Effectiveness of Localized Context-Based STEM Education Approach on Teaching Science 6

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ABSTRACT

This study employed a one-group pretest–posttest experimental design to determine the effectiveness of a localized context-based STEM education approach in enhancing the conceptual understanding of Grade 6 learners at Sultan Naga Dimaporo Memorial Integrated School (SNDMIS), Lanao del Norte. Thirty-seven (37) pupils participated in the study during the Academic Year 2025–2026. A 20-item multiple-choice test aligned with the Science 6 curriculum was administered before and after the intervention. Data were analyzed using frequency, percentage, mean, and paired-sample t-test. Results revealed a significant improvement in learners' performance, with mean scores increasing from 13.51 (pretest) to 16.22 (posttest). Statistical analysis confirmed a significant difference between scores ($t = –9.50$, $p < 0.05$), indicating that the intervention contributed to enhanced conceptual understanding. Learners also demonstrated high engagement (grand weighted mean = 2.64), particularly in collaborative and hands-on activities. As part of the intervention, pupils designed a Coral Reef Water Cleaner prototype using recyclable materials. Evaluation results (90.8%–96.4%) reflected outstanding performance in creativity, functionality, and teamwork. These findings suggest that localized context-based STEM instruction enhances academic performance, engagement, and real-world application of scientific concepts.

Keywords: Context-Based Learning, STEM Education, Conceptual Understanding, and Experimental Research

INTRODUCTION

The Science Capital and STEM Capital teaching approaches encourage teachers to personalize and localize science and STEM content so that students can see how science is present in their everyday lives and in their communities, with the aim of enhancing engagement, aspiration, and achievement in science (Moote et al., 2020).

The context of STEM education instruction requires solving the real-world problem or task through teamwork. Another conceptualized idea of teaching and learning in STEM education was suggested by Williams (2019). He provided some practical ideas of STEM teaching and learning which focuses on processes and engagement of students in collaborative activity. He discussed that the principles of teaching and learning in STEM Education: (1) involves the integration of science, technology and mathematics, (2) is student centered, (3) engages students in collaborative activity, (4) focusses on processes, (5) occurs within the curriculum (is not extra-curricular); and (6) is project and/or problem based.

According to William (2019) he reminded some implications when students move on the processes of doing STEM activities. STEM education should focus more on process rather than content. The STEM education is important learning occurs through the activities of the process. However, content could be applied when the learning of content is necessary through an activity to a situation. It focuses on the activities of the process will also enable student to learn from failure. Therefore, teachers should not expect too much too soon from students. It will take time for them to get used to this complexity, and the progressive development from a simple approach to something more complex.

Furthermore, localized learning includes pedagogical approaches that use local contexts to enhance the relevance and authenticity of STEM education to students in primary and secondary schools. Pedagogical approaches are an example of school-level factors, which are a promising area of research given their potential malleability (van den Hurk et al., 2019). The STEM motivation scale, originally called "Development and practicing of a scale to measure students' STEM continuing motivation," developed by Luo et al. (2019), was used to reveal students' motivation levels for STEM. The scale was developed to measure the STEM motivations of 7th and 8th-grade students (Şimşek &Hamzaoğlu, 2022).

Despite the increasing emphasis on STEM education, its implementation at the elementary level—particularly in Science 6—remains limited, especially in terms of integrating localized and context-based strategies. Many instructional approaches still rely on abstract content delivery, which may reduce learners' ability to connect scientific concepts with real-life experiences.

This study addresses this gap by investigating the effectiveness of a localized context-based STEM education approach in improving learners' conceptual understanding, engagement, and academic performance. By situating learning within familiar environmental contexts, this research provides empirical evidence on how contextualized STEM instruction can enhance meaningful learning among elementary pupils.

