The Role Played by the Student-Centred Approach in the Acquisition and Development of 4Cs of 21st Century Skills Through a Project-Based STEM Curriculum

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Abstract
The study aims to investigate the role played by the student-centred approach to teaching and learning in the transfer and development of the 4Cs (creativity, critical thinking, collaboration and communication) of 21st-century skills via a project-based STEM curriculum. In a rapidly changing world with technological advancements, where most algorithmic functions are on the verge of automation, 4Cs have become pivotal for future career success. Thus, the schools, being institutions that prepare students for the future, should be able to equip them with the required skill set through the curriculum and instructional approaches used. Project-based learning and STEM learning are the two most popular strategies for cultivating 21st-century skills. There is substantial empirical evidence to support the positive impact project based STEM has on the 4Cs. It is equally important to understand the influence of the pedagogical approaches on the positive nurturing relationship between project-based STEM and the 4Cs of 21st century skills. The context for the current study is created at the middle school level in an international school in Colombo, Sri Lanka. The study used a mixed method research prerogative to explore the effects of the student-centred instructional approach on project-based STEM curriculum. The quantitative and qualitative data analysis converged on a student-centred instructional approach to significantly impact the acquisition and development of 4Cs through a project-based STEM curriculum, thus qualifying a student-centred pedagogical approach as a recommended instructional method for project-based STEM.

Keywords: Student-Centred Approach, 21st Century Skills, STEM Learning, Project Based Learning, Collaboration, Communication, Critical Thinking, Creativity

Introduction

STEM is a learning strategy that incorporates components of Science, Technology, Engineering, and Mathematics into the learning process. STEM education employs problem-solving-based learning by inadvertently including scientific study and the application of mathematics in the construction of technology as a problem-solving strategy (Johnson et al., 2016). Scientific inquiries are uncommon in technology education, while technological design is uncommon in scientific classes. However, in ordinary life, design and scientific research are frequently used in tandem as a technical solution to real-world challenges (Sanders, 2009). These aspects encompass the ability to inquire about scientific concepts and identify problems, devise and execute investigations, utilize mathematical skills, employ information and computer technology, apply computational thinking, and acquire, evaluate, and convey information (Afriana et al., 2016). Project- based learning is highly beneficial and provides strong support for students. One way to facilitate the implementation of habituation activities is by incorporating the STEM (Science, Technology, Engineering, and Mathematics) approach in the classroom. This involves assigning project tasks to learners, which can help them develop skills and knowledge in these areas (Anggraini & Huzaifah, 2017). The ability to think critically is essential for learners to effectively address the diverse challenges they encounter in today's world. By engaging in a systematic thinking process, individuals can develop the necessary skills to analyse and solve problems (Bhakti et al. 2018). Extensive research conducted comprehensively examined the impact of a student-centered learning method on the transfer of the 4Cs of 21st-century abilities (Critical Thinking, Communication, Collaboration, and Creativity) within a project-based STEM curriculum. The concept of student-centered learning places a strong emphasis on learner agency, which empowers students to actively participate in their educational experiences and assume responsibility for their own learning process.

4C's and Student-Centred Learning

The implementation of a student-centered approach in education promotes the development of critical thinking skills through the encouragement of students to actively engage in questioning, analyzing information, and autonomously exploring potential solutions. The implementation of project-based STEM assignments requires students to engage in the critical evaluation of information sources and the use of analytical reasoning to address intricate challenges. This aligns with the cultivation of critical thinking abilities, as highlighted by Kwon and colleagues (2017). The implementation of student-centered learning methodologies facilitates the development of communication skills by means of interactive activities that necessitate students to express their thoughts, participate in peer dialogues, and provide presentations of their discoveries. In the context of project-based STEM education, it is imperative for students to engage in collaborative teamwork, which requires them to effectively communicate difficult technical concepts to their colleagues and stakeholders (Hmelo-Silver et al., 2007).

