives for institutions aiming to improve active learning approaches in engineering education. The incorporation of various tools and approaches, along with an emphasis on personalized learning experiences, can enhance the educational environment in a more comprehensive and influential manner.

Acknowledgement

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