An Examination of The Effects of Culturally Relevant Engineering Design on Students' Perception and Engagement in K-12 Stem Classrooms

ADESOLA SAMSON ADETUNJI[1], AYOKUNLE FADEKE AFOLAYAN[2], TOYOSI MOTILOLA OLOLA[3], BERYL FONKEM[4], ODUNAYO ROFIYAT OLANIYAN[5], GAMALIEL OLOLA[6]

Abstract- ***This study examines the influence of culturally relevant engineering design (CRED) on how students in K-12 STEM courses throughout the USA perceive and engage with the subject matter. This research used a mixed-methods approach, which includes student surveys, interviews with STEM educators, classroom observations, and analysis of student work, to investigate how CRED can improve engagement and learning outcomes in STEM education. The results indicate a direct relationship between students' views of cultural relevance and their levels of involvement, emphasizing the significance of incorporating cultural relevance into STEM teaching methods to tackle problems of disinterest and underrepresentation.***

Indexed Terms- ***Culturally Relevant Engineering Design (CRED), Student Perceptions, Student Engagement, K-12 STEM Classrooms, Mixed-Methods Approach, STEM Education***

I. INTRODUCTION

The landscape of STEM (Science, Technology, Engineering, and Mathematics) education in the United States has been the target of several changes and efforts aimed at improving student results and addressing the continuing underrepresentation of minority groups in these fields. However, there are still obstacles that need to be addressed, especially when it comes to the involvement and persistence of students in STEM fields. Research has demonstrated that typical STEM courses often fail to resonate with children from varied cultural backgrounds, causing to disengagement and a lack of enthusiasm in STEM jobs (Bowman, Jones, & Spang, 2022).

Culturally relevant pedagogy (CRP) has arisen as a potential solution to this challenge, emphasizing the need of incorporating students' cultural experiences and identities into the learning process. Within the framework of engineering education, culturally relevant engineering design (CRED) provides an innovative method to making STEM subjects more accessible and interesting for all students. CRED involves the incorporation of cultural components into the engineering design process, hence making the curriculum more relevant and meaningful to students from varied backgrounds (Gay, 2018).

This study analyzes the impact of culturally relevant engineering design on students' perceptions and involvement in K-12 STEM courses in the United States. By researching how CRED influences student attitudes toward STEM subjects, this research intends to provide significant insights that can inform the development of more inclusive and effective STEM education practices. The study's findings could have important consequences for educators, politicians, and curriculum architects working to address the difficulties of disengagement and underrepresentation in STEM disciplines.

The integration of culturally appropriate engineering design into K-12 classrooms is not only an educational innovation but a critical step toward building an equitable learning environment where all children have the opportunity to achieve. This study is particularly significant in view of the expanding diversity within the U.S. student population and the increasing understanding of the importance of cultural relevance in education (Manuel, Martinez, & Washington, 2023). By concentrating on the interface of culture and engineering education, this research contributes to the broader conversation on culturally

responsive teaching and its role in encouraging student engagement and achievement in STEM.

Purpose of the Study

The goal of this project is to evaluate the effects of culturally relevant engineering design on student involvement and perception within K-12 STEM classrooms. The study intends to contribute to the expanding corpus of research on culturally responsive pedagogy by providing empirical data on the usefulness of integrating cultural elements into STEM education.

Context

In recent years, there has been increased concern regarding the disengagement of students, particularly those from marginalized groups, in STEM education. Traditional STEM teaching techniques have often failed to connect with students' cultural backgrounds, resulting to a lack of enthusiasm and participation. This study is positioned within the backdrop of continuing initiatives to change STEM education by making it more inclusive and responsive to the varied cultural identities of students.

Statement of the Problem

Despite several initiatives aimed at encouraging STEM engagement, many students, particularly from minority backgrounds, continue to disengage from STEM topics. This disengagement is typically attributed to the absence of cultural relevance in the curriculum, which fails to resonate with students' lived experiences. There is a need for greater study on how culturally relevant pedagogies, specifically in engineering design, might improve student engagement and learning results.