Research objective

This study aimed to determine the effectiveness of a localized context-based STEM education approach in teaching Science 6 at Sultan Naga Dimaporo Memorial Integrated School (SNDMIS). Specifically, it sought to, describe the demographic profile of the respondents, assess learners' pretest and posttest performance, determine the significant difference between pretest and posttest scores and evaluate learners' level of engagement during the intervention.

Hypothesis

This study proposed that there is no significant difference between the pre-test and post-test scores of the pupils taught using the localized context-based STEM education approach.

Theoretical framework

A research framework for implementing the Localized Context-Based STEM Education Approach was anchored on several learning theories that emphasize the importance of experience, context, and social interaction in the learning process. Constructivist Learning Theory (Piaget, 1950; Vygotsky, 1978) underscores that learners actively build their understanding through experiences and social interactions. This aligns with localized STEM education, which enables students to construct scientific knowledge through engagement with familiar, real-life contexts. Contextual Learning Theory (Hull, 1995) emphasizes that learning becomes meaningful when new knowledge is connected to real-world situations. This supports the integration of local issues and community-based examples into Science instruction, allowing students to relate academic concepts to their everyday lives and develop applicable problem-solving skills. Situated Learning Theory (Lave & Wenger, 1991) further supports this approach by asserting that learning is most effective when it occurs within authentic contexts and communities of practice. Through hands-on, community-centered activities, students can apply scientific concepts in real-world environments, promoting deeper understanding and sustained engagement. Taken together, these theoretical foundations provide a strong basis for implementing a localized, context-based STEM approach in Science 6. By situating learning within students' local environment and experiences, the approach promotes active participation, meaningful learning, and improved conceptual understanding, while fostering problem-solving skills and real-world application of scientific knowledge.

RESEARCH METHODOLOGY

The study employed a one-group pretest–posttest experimental research design to determine the effectiveness of the localized context-based STEM education approach in teaching Science 6. Quantitative data were supported by descriptive observations of learner engagement during the implementation of the intervention. Data were collected through pretest and posttest assessments, engagement questionnaires, and prototype evaluation rubrics.

A purposive sampling technique was used in selecting the respondents. The participants consisted of thirty-seven (37) Grade 6 pupils from Section A of Sultan Naga Dimaporo Memorial Integrated School (SNDMIS), who were selected based on predefined criteria relevant to the objectives of the study.

The test instrument was validated by subject experts to ensure content alignment with the Science 6 curriculum. Reliability was established through pilot testing to ensure consistency of the measurement tool.

Data analysis involved both quantitative and descriptive techniques. Pretest and posttest scores were analyzed using frequency, percentage distribution, mean, and paired-sample t-test to determine whether a significant difference existed between learners' performance before and after the intervention. Engagement levels and prototype evaluation results were analyzed using weighted mean and descriptive interpretation.

Ethical considerations were strictly observed throughout the conduct of the study. Informed consent was obtained from the respondents prior to data collection to ensure voluntary participation. The respondents were fully informed of the purpose of the study, their rights as participants, and their option to withdraw at any time without penalty. Confidentiality and anonymity of responses were maintained to protect participants' privacy.

Research findings

Respondents' Profile

Table 4.1 presents the frequency and percentage distribution of the respondents according to their age. Out of the thirty-seven (37) pupils, the majority were 11 years old (f = 31, 83.78%), followed by those aged 12 (f = 3, 8.11%), 10 (f = 2, 5.41%), and 13 (f = 1, 2.70%). These results indicate that most of the respondents fall within the expected age range for Grade 6 learners. According to Piaget (1972), children around the age of 11 enter the formal operational stage, which allows abstract reasoning. Vygotsky also emphasized that effective learning occurs when instruction is linked to cultural and community contexts. Holmes et al. (2012) and Kostol & Remmen (2022) supported this by stating that localized STEM enhances comprehension when tied to real-life applications.