Collaboration serves as a fundamental principle in both student-centered learning and project-based STEM education. Collaborative tasks within project-based environments bear resemblance to real-world situations, as students engage in collective efforts to combine multiple viewpoints, navigate discrepancies, and jointly generate knowledge (Krajcik & Shin, 2008). Creativity is fostered within student- centered learning environments, as they provide opportunities for students to engage in critical thinking and explore novel methodologies. The integration of project-based STEM education enables students to develop innovative solutions to real-world problems by granting them the independence to invent their own techniques while applying STEM principles (Häkkinen et al., 2017). Educators can enhance student engagement and facilitate deeper learning experiences by implementing a project-based STEM curriculum that prioritizes a student-centered approach. This method 34 capitalizes on students' innate motivation and interests, as highlighted by Prince and Felder (2006). This approach is in accordance with the 4Cs framework, since it promotes the development of critical thinking skills, effective communication abilities, meaningful collaboration, and the use of creative potential within a supportive and empowering educational setting.

There is evidence of a statistically significant beneficial relationship between the implementation of student-centered learning approaches and the enhancement of the 4Cs skills, namely Critical Thinking, Communication, Collaboration, and Creativity. Numerous studies have consistently shown that educational methodologies that prioritize student-centered learning, thereby granting learners agency and fostering active participation, are correlated with heightened critical thinking abilities (Prince & Felder, 2006), enhanced communication skills (Hmelo-Silver et al., 2007), more successful collaborative efforts (Johnson et al., 2016), and heightened levels of creativity (Häkkinen et al., 2017) among student populations. The aforementioned results collectively emphasize the beneficial impact of student-centered learning in promoting the development of the 4Cs skills, hence contributing to comprehensive and well-rounded educational achievements. The extant literature also provides evidence of a statistically significant association between student-centered learning and the acquisition of 4Cs skills (Critical Thinking, Communication, Collaboration, and Creativity) through the implementation of a project-based STEM curriculum. Research findings suggest that the implementation of student-centered methodologies in project-based STEM education facilitates the cultivation and utilization of the 4Cs skills, as supported by studies conducted by Hung and colleagues (2008) and Krajcik and Shin (2008). Learners actively participate in project-based activities where they work together to address authentic challenges, fostering the development of critical thinking, proficient communication, productive teamwork, and innovative problem-solving abilities (; (Bell, 2010; Shin & Kim, 2019). The incorporation of student-centered learning into the project-based framework fosters a mutually beneficial connection between both instructional methods, thereby augmenting the acquisition of 4Cs abilities and equipping students to tackle the problems of the 21st century.

Theoretical Framework

Integrating social constructivism, social cognitive theory, and digital connectivism provides a comprehensive theoretical foundation for investigating the role played by student-centred learning approaches in project-based STEM (Science, Technology, Engineering, and Mathematics) education. The theoretical framework of social constructivism, founded on the ideas of Vygotsky, emphasizes the importance of collaborative processes in building knowledge through interactions among peers and the development of common understanding. This perspective aligns well with the collaborative character of project-based STEM assignments and with the ideas such as agency and active engagement of students in the student-centred approaches. (Bell, 2010; Vygotsky, 1978). Bandura's social cognitive theory provides a valuable perspective that aligns with the aforementioned argument. It emphasizes the significance of learners' observation and imitation of their peers' activities within project-based STEM groups. This process enhances many cognitive abilities, including problem-solving, critical thinking, and communication skills (Bandura & Walters, 1963). Self-efficacy in Bandura's theory is closely linked with student-centred practices in learning. Digital connectivism is a concept that explores the influence of technology-mediated networks, with a particular focus on the significance of digital tools and online communities in project-based STEM learning. It highlights promoting cooperation and broadening access to various information sources (Siemens, 2004). In the digital space students get to exercise more autonomy and creates more opportunities for student agency. The synthesized framework presented in this study serves as a guiding framework for research in project-based STEM contexts. It emphasizes the importance of collaboration, observational learning, technological integration, and self-regulation in these contexts. By adopting a holistic perspective, this framework enables researchers to examine effective instructional strategies and outcomes comprehensively.