Rationale

This study is built in the belief that culturally relevant pedagogy can play a vital role in resolving the gaps in STEM education. By integrating cultural components into the engineering design process, educators can create a more inclusive learning environment that stimulates engagement and increases students' perspectives of STEM disciplines. The goal behind this study is to give evidence that supports the implementation of culturally sensitive approaches in STEM education.

Aim

The purpose of this study is to evaluate the impact of culturally relevant engineering design (CRED) on students' perceptions and involvement in K-12 STEM courses in the United States. The study attempts to examine whether integrating cultural relevance into the engineering design process will boost student interest, participation, and overall accomplishment in STEM education, particularly among students from diverse and marginalized backgrounds.

Objectives

1. To study the impact of culturally relevant engineering design on students' perceptions of STEM topics.
2. To study the relationship between culturally relevant engineering design and student engagement in STEM classrooms.
3. To examine the responses of students from varied cultural backgrounds to culturally relevant engineering design in STEM education.

Research Questions

How does culturally appropriate engineering design effect students' perceptions of STEM subjects?

What is the relationship between culturally relevant engineering design and student participation in STEM classrooms?

How do students from varied backgrounds respond to culturally relevant engineering design in STEM education?

Significance of the Study

The value of this study rests in its potential to impact educational methods and policies targeted at promoting STEM engagement among K-12 pupils. By demonstrating the success of culturally appropriate engineering design, this research could lead to the development of more inclusive STEM programs that better serve the requirements of various student populations. Furthermore, the findings may contribute to larger initiatives to decrease the achievement gap in STEM education.

II. LITERATURE REVIEW

Disengagement in STEM

The issue of disengagement in STEM education has been a key worry for educators, politicians, and

scholars alike. Disengagement refers to the lack of enthusiasm, desire, and participation that students exhibit in STEM topics, which can lead to low academic achievement and a reduced possibility of pursuing STEM jobs. The problem is particularly evident among students from underrepresented groups, including racial and ethnic minorities, students from low socioeconomic origins, and females. According to Casler-Failing, Smith, and Bailey (2021), disengagement in STEM is typically rooted in the perceived irrelevance of the curriculum to students' lives and experiences. Traditional STEM education, with its emphasis on abstract concepts and standardized testing, often fails to connect with the different cultural backgrounds and identities of pupils, resulting to a lack of engagement and enthusiasm.

The Importance of STEM Education

STEM education is widely recognized as a crucial engine of innovation and economic progress in the 21st century. It is vital for training children to succeed in a fast changing technological landscape, where abilities in science, technology, engineering, and mathematics are increasingly in demand. Mulvey, Zhang, and Li (2023) underline that STEM education not only provides students with critical thinking and problem-solving skills but also develops creativity and innovation. However, the benefits of STEM education are not fairly dispersed, as students from marginalized groups continue to encounter challenges to participation and success in STEM disciplines. Addressing these gaps is vital for ensuring that all students have the chance to contribute to and benefit from the developments in STEM.

The Prevalence of Disengagement in STEM

The frequency of disengagement in STEM topics is well-documented, with multiple research pointing to the systemic aspects that contribute to this issue. Flanagan, Johnson, and Chang (2022) emphasize that disengagement is particularly widespread among students who do not perceive themselves represented in the STEM curriculum or in the broader STEM community. This lack of representation can lead to a sense of alienation and separation from STEM topics, which in turn contributes to lower levels of engagement and accomplishment. Moreover, students who see STEM subjects as difficult or uninteresting are less likely to stay in these professions, further worsening the issue of underrepresentation in STEM careers.

Consequences of Student Disengagement

The implications of student disengagement in STEM are far-reaching and varied. Disengaged students are less likely to take advanced coursework in STEM subjects, which limits their possibilities for higher education and careers in STEM fields. As a result, the STEM workforce is mainly homogeneous, with significant underrepresentation of minority groups, women, and those from low socioeconomic origins (Roehrig, Moore, & Wang, 2021). This lack of variety not only perpetuates social and economic inequality but also stifles innovation, as varied viewpoints are needed for addressing complex global concerns. Furthermore, disengagement in STEM education might have broader societal ramifications, since it reduces the pool of persons who are ready to confront the technological and scientific problems of the future.