Table 6.1. Frequency and Percentage Distribution of the Respondent of the Demographic Profile in terms of Age (n=37)

Age	Frequency	Percentage
13	1	2.70
12	3	8.11
11	31	83.78
10	2	5.41

Table 4.2 shows the gender distribution of the respondents. Out of thirty-seven (37) pupils, 22 (59.46%) were female, while 15 (40.54%) were male. This reflects a slightly higher number of female participants in the study. The predominance of female respondents highlights the potential of localized STEM approaches to promote inclusivity in Science education. Female learners are often underrepresented in STEM fields, and providing meaningful, localized instruction may encourage greater participation.

According to Berger et al. (2020), gender differences in STEM often emerge early, placing female learners at a disadvantage. However, Moote et al. (2020) emphasized that localized and personalized instruction can enhance engagement among girls. Likewise, Freeman et al. (2019) highlighted the crucial role of teacher strategies in ensuring equitable participation in STEM classrooms.

Table 6.2. Frequency and Percentage Distribution of the Respondent of the Demographic Profile in terms of Gender (n=37)

Gender	Frequency	Percentage
Male	15	40.54
Female	22	59.46

Pretest and Posttest Gain Scores of the Respondents

Table 4.3 shows a clear improvement in pupils' performance from the pretest to the posttest. Initially, most respondents scored in the "High" (48.65%) and "Very High" (35.14%) categories, with a smaller portion in the "Low" category (16.22%) and none in "Very Low," indicating that pupils had a foundational understanding of Science but still needed reinforcement. After the intervention, all pupils scored either "High" (40.54%) or "Very High" (59.46%), with no scores in the lower ranges. This demonstrates that the localized STEM intervention effectively strengthened pupils' understanding, allowing them to build on prior knowledge and apply concepts more successfully. The elimination of lower scores also suggests that contextualized instruction helped address learning gaps and fostered more uniform achievement, reducing disparities and elevating overall mastery of scientific concepts. According to Simsek & Hamzaoglu (2023), contextualization improves comprehension, while Holmes et al. (2021) reported that linking Science to real-world contexts enhances motivation and test outcomes. Bybee & Williams (2013) also emphasized STEM's role in cultivating critical 21st-century skills.

Table 6.3 Frequency and Percentage Distribution of the Pupils' Pre-Test and Posttest Scores of the Respondents (n=37)

Score	Performance	Pretest		Posttest	
		F	%	F	%
16-20	Very High	13	35.14	22	59.46
11-15	High	18	48.65	15	40.54
6-10	Low	6	16.22	0	0.00
1-5	Very Low	0	0.00	0	0.00

Figure 4.1 presents the line graph compares the Pretest and Posttest scores of participants across four score ranges (1–5, 6–10, 11–15, and 16–20). As shown, the Pretest scores started low in the 1–5 range and gradually increased, peaking at the 11–15 range before slightly declining in the 16–20 range. In contrast, the Posttest scores show a consistent upward trend, starting from zero in the 1–5 range and increasing steadily up to the 16–20 range, where they reached the highest point.

This indicates that participants generally performed better in the posttest compared to the pretest. The improvement suggests that the intervention or learning activity conducted between the two tests had a positive impact on the participants' performance.