Present Study

Considering all the literature analyzed in the review above, it can be understood that room exists for a study to investigate the role played by student-centred learning approach in the acquisition and development of the 4Cs of 21st-century skills via a project-based STEM curriculum in the South Asian region at the middle secondary education level to establish statistical significance through the quantitative survey analysis and to further explore in depth any other interrelationships that exist through collection and analysis of qualitative data. Thus, the research gap can be identified as related to geography, which is the South Asian region (Sri Lanka), an academic level which is middle secondary school level (age 12 years to 14 years).

Method

The current study used a case study research model as it has only collected data from a single school in Sri Lanka and conducted a mixed methods study using a convergent parallel design. Researchers used both quantitative and qualitative measurements to analyse the degree and direction of influence student-centred learning has on project-based STEM. Statistical analyses, such as regression analysis, generated helpful information on the degree of link between variables (Hair Jr et al., 2019). Mixed methods allow the author to explore the research questions more comprehensively while drawing from the strengths of both quantitative and qualitative methods and also mitigating their weaknesses (Creswell & Plano, 2011).

When gathering quantitative data authors implemented the Morgan sample size calculator to calculate sample size from a population of 140 middle school students. The sampling strategy used for this study was stratified proportionate random sampling as the middle school student population at the international concerned has unequal gender distribution; thus, this sampling technique ensures that the random sample chosen is reflective of the real population. This method ensures that male and female students are fairly represented in the sample by segmenting the population into different strata based on gender (Fowler Jr., 2013). According to the Table 1, the study used a sample size of 103 students. Researchers can more accurately capture these variances using stratified proportionate random sampling, leading to a better understanding of the total student population (Creswell & Plano, 2012). As it prevents potential biases and guarantees that the research findings are fair and applicable to all gender groups, ensuring proportionate representation of genders in the sample is also crucial from an ethical standpoint (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979).

When selecting the sample for a focus group interviews, purposive sampling was thought to be the best strategy. With this approach, volunteers were specifically chosen based on traits, backgrounds, or areas of knowledge related to the study's subject. The depth and richness of the focus group talks were increased through purposeful sampling, providing deeper insights. Researchers can choose participants through purposive sampling if their characteristics closely match the goals and issues of the 72 study (Klassen et al., 2012). The focus group talks delivered focused and applicable insights by selecting participants with knowledge, experiences, or viewpoints that are relevant to the study. Focus group discussions aim to produce in-depth and complex insights (Patton, 2014). This strategy allowed diverse perspectives in the debate thus contribute to enhance the validity of the qualitative data (Onwuegbuzie & Leech, 2007). By streamlining the participant selection procedure, researchers collected data from resourceful participants who were knowledgeable about the subject matter. Selectively selecting participants who can offer distinctive insights that would not be easily obtained through other methods is made easier using purposive sampling (Dillman et al., 2014; Palinkas et al., 2015).

Survey questionnaire was developed using validated survey items from Project-based learning impact on 21st century skills survey by Hixson and colleagues (2012), items related to STEM learning from Engagement in Science Learning Activities version 3.2 by Masters (1982), and items feeding to 4Cs from 21st century skills survey developed by R. Kelley and colleagues (2019).

Procedure & Ethical Considerations

Participants were asked to complete the survey on paper; the survey consisted of 35 items on a 5-point Likert scale, where each participant was asked to select strongly agree, agree, undecide, disagree, and strongly disagree for each survey item presented. Cronbach's alpha for 4Cs overall was found to be 0.777, and for student-centred learning is 0.853 in the questionnaire, which is acceptable in terms of reliability. To abide by the ethical guidelines, written permission was obtained from the school authorities for data collection. Since participants were legally minors, consent was taken from their parents via a standard informed consent form, which aided in alleviating any concerns about deception or manipulation (Busher & James, 2012). Measures were taken to secure the anonymity and confidentiality of the participant data. Student identities were not collected, so researcher responses could not be linked to specific students (Lapan et al., 2012; Walker, 2017). A participant ID was generated using open-source software, enabling the author to remove the data gathered from a particular participant on request.