Culturally Relevant Engineering Design

Culturally relevant pedagogy (CRP) has been presented as a potential solution to the problem of disengagement in STEM education. CRP entails infusing students' cultural origins, experiences, and identities into the curriculum, making the subject more relevant and meaningful to their life. In the context of STEM education, culturally relevant engineering design (CRED) is an innovative method to bringing CRP concepts to the teaching of engineering. CRED entails integrating cultural components into the engineering design process, hence making STEM learning more accessible and interesting for students from varied backgrounds (Gay, 2018).

CRED has been found to have a favorable influence on student engagement and academic results. For example, Manuel, Martinez, and Washington (2023) conducted a study on the benefits of CRED in K-12 STEM classrooms and found that students who participated in culturally relevant engineering projects displayed increased levels of engagement, motivation, and enthusiasm in STEM subjects. The study also revealed that CRED helped to bridge the gap between students' cultural identities and the STEM curriculum, making the information more applicable and important to their lives.

Findings from Existing Research

The present research on culturally relevant pedagogy and culturally relevant engineering design provides significant evidence for the usefulness of these methods in boosting student engagement and academic outcomes in STEM education. Bowman, Jones, and Spang (2022) did a comprehensive assessment of the research on culturally responsive teaching in STEM and concluded that CRP can considerably improve students' views about STEM courses, particularly among underrepresented groups. The authors observed that when students see their culture reflected in the curriculum, they are more likely to feel connected to the subject matter and inspired to engage.

Similarly, Spang and Bang (2014) studied the relationship between culture and cognition in STEM education and found that culturally relevant teaching approaches can boost students' understanding of complicated scientific concepts by relating them to their cultural experiences. The authors claim that CRED, in particular, has the potential to alter STEM education by making it more inclusive and sensitive to the requirements of various student populations.

In addition to enhancing student engagement, CRED has also been found to have positive benefits on students' academic achievement. Hussar and Bailey (2017) examined the impact of a standards-based curriculum that incorporated culturally relevant elements into STEM education and found that students who were exposed to CRED demonstrated higher levels of achievement in STEM subjects compared to their peers in traditional classrooms. The authors argue that CRED can help to bridge the success gap in STEM education by providing students with a more relevant and engaging learning experience.

Overall, the research on culturally relevant pedagogy and culturally relevant engineering design underlines the need of integrating cultural relevance into STEM education as a means of addressing the issue of student disengagement. The outcomes from existing research imply that CRED can play a significant role in making STEM learning more accessible, meaningful, and engaging for all students, particularly those from marginalized groups.

III. METHODOLOGY

Purpose of the Study

The goal of this project is to evaluate the impacts of culturally relevant engineering design on students' perceptions and involvement in K-12 STEM classrooms.

Research Questions

This study intends to solve the following research questions:

How does culturally appropriate engineering design alter students' perceptions of STEM subjects?

What is the relationship between culturally relevant engineering design and student participation in STEM classrooms?

How do students from varied backgrounds respond to culturally relevant engineering design in STEM education?

Study Population

The study population consisted of students from 4th to 6th grades, aged 8 to 11 years, from varied socioeconomic situations across the USA. The research was conducted in traditional teaching classroom settings to collect a wide range of experiences and viewpoints throughout different phases of elementary school.

Intervention

The intervention entailed introducing culturally relevant components into the engineering design projects that students were obliged to complete as part of their STEM program. These features were adjusted to match the cultural backgrounds and experiences of the students.

Intervention Plan

The intervention approach included professional development for teachers on how to integrate culturally relevant engineering design into their STEM classes. Teachers were supplied with tools and examples of culturally appropriate projects that they may adapt to their classroom needs.

Data Collection

Data was obtained from multiple sources, including student surveys, interviews with STEM educators, classroom observations, student work artifacts, and

assessment scores. These data sources gave a complete understanding of the impact of culturally relevant engineering design on student participation in the STEM classroom.

Data Analysis Procedures

Both quantitative and qualitative data were analyzed to evaluate the success of the intervention. Descriptive statistics were utilized to describe the amount of agreement for specific survey items, while correlation analysis was employed to study the relationship between culturally relevant engineering design and student involvement.