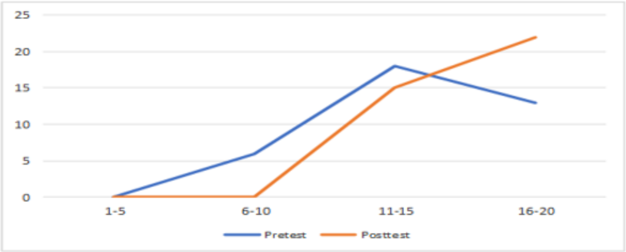

Figure 4.1 Line Graph of the Respondents' Pretest and Posttest Score

Difference Between Pretest and Posttest Gain Scores of the Respondents

Table 4.4 presents the difference between the pretest and posttest scores of the respondents in terms of mean, standard deviation (SD), t-value, and p-value. The results indicate a significant improvement in scores from pretest to posttest. The mean pretest score was 13.51 (SD = 3.18), while the mean posttest score increased to 16.22 (SD = 2.66), indicating improved performance after the intervention. A paired-samples t-test revealed a statistically significant difference between pretest and posttest scores, t(36) = –9.50, p < .001. The effect size, computed using Cohen's d for paired samples, was 0.92, indicating a very large practical effect. This suggests that the localized context-based STEM intervention had a substantial impact on learners' conceptual understanding beyond statistical significance. The negative t-value indicates that posttest scores were significantly higher than pretest scores, confirming the effectiveness of the intervention in improving pupils' Science performance. Consequently, the null hypothesis stating no significant difference between pretest and posttest scores is rejected. These results align with the findings of Holmes et al. (2021) and Kostøl & Remmen (2022), who reported that contextualized STEM learning enhances comprehension and retention by linking lessons to real-world contexts. Similarly, Simsek and Hamzaoglu (2023) emphasized that context-based instruction promotes meaningful learning, while Fraser et al. (2021) highlighted its role in increasing learner engagement. Therefore, the findings confirm that localized STEM-based instruction significantly improves pupils' understanding and mastery of Science concepts.

Table 6.4 Difference Between the Pretest and Posttest Gain Scores of the

Respondents (n=37)

Paired Scores	Mean	SD	t-value	p-value	Remark
Pretest	13.51	3.18			
Posttest	16.22	2.66	-9.50	0.000**	**Significant**

Note: **significant at .05 level

Level of Engagement of the Pupils

Table 4.5 presents the pupils' level of engagement during the intervention. Results reveal that most indicators were rated as "Highly Engaged," with weighted means ranging from 2.60 to 2.92. The highest score was recorded for "I listened carefully during the Science lesson" (WM = 2.92).

Five indicators were rated "Moderately Engaged," with the lowest being "I asked questions when I did not understand" (WM = 2.41). This suggests that although students actively participated in group activities, some were reluctant to ask questions individually. The grand weighted mean of 2.64 suggests a generally high level of engagement; however, closer examination of individual indicators reveals variability. Notably, the item "I asked questions when I did not understand" (WM = 2.41) falls within a moderate engagement range based on the scale. This indicates that while learners were active in collaborative tasks, independent inquiry and questioning behaviors were less developed.

These findings imply that the localized STEM approach successfully fostered attentiveness, collaboration, and enthusiasm among learners—qualities essential for meaningful classroom participation. However, the moderate results in questioning and independent confidence suggest the need for instructional strategies that encourage inquiry-based learning, self-directed exploration, and stronger real-life connections. Teachers may need to provide scaffolding and create a supportive classroom culture where students feel comfortable asking questions and applying concepts beyond the classroom. This also indicates the importance of designing activities that gradually transition from group collaboration to individual accountability in order to strengthen independent engagement.

According to Holmes et al. (2021) and Kostøl & Remmen (2022), localized context-based STEM fosters greater attentiveness, collaboration, and active participation among learners, which is consistent with the high engagement reflected in this study. Pupils were most engaged in listening and group activities, supporting Attard et al. (2021) who highlighted the role of such approaches in enhancing communication and problem-solving. However, the moderate ratings in questioning and independent work mirror the findings of Margot & Kettler (2019) and Littrell et al. (2020), who noted that students may still struggle with inquiry and self-directed learning. This implies that while localized STEM effectively boosts overall engagement, teachers should implement strategies that encourage questioning and independent exploration to maximize its benefits.