Credibility and Trustworthiness

To ensure the effectiveness and the high quality of the data gathered at focus group interviews the following measures were taken. The study objectives and the precise information sought through focus group interviews were explicitly outlined (Krueger & Casey, 2015). This helped to keep the talks focused and relevant. Participants with appropriate expertise or experience with the research issue were carefully chosen. This contributed to the variety and depth of the talks (Morgan, 2014). To successfully lead talks, promote participation, and manage group dynamics, skilled and experienced moderators were used (Barbour & Morgan, 2017). Prior to the session, participants were given detailed information regarding the focus group format and objectives helped to prepare the participants and contributed to a more informed discussion (Morgan, 2014). The focus group discussion was well structured to meet the objectives, and the group size was at optimum 6 participants to allow more in-depth discussion (Morgan, 2014; Krueger & Casey, 2015).

Various procedures were employed to ensure the credibility and trustworthiness of qualitative data, specifically for data collected via focus group discussions (FGDs) utilizing purposive sampling. The utilization of multiple data sources and methodologies, as proposed by Denzin (1978), contributed to the credibility of the research. the practice of member checking, as advocated by Lincoln and Guba (1985), which entailed sharing research findings with participants to ensure the accuracy and validity of the results. The authors also engaged in reflexive journaling (Charmaz, 2006), which served to uphold transparency and allowed researchers to critically examine any biases. The adherence to qualitative research principles was observed through the establishment of consistency in data collecting (Gibbs, 2007), the incorporation of a theoretical framework to guide the research (Charmaz, 2006), and the deliberate selection of a diverse purposive sample. The implementation of these techniques together served to augment the credibility and reliability of qualitative findings.

The corresponding author was mindful of his background and experiences related to STEM curricula, activities, and views about student-centred learning may have introduced biases into the study. As a teacher by profession, the author strongly supported the idea of activity-based STEM learning to improve skills such as critical thinking, creativity, innovation, and teamwork, so there might been a larger room for subjectivity in collecting qualitative data as it is based on purposive sampling. To overcome, the authors incorporated reflexivity practices where a deliberate attempt was made to list out the authors' own views about the investigation and the variable in concern, then a careful thought process as to how those may have influenced the selection and interpretation of the qualitative data. Authors presented the findings to focus group participants following thematic analysis to verify whether the transcription of the analysis has omitted or distorted their ideas, over a genuine attempt to convey their original ideas. Since the study was a mixed method, the collection and integration of quantitative data aids in adding more objectivity and minimizing researcher bias. For this purpose, triangulation of quantitative and qualitative data was carried out.

Data Analysis

H_{01}	Student-centred learning practices have a significant positive impact on the development of the 4 Cs of 21st century skills in a learning context where project-based STEM activities are conducted

Data was subjected to a linear regression and correlational analysis to test the hypothesis. Regression analysis aided in quantifying the impact of STEM activities and controlling for confounding variables, offering predictive insights. Correlational analysis, on the other hand, explored the strength and direction of these relationships, providing initial insights and a simpler interpretation (Creswell et al., 2012). Together, these methods provide a robust approach to understanding the benefits of STEM activities on student development via the transfer of 4Cs of 21st century skills.

Following the coding and thematic analysis of focus group data, themes emerging from data was compared with survey items used for quantitative data collection, to identify the recurrence of themes, themes converging into variables measured, and points that stand apart (diverge), charts were used by the author to visualize these patterns. The author employed the themes derived from qualitative data to elucidate and provide context for the patterns noticed in the quantitative results, thus yielding a more comprehensive and nuanced interpretation (Teddlie & Tashakkori, 2010). Furthermore, an additional approach was implemented in which a single dataset was utilized to corroborate or substantiate the conclusions drawn from the other dataset, hence augmenting the total credibility of the research (Creswell et al., 2012).

Findings

Regression Analysis

Table 1: Result of R Square Values

R	R Square	Adjusted R Square	Std. Error of the Estimate
.872[a]	.0.83	.870	9.479

Based on the R Square value of 0.83 is pivotal. It reveals that approximately 83% of the variance in 4C's skills can be explained by variations in student-centered learning activities. With a reasonable standard error estimated at 9.479, and an adjusted R square of 0.870 this analysis emphasizes the crucial role of student-centered learning activities in enhancing 4C's skills.

