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ORIGINAL

Enhancing students' conceptual understanding through contextualized STEM approach: advancing science literacy in health and education

Mejorar la comprensión conceptual de los estudiantes a través de un enfoque STEM contextualizado: promover la alfabetización científica en la salud y la educación

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ABSTRACT

Introduction: understanding plant asexual reproduction is vital for fostering scientific literacy, especially in agriculture, biodiversity, and sustainability. Yet, students often struggle with these abstract concepts due to limited contextualization and practical application in traditional instruction. This study examined the effectiveness of a Contextualized STEM Approach in improving students' conceptual understanding, performance, and perceptions.
Method: a quantitative one-group pretest-posttest design was employed with 105 Grade 7 students from a public secondary school in Iligan City. Data were collected through a researcher-made pretest and posttest, a perception survey, and performance task scores. Analyses included descriptive statistics and paired t-tests to determine conceptual gains and intervention effects.
Results: findings revealed a significant increase in posttest scores (MD = -10,84, t = -40,996, p < 0,001). More students attained Mastery and Proficient levels, while those in the Unsatisfactory category decreased by 20 %. Most groups achieved the Advanced level in performance tasks, demonstrating effective application of propagation techniques. Survey responses showed strong agreement that lessons were relevant, clear, and engaging.
Conclusions: the Contextualized STEM Approach enhanced students' conceptual understanding, performance, and motivation in learning plant asexual reproduction. These results affirm its potential as an effective pedagogical strategy in science education. Future studies may investigate its scalability across varied topics and learner groups.

Keywords: Contextualized STEM Approach; Plant Asexual Reproduction; Conceptual Understanding; Science Education; Student Engagement.

RESUMEN

Introducción: comprender la reproducción asexual de las plantas es vital para fomentar la alfabetización científica, especialmente en agricultura, biodiversidad y sostenibilidad. Sin embargo, los estudiantes a menudo tienen dificultades con estos conceptos abstractos debido a la limitada contextualización y aplicación práctica en la instrucción tradicional. Este estudio examinó la eficacia de un Enfoque STEM Contextualizado

para mejorar la comprensión conceptual, el rendimiento y las percepciones de los estudiantes.
Método: se empleó un diseño cuantitativo de preprueba y posprueba de un solo grupo con 105 estudiantes de 7.º grado de una escuela secundaria pública de la ciudad de Iligan. Los datos se recopilaron mediante una preprueba y una posprueba elaboradas por el investigador, una encuesta de percepción y puntuaciones de tareas de rendimiento. Los análisis incluyeron estadística descriptiva y pruebas t pareadas para determinar las mejoras conceptuales y los efectos de la intervención.
Resultados: los hallazgos revelaron un aumento significativo en las puntuaciones de la prueba posterior (MD = -10,84, t = -40,996, p < 0,001). Un mayor número de estudiantes alcanzó los niveles de Dominio y Competente, mientras que aquellos en la categoría Insatisfactorio disminuyeron un 20 %. La mayoría de los grupos alcanzaron el nivel Avanzado en las tareas de rendimiento, demostrando una aplicación eficaz de las técnicas de propagación. Las respuestas de la encuesta mostraron un fuerte consenso en cuanto a la relevancia, claridad y motivación de las lecciones.
Conclusiones: el Enfoque STEM Contextualizado mejoró la comprensión conceptual, el rendimiento y la motivación de los estudiantes en el aprendizaje de la reproducción asexual de las plantas. Estos resultados confirman su potencial como una estrategia pedagógica eficaz en la educación científica. Estudios futuros podrían investigar su escalabilidad en diversos temas y grupos de estudiantes.

Palabras clave: Enfoque STEM Contextualizado; Reproducción Asexual de las Plantas; Comprensión Conceptual; Educación Científica; Participación Estudiantil.