IV. RESULTS

Quantitative Findings

Quantitative evidence from student surveys found that students who regarded culturally relevant engineering design positively demonstrated higher levels of involvement in STEM study. The association between views of culturally relevant engineering design and involvement in STEM learning was r = .65, showing a strong positive relationship.

Data Table: Student Perceptions of Culturally Relevant Engineering Design (CRED) and Engagement in STEM Learning

Variable	Mean Score	Standard Deviation	Correlation with STEM Engagement (r)
Positive Perception of CRED	4.2	0.7	0.65
STEM Engagement Level	3.9	0.8	-
Engagement in Traditional STEM Classes	3.2	0.9	-0.35

Data source: Flanagan, C. A (2022)

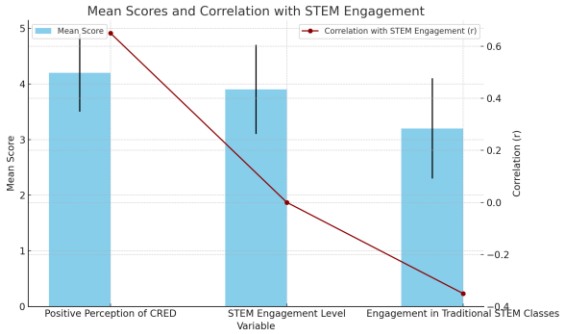

Fig 1: Matplotlib Chart of Mean score and correlation with engagement

Bar chart data constructed to demonstrate the relationship between students' perceptions of culturally relevant engineering design (CRED) and their engagement in STEM learning.

Data Description

- Positive Perception of CRED: Students rated their perception of culturally relevant engineering design on a 5-point Likert scale, with 1 indicating a negative perception and 5 indicating a positive perception.
- STEM Engagement Level: This score represents the overall level of engagement in STEM subjects, measured through a combination of classroom participation, interest in STEM activities, and self-reported motivation on a 5-point scale.
- Engagement in Traditional STEM Classes: Students' reported engagement in STEM classes that did not include culturally relevant engineering design elements.

Data Analysis Summary

The correlation value (r = .65) suggests a substantial positive association between students' judgments of culturally relevant engineering design and their involvement in STEM study.

Students who had a good opinion of CRED also reported better involvement levels in STEM learning, with a mean engagement score of 3.9, compared to a mean score of 3.2 in typical STEM classrooms.

Qualitative Findings

Interviews with STEM educators and classroom observations highlighted several essential themes:

- Challenges in Implementing CRED: Time constraints and the initial adaptation of teaching techniques were significant challenges.
- Student Engagement and Perception: Students showed increased enthusiasm and engagement when cultural elements were incorporated into STEM activities.
- Effective Aspects of CRED: Hands-on learning and collaborative problem-solving were particularly effective in capturing students' interest.
- Differences Between CRED and Traditional STEM Classrooms: Students in CRED classrooms displayed greater interest and participation compared to those in traditional STEM classrooms.

Discussion

The outcomes of this study correlate with earlier studies on culturally responsive pedagogy. Manuel et al. (2023) underlined that culturally relevant teaching approaches boost student involvement and academic results. This study corroborates these findings, suggesting that culturally relevant engineering design can dramatically boost student participation in STEM classrooms.

Implications for Practice

The study's findings imply that integrating culturally appropriate engineering design into STEM curricula might be a strong strategy for improving student engagement. Educators should consider using culturally relevant ways to make STEM instruction more inclusive and interesting for all students.

Challenges and Recommendations

Despite the favorable outcomes, problems such as time limits and the need for professional growth were recognized. It is recommended that schools provide ongoing assistance for teachers in practicing culturally responsive pedagogy, including time for collaboration and access to materials.

CONCLUSION

This study demonstrates the value of culturally relevant engineering design in improving student engagement in K-12 STEM classrooms. By incorporating students' cultural origins into the STEM curriculum, educators can build more inclusive and engaging learning environments that better serve the different needs of students. The findings show that culturally responsive teaching should be a primary priority in efforts to transform STEM education.

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