Table 2: Result of Regression Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10975.83	1	10975.831	25.884	.000[b]
	Residual	41555.31	98	424.034		
	Total	52531.14	99			
a. Dependent Variable: skills (4C’s)						
b. Predictors: (Constant), student-centered learning activities						

The ANOVA table clearly demonstrated the strong statistical significance of the regression model incorporating the predictor variable "student-centered learning activities" (F-statistic=25.884, p<0.0005). This indicated a substantial influence of “student-centered learning activities” on skills (4C’s). The model accounted for a significant portion of the variability in skills (4C’s), as indicated by the high R-squared value.

Table 3: Result of Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	68.838	5.667		12.147	.000
	Student-centered learning	.448	.088	.457	5.088	.000
a. Dependent Variable: 21st century skills (4C’s)						

As per the results of table 3, the linear regression model assessed the relationship between student-centered learning and 21st Century skills (4C’s) in a STEM and project-based learning environment. Results revealed a significant positive impact of student-centered learning on 21st Century skills. The constant (B=68.838) represents the expected 4C's score when student-centered learning is zero. Student-centered learning (B=0.448) positively affected 4C's skills, with a standardized coefficient (Beta) of 0.457.

The t-statistic (5.088) was highly significant ($p<0.001$), confirming the substantial positive influence. This supports the objective that student-centered learning activities positively impact 21st Century skills in the specified learning environment.

Thematic Analysis

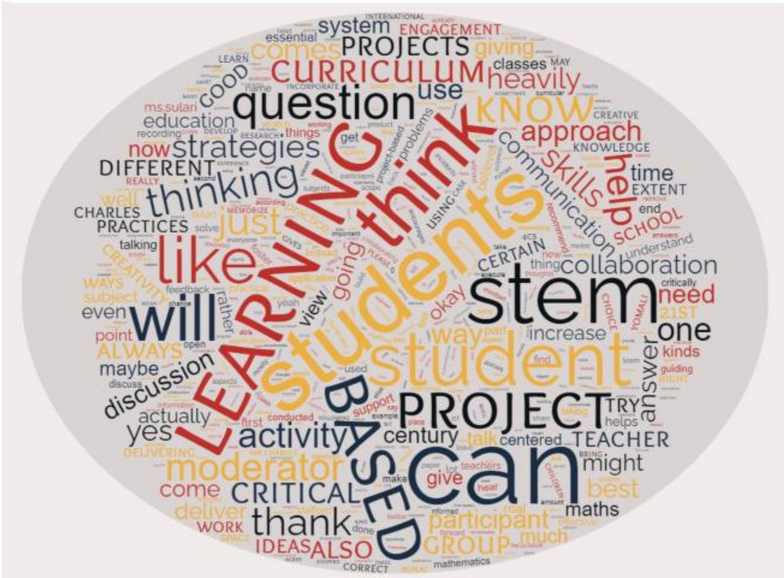

Figure 1: Word Frequency Chart from Teachers' Focus Group

The main themes emerged 4C's, project-based STEM learning and student-centred learning is in apparent agreement with the literature available. Among the sub themes catering to diverse learners relating to student-centred learning and purposeful learning process related to project-based STEM learning were noticeable. Figure 12 depicts the code references and Figure 13 illustrates the word frequencies of these results. Further, appendix 18 provides selected quotes for each theme identified.