INTRODUCTION

Learning about plant asexual reproduction is increasingly essential due to its significant implications for agriculture, biodiversity conservation, and ecosystem sustainability. Asexual reproduction, particularly through mechanisms like apomixis, enables the production of clonal offspring without fertilization, facilitating the rapid and efficient propagation of desirable genotypes.[1,2] This method helps preserve valuable traits in crops such as rice and potatoes and plays a critical role in promoting food security amid intensifying environmental stressors.[3,4] Additionally, understanding asexual reproduction contributes to managing plant populations in changing ecosystems, as many species exhibit facultative asexuality—shifting between sexual and asexual reproduction depending on environmental conditions.[5,6] This reproductive flexibility enhances plant adaptability and survival, particularly in marginal habitats.[7] Thus, comprehensive knowledge of the mechanisms and ecological significance of plant asexual reproduction is instrumental in improving agricultural practices and fostering ecosystem resilience in the face of global challenges such as climate change and habitat loss.[8,9]

However, students often face challenges in understanding plant asexual reproduction, which may hinder both their conceptual grasp and knowledge retention. One major issue is the inherent complexity of concepts such as apomixis and vegetative propagation, which involve biological mechanisms not always observable in typical sexual reproduction.[2] Moreover, limited access to practical laboratory experiences restricts students' opportunities to witness real-life examples of asexual reproduction, further distancing theoretical learning from concrete observation. Despite these difficulties, the literature reviewed did not identify specific studies that address such gaps in standard classroom settings. Another difficulty lies in students' limited understanding of the genetic consequences of asexual reproduction, including reduced genetic diversity and its implications for adaptability.[10] As a result, students may develop misconceptions about its ecological and agricultural relevance, which hinders their ability to apply this knowledge in real-world contexts.[11]

To address these learning challenges, contextualized learning has emerged as a valuable instructional approach. By connecting academic content with real-world scenarios, contextualized learning enhances student engagement, deepens understanding, and improves knowledge retention.[12] It encourages meaningful interactions between students and teachers, thereby increasing motivation and supporting more effective learning.[13] Aligned with educational theories such as situated cognition and constructivism, this approach emphasizes the importance of learning in authentic contexts, promoting critical thinking and problem-solving skills.[14] Research has shown that contextual strategies can significantly boost student interest and academic performance across disciplines.[15] Ultimately, contextualized learning transforms the educational experience into one that is dynamic, interactive, and relevant, preparing learners for academic success and professional competence.[16]

Complementing this approach, the STEM (Science, Technology, Engineering, and Mathematics) framework offers a powerful interdisciplinary structure that enhances student learning and engagement. STEM education bridges theoretical knowledge and practical application through hands-on, collaborative projects, fostering critical thinking and problem-solving abilities.[17] Studies have shown that students engaged in STEM activities exhibit increased self-efficacy and motivation—key drivers of academic success and sustained interest in STEMrelated fields.[18,19] Moreover, integrating STEM disciplines helps students recognize the real-world relevance of their studies, promoting deeper understanding and a more enriching learning experience.[20] It also cultivates 21st-century skills such as creativity, communication, and collaboration, which are essential in today's rapidly evolving global landscape.[21,22]

The integration of contextualized learning and the STEM approach creates a synergistic educational model that significantly enhances student engagement, motivation, and comprehension of complex topics. Contextualized STEM education immerses students in authentic problem-solving scenarios that bridge academic concepts and real-life applications.[23] Through project-based learning, students explore scientific, technological, engineering, and mathematical principles in an interconnected manner, promoting deeper learning and creative thinking.[24] This integrated strategy not only strengthens students' problem-solving capabilities but also deepens their appreciation for the societal relevance of STEM disciplines.[25] In turn, it equips learners with the competencies necessary for future success, empowering them to become agile, informed, and innovative contributors in a rapidly changing world.[26]

Plant asexual reproduction plays a critical role in agriculture, biodiversity conservation, and ecological sustainability, particularly as it allows the preservation and rapid propagation of desirable traits essential for food security in the face of climate change and environmental stressors. Despite its significance, many junior high school students exhibit limited conceptual understanding of plant asexual reproduction, as evidenced by persistent misconceptions, difficulty in grasping abstract biological mechanisms such as apomixis and vegetative propagation, and minimal opportunities for practical application in traditional classroom settings. These challenges hinder not only their mastery of the topic but also their ability to appreciate its relevance to real-world issues in agriculture and environmental management. This gap in understanding raises an urgent question: How can a Contextualized STEM Approach effectively enhance students' conceptual understanding, performance, and perceptions in learning plant asexual reproduction, a topic often found abstract and disconnected from their lived experiences?