Table 6.5 Weighted Mean on Level of Engagement of the Respondents during the Intervention (n=37)

Indicators	**WM**	**Interpretation**
1. I listened carefully during the Science lesson.	2.92	Highly Engaged
2. I joined in the class activities or experiments during the Science lesson.	2.82	Highly Engaged
3. I felt excited to join group work and experiments during the Science class.	2.82	Highly Engaged
4. I stayed focused and did not get distracted during the Science class	2.6	Highly Engaged
5. I worked will with my group during the Science class.	2.71	Highly Engaged
6. I asked questions when I do not understand something in Science class.	2.41	Highly Engaged
7. I shared my ideas and helped my classmates during Science activities.	2.55	Highly Engaged
8. I related the Science lesson into real-life situations.	2.49	Highly Engaged
9. I felt confident to do experiments or activities by myself. 10. I reviewed or studied the Science lesson after class.	2.54 2.55	Highly Engaged Highly Engaged

Grand Weighted Mean 2.64 Highly Engaged

Evaluation Result of Coral Reef Water Cleaner Prototype

The prototype of the three groups was evaluated by the Science teachers of Sultan Naga Dimaporo Memorial Integrated School, together with invited visitors who served as guest judges, including school staff and community representatives. The evaluation was based on five criteria: Design and Creativity, Functionality, Use of Recycled Materials, Teamwork/Participation, and Explanation/Presentation. Each group presented and demonstrated their work, answered questions from the evaluators, and was scored accordingly. After the presentations, evaluators gave feedback, praising creativity, teamwork, and effective use of recycled materials, while suggesting improvements in presentation clarity and design refinement.

Group 1

Figure 4.7.1 Prototype of the Respondents and Application of their Prototype

Group 2

[redacted]

Figure 4.7.2 Prototype of the Respondents and Application of their Prototype

Group 3


[redacted]

Figure 4.7.3 Prototype of the Respondents and Application of their Prototype

The results showed Group 1 as the top performer with 482 points (96.4%), excelling in functionality and use of recycled materials. Group 2 followed with 472 points (94.4%), showing strong performance but slightly lower presentation scores. Group 3 scored 454 points (90.8%), doing well functionality but needing improvement in design and presentation. Overall, the critique highlighted each group's strengths and areas for growth, motivating them to keep innovating.

Table 6.6 Overall Evaluation Result of Coral Reef Water Cleaner Prototype.

Group	Percentage	Description	Verbal Interpretation
Group 1	96.40%	Excellent	Outstanding
Group 2	94.40%	Excellent	Outstanding
Group 3	90.80%	Excellent	Outstanding

DISCUSSION

` The findings of this study provide compelling empirical evidence that a localized context-based STEM education approach can enhance learners' conceptual understanding, engagement, and application of scientific knowledge in Grade 6 Science. Embedding scientific concepts within familiar environmental and community contexts appears to create meaningful learning experiences that extend beyond memorization and promote deeper cognitive processing. The significant improvement in learners' posttest scores (from $M = 13.51$ to $M = 16.22$, $t(36) = -9.50$, $p < .001$, $d = 0.92$) indicates that contextualized STEM instruction had a substantial effect on academic achievement. The large effect size further suggests that the observed improvement is not only statistically significant but also educationally meaningful.

These results support constructivist principles, which posit that knowledge is actively constructed through experience rather than passively received. In this study, learners functioned as active participants who designed, tested, and refined solutions to real-world environmental problems. This process likely facilitated deeper cognitive engagement and improved understanding of scientific concepts and processes. By situating learning within authentic contexts, the intervention enabled learners to connect abstract ideas to tangible experiences, thereby strengthening conceptual retention and transfer of learning.

In terms of engagement, learners demonstrated a high level of participation (grand mean = 2.64), particularly in collaborative activities, attentive listening, and hands-on tasks. This suggests that localized STEM instruction effectively promotes active involvement and sustained interest in Science lessons. The integration of real-world environmental issues and group-based prototype development likely contributed to increased motivation and engagement throughout the learning process.

However, a notable pattern emerged in relation to independent learning behaviors. Indicators related to questioning and self-directed inquiry received comparatively lower ratings, suggesting that while the intervention effectively supports collaborative engagement, it is less effective in fostering individual inquiry skills. This finding is consistent with previous research indicating that learners in structured STEM environments may initially rely on group dynamics and require intentional scaffolding to develop autonomous questioning and critical thinking abilities.