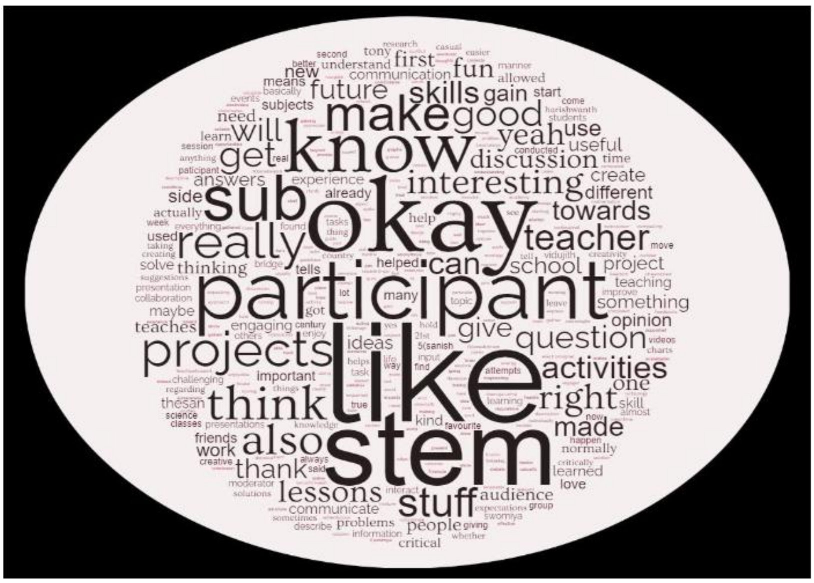

Figure 2: Word Frequency Chart from Students' Focus Group

The main themes emerged from students' focus group were 4C's, project-based STEM learning, and student-centred learning was in apparent agreement with the literature available. Among the sub themes learner satisfaction relating to student-centred learning and design and planning process related project-based STEM learning were noticeable. Figure 2 illustrates the word frequencies of these results.

4C's, project-based STEM learning and student-centred learning was found as sub themes in the survey questionnaire that was administered to gather quantitative data from the students. The word frequency chart is given in Figure 3.

Figure 3: Word Frequency Chart for the Survey Questionnaire

Qualitative findings could be further supported by the following extracts from the focus group interviews.

> Participant T2: "It encourages them to study the subject much more than when we compare it with a situation." "So, you apply those things where it is necessary, and it helps in, you know, Motivating the student and keeping."
>
> "So, we try as much as possible to bring the practical aspects of what we are learning into the subject. Uh, Maybe we can try to do it as a group activity."
>
> "We try to diversify a bit and try to implement different methods of approach to get the knowledge across."
>
> "It helps all kinds of students achieve their learning goals instead of just focusing on one type of student."
>
> Participant T2: "When it gives independent thinking skills for the students to stand on their ground, for their own opinion."
>
> Participant S6: "Come up with like problems and we'll have to, you know, think how to solve it. And sometimes we have events and stuff, which I think is really fun. And

also, I just think that A teaching is really good because it's like a more casual approach in my opinion."

Participant S4: "Give us examples of what we have to do. So he would show us, what he's expecting of us, and then he would point out what we can do to maybe improve and like go beyond his expectations and we would find it fun and we would normally meet his expectations."

Participant S1: "We are allowed to do anything. What we want or like related to STEM

Triangulation and Convergence

The qualitative findings of this study are in congruence with the existing body of research. As The findings propose integration of student-centered learning methodologies and project-based STEM education is mutually beneficial in fostering the development of the 4Cs, namely Critical Thinking, Creativity, Collaboration, and Communication. Student-centered learning, a pedagogical approach that prioritizes active participation, individualized exploration, and self-directed investigation (Means et al., 2014), aligns with project-based STEM education by positioning students as the focal point of their educational journey. The cultivation of autonomy in students fosters the development of critical thinking abilities, as they engage in the examination of problems, assess many potential solutions, and ultimately arrive at well-informed conclusions within the context of project-based learning (Partnership for 21st Century Skills, 2007). Moreover, the iterative and inquiry-based characteristics of student-centered learning are in perfect harmony with the problem-solving element of project-based STEM activities, creating a suitable atmosphere for the cultivation of innovative thinking and creativity.

project-based STEM education offers a tangible and contextualized platform for the utilization of information and skills obtained through student-centered learning. By engaging in practical assignments, students work together to address real-world STEM problems, so strengthening their abilities in collaboration and communication, as outlined by Bell (2010). The interaction between student-centered learning and project-based STEM approaches facilitates the acquisition of theoretical knowledge and its practical application through collaborative projects. This process enhances students' skills in effective communication and teamwork (Thomas, 2000). The integration of student-centered learning and project-based STEM education fosters a mutually beneficial learning environment that is congruent with the comprehensive development of the 4Cs, equipping students with the diverse set of skills necessary for achievement in the modern era.