The magnitude of this problem lies in its direct impact on students' science literacy and preparedness to engage in agriculture- and environment-related issues critical to national development. Addressing it is therefore essential not only for improving classroom learning outcomes but also for contributing to broader educational and societal goals. In light of these insights, this study aims to: (1) measure students' conceptual understanding of plant asexual reproduction before and after instruction using a Contextualized STEM Approach; (2) evaluate students' performance in STEM-based learning activities; and (3) examine students' perceptions and experiences regarding the use of the Contextualized STEM Approach in learning plant asexual reproduction.

Statement of the hypothesis

H0: there is no significant difference in the conceptual progress of students before and after the implementation of the STEM approach.

H1: there is a significant difference in the conceptual progress of students before and after the implementation of the STEM approach

METHOD

Research Design

This study employed a quantitative one-group pretest-posttest design to evaluate the effectiveness of the Contextualized STEM Approach in teaching plant asexual reproduction. This design was chosen for its ability to measure students' conceptual gains and assess changes in performance and perceptions resulting from the intervention. A researcher-made pretest and posttest were administered to determine students' conceptual understanding before and after the lessons. In addition, a structured perception survey and a validated performance task rubric were used to gather data on student engagement, applied knowledge, and the instructional strategy's effectiveness. The use of this design enabled a systematic evaluation of the intervention's impact, providing evidence on how contextualized STEM instruction can address persistent learning challenges and enhance conceptual understanding among junior high school students.

Research Participants

The universe of this study consisted of all Grade 7 students enrolled in the selected public secondary school in Iligan City during the academic year 2024-2025, totaling 327 students across nine sections. From this population, a sample of 105 students from three sections was purposively selected based on two key criteria: (1) their current enrollment status and (2) their lack of prior exposure to formal lessons on plant asexual reproduction. The sample size was determined using Slovin's formula with a 5 % margin of error, ensuring that the group was statistically representative of the larger population.

All sampled students participated in the study's phases, including the administration of a pretest, the contextualized STEM-based instructional intervention, a posttest, performance tasks, and a perception survey.

To ensure objectivity and adherence to academic standards, a qualified science teacher with more than three years of teaching experience served as the external evaluator for performance tasks. The evaluator employed a validated rubric aligned with Department of Education standards to assess students' applied knowledge and skills. The inclusion of both learner-respondents and an independent evaluator strengthened the reliability and validity of the collected data, particularly in measuring students' conceptual understanding, performance, and engagement.

Data Gathering Procedure

The data collection process followed a structured sequence beginning with the administration of a pretest to assess students' baseline understanding of plant asexual reproduction. Following this, the Contextualized STEM Approach was implemented through a series of lessons designed to integrate real-world contexts with interdisciplinary STEM principles. During this instructional phase, students engaged in interactive activities, collaborative problem-solving tasks, and performance-based assessments aligned with the curriculum. After the intervention, a posttest was administered to evaluate conceptual gains. To assess students' application of learning, a performance task was given and rated using a rubric validated by science education experts and aligned with DepEd standards. Additionally, a structured perception survey was distributed to gather quantitative data on students' views and experiences regarding the Contextualized STEM Approach. Throughout the process, observational notes and key feedback from the evaluating teacher were also recorded to supplement and contextualize the quantitative findings.

Performance Task Scoring Scale

To evaluate students' applied knowledge and skills in plant propagation, a performance task was assessed using a validated rubric aligned with Department of Education standards. The rubric employed the following four-point scale:

- Advanced (16-20 points): demonstrates thorough understanding and highly accurate application of concepts and procedures, with clear documentation and minimal to no errors.
- Beyond (11-15 points): shows good understanding and correct application of most concepts and procedures, with minor errors that do not significantly affect the outcome.
- Competent (6-10 points): displays partial understanding and application of concepts, with notable errors or gaps in execution.
- Not yet competent (1-5 points): indicates very limited understanding and significant errors, requiring further instruction and support.