The prototype development activity further demonstrates the practical value of the intervention. Learners successfully applied integrated STEM concepts to design a Coral Reef Water Cleaner using recyclable materials, achieving outstanding evaluation ratings (90.8%–96.4%). These outcomes reflect not only conceptual understanding but also the development of creativity, collaboration, and problem-solving skills. Moreover, learners' ability to explain and justify their designs during evaluation indicates emerging scientific communication skills and conceptual clarity.

From a pedagogical perspective, the findings highlight the importance of contextualization in STEM education. Situating learning within local environmental issues appears to enhance learners' perception of relevance, thereby improving engagement and knowledge application. At the same time, the results underscore the need for instructional refinement, particularly in promoting inquiry-based behaviors such as questioning, investigation, and independent reflection.

Therefore, the findings suggest that localized context-based STEM instruction is an effective pedagogical approach for improving Science learning outcomes in elementary education. Its strength lies in bridging classroom learning with real-world application, thereby supporting both cognitive and affective development. However, to maximize its impact, future implementations should incorporate structured inquiry strategies that progressively develop learners' independence and critical thinking skills.

CONCLUSION

After analyzing the data from the implementation of the Localized Context-Based STEM Education approach, it was found that the respondents' demographic profile was typical of Grade 6 learners, with the majority being 11 years old and female pupils slightly outnumbering male pupils. These characteristics, however, did not significantly influence their performance in Science.

The intervention, which involved the integration of localized contexts and STEM strategies into classroom instruction, demonstrated a positive impact on learners' achievement. The comparison between pretest and posttest results revealed a statistically significant improvement, indicating that the approach effectively enhanced students' understanding of scientific concepts.

Learners actively engaged in contextualized learning activities that connected Science concepts to real-world situations. They participated in hands-on experiences such as creating waste material collages, educational posters, DIY projects, and graphical representations of observed data. These activities fostered creativity, critical thinking, and collaboration among learners, while also enhancing their appreciation for applied science in their daily lives. Quantitative results confirmed the effectiveness of the approach, with posttest scores significantly higher than pretest scores, demonstrating substantial gains in conceptual understanding and science process skills.

Learner reflections highlighted increased motivation, engagement, and enjoyment in learning Science through practical activities, reporting tasks, and collaborative projects. Overall, the study confirms the feasibility and effectiveness of the Localized Context-Based STEM Education approach. It not only improved student performance and conceptual understanding but also fostered positive attitudes toward science, creativity, and responsibility, emphasizing the value of contextualized, interactive, and inquiry-driven strategies in elementary Science education.

Suggestion

Based on the findings of the study, it is recommended that the localized context-based STEM education approach be integrated into the teaching of other Grade 6 Science topics, particularly those related to environmental systems and human–environment interactions. The observed improvement in learners' academic performance and engagement suggests that contextualized and hands-on STEM activities are effective in enhancing conceptual understanding and Science achievement.

To support effective implementation, teachers should be provided with targeted professional development on the design and delivery of localized STEM instruction. Training programs may focus on inquiry-based teaching strategies, collaborative learning approaches, and the development and assessment of STEM projects, as these components were found to contribute to learners' active participation and improved performance.

In addition, future classroom implementations should incorporate structured opportunities that promote learner independence and self-directed inquiry. While engagement levels were generally high, encouraging learners to ask questions, conduct simple investigations, and reflect on their learning may further strengthen critical thinking and inquiry skills.

The quality of STEM project outputs may also be enhanced by allocating sufficient time and resources for prototype design, testing, and refinement. Providing learners with extended opportunities to iterate on their designs can support the development of creativity, innovation, and engineering skills.

Finally, future research is recommended to examine the long-term effects of the localized context-based STEM education approach across different grade levels and learning contexts. Studies employing larger samples, longer intervention periods, and controlled experimental designs may provide stronger evidence of its impact on academic achievement, learner engagement, and environmental awareness.

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