Conclusion

A deeper exploration of the regression coefficients provides nuanced insights. The positive effect of student-centered learning on 4C's skills is quantified by a standardized coefficient (Beta) of 0.457, with the t-statistic's pronounced significance ($p < 0.001$) attesting to the substantive positive influence of these pedagogical approaches. These quantitative findings reinforce the assertion that student-centered learning activities are indispensable in positively shaping 21st Century skills within the designated project-based STEM learning environment. Qualitatively, participant testimonials further illuminate the positive impact of student-centered learning activities. Participants articulate how these pedagogical approaches foster independent thinking, enhance motivation, sustain engagement, and facilitate the practical application of knowledge through collaborative group activities. The qualitative narratives resonate with the quantitative outcomes, spotlighting the multifaceted advantages of student-centered learning in championing a diverse array of skills. These findings advocate for a steadfast emphasis on student-centered pedagogies, urging educators to embrace and refine these practices as they constitute a linchpin for nurturing a versatile skill set essential for triumph in the ever-evolving landscape of STEM disciplines and beyond.

Avenues for Future Research

The implementation of longitudinal research would provide significant contributions in understanding the enduring effects of project-based STEM education and student-centered learning on the continuous enhancement of 21st Century skills. By conducting longitudinal studies on students, researchers would have the opportunity to study the progression of skill acquisition and retention over an extended period. This would contribute to a more comprehensive comprehension of the long-term impacts of different educational approaches. The examination of the impact of cultural and socioeconomic factors on the correlation between educational methods and the development of 21st Century abilities is a promising avenue for research. The examination of how various cultural contexts and socioeconomic backgrounds influence the ways in which students engage with project-based STEM activities and student-centered learning has the potential to enhance educational methods that are culturally sensitive and inclusive. Tailoring Instruction for Different Age Groups: Considering the observed disparities in age within the current study, it would be beneficial for future research to explore the customization of instructional methodologies to cater to distinct age groups. Examining the impact of students' developmental stages on their involvement in project-based STEM activities and student-centered learning would yield practical knowledge for educators to modify their methodologies to effectively cater to the varying requirements of students during different phases of adolescence.

Limitations of the Study

In collecting quantitative data, the research utilized a sample size of 104 individuals chosen by a random stratified proportionate sampling method. Even though this strategy improves representativeness, the sample size may still be insufficient to capture the variety of experiences that middle school students have had with project-based STEM learning. Because of this, it is possible that the findings cannot be properly generalized to a larger population of pupils. There is a concern regarding response bias in quantitative data, even though random stratified proportionate sampling was utilized. It is possible that participants will provide socially desirable responses, which will affect the correctness of the quantitative data. The environment of the study may have an effect on the degree to which the responses of the participants provide an accurate reflection of their experiences and attitudes.

When considering the qualitative data utilization of two focus groups, which were chosen through the process of purposive sampling, it might not completely encompass the many points of view that are present within the participant pool. There is a possibility that the qualitative findings will be impacted by the particular qualities of the individuals who participated in the focus group. This could potentially restrict the ability of qualitative insights to be transferred to a more general setting. Dynamics of Focus Groups Due to the nature of focus group talks, there is a possibility that social desirability bias or dominating voices within the group could be introduced, which could have an impact on the qualitative data. The richness and authenticity of the qualitative findings may be impacted by the fact that some participants may be reluctant to share thoughts contrary to the group norms or may comply with the norms they perceive to be prevalent. The research was carried out in a particular middle school that is part of an international school in Sri Lanka because of the distinctive context of the school. It is possible that the findings cannot be generalized to other educational settings due to the specific characteristics of this particular school, which include its cultural and educational context. This is especially true for educational settings that have different curriculum frameworks or student demographics.

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