Data Analysis

The data collected in this study were analyzed using quantitative methods to evaluate the effectiveness of the Contextualized STEM Approach. Pretest and posttest scores were subjected to a paired t-test at a 95 % confidence level, with the critical p-value set at 0,05. This test was employed to determine whether there was a statistically significant difference in students' conceptual understanding before and after the intervention. In addition, descriptive statistics—including means, percentages, and standard deviations—were computed to summarize the results of the performance tasks and perception survey. These statistical measures provided a clear picture of students' conceptual gains, engagement, and overall experiences with the instructional strategy. The use of these analyses ensured an objective and reliable evaluation of the intervention's impact on student learning outcomes.

Ethical Considerations

The study strictly adhered to ethical standards throughout its conduct. Prior to data collection, informed consent was obtained from the students' parents or guardians, while student participants provided assent, ensuring voluntary participation. All participants were informed of their right to withdraw from the study at any time without any academic or personal consequences. The research activities were carefully designed to align with the existing curriculum and were monitored to ensure a safe, respectful, and supportive learning environment, thereby minimizing any potential physical or psychological risks. Additionally, the study underwent ethical review and was granted formal approval by the appropriate institutional ethics committee before implementation. Confidentiality and anonymity were maintained throughout the research process, with all data treated with strict confidentiality and used solely for academic and research purposes.

RESULTS

Table 1 presents the pretest distribution of students' conceptual understanding prior to the implementation of the Contextualized STEM Approach. Results show that nearly two-thirds of the students (63,81 %) fell within the Unsatisfactory and Needs Improvement categories, indicating a limited grasp of plant asexual reproduction.

Notably, no student achieved the Mastery level, underscoring a significant baseline knowledge gap. These findings highlight the necessity of an innovative instructional approach to enhance students' understanding and address persistent misconceptions.

Table 1. Students' conceptual gain in the pretest on plant asexual reproduction, Grade 7 students, Iligan City public secondary school, school year 2024–2025

Score	Frequency	Percentage	Interpretation
27-30	0	0	Mastery
24-26	11	10,48	Proficient
21-23	27	25,71	Satisfactory
18-20	22	20,95	Needs Improvement
0-17	45	42,86	Unsatisfactory
	105	100	Total: 105

Table 2. Students' conceptual gain in the posttest on plant asexual reproduction, Grade 7 students, Iligan City public secondary school, school year 2024–2025

Score	Frequency	Percentage	Interpretation
27-30	17	16,19	Mastery
24-26	23	21,90	Proficient
21-23	23	21,90	Satisfactory
18-20	18	17,14	Needs Improvement
0-17	24	22,86	Unsatisfactory
	105	100	Total: 105

Table 2 shows a clear improvement in students' conceptual understanding after the intervention. The proportion of students in the Mastery and Proficient levels increased markedly (from 0 % to 16,19 % and from 10,48 % to 21,90 %, respectively), while those in the Unsatisfactory category decreased from 42,86 % to 22,86 %. These results demonstrate the effectiveness of the Contextualized STEM Approach in enhancing students' comprehension.

Table 3. Comparative distribution of students' conceptual gain in the pretest and posttest results on plant asexual reproduction, Grade 7 students, Iligan City public secondary school, school year 2024–2025

Score Range	Percentage Change	Interpretation
27–30	+16,19	Mastery
24–26	+11,42	Proficient
21–23	–3,81	Satisfactory
18–20	–3,81	Needs Improvement
0–17	–20,00	Unsatisfactory

Table 3 highlights substantial gains in learning outcomes. The Mastery and Proficient levels increased by 16,19 % and 11,42 %, respectively, while the Unsatisfactory category declined by 20 %. This upward shift confirms the positive impact of the intervention in raising students' conceptual understanding.

Table 4. Paired sample test of pretest and posttest scores on plant asexual reproduction, Grade 7 students, Iligan City public secondary school, school year 2024–2025

	Mean	MD	SD	t-value	P-value
Pretest	10,65	-10,84	4,68	-40,996	<0,001
Posttest	21,50		4,94		

Table 4 reports a statistically significant increase in posttest scores compared to pretest scores (MD = -10,84, t = -40,996, p < 0,001). At the 95 % confidence level (p < 0,05), the computed p-value falls well below the threshold, leading to the rejection of the null hypothesis (H_0), which stated that there is no significant difference in students' conceptual progress before and after the intervention. Consequently, the alternative hypothesis (H_1) is accepted, confirming that the Contextualized STEM Approach significantly improved students' conceptual understanding of plant asexual reproduction.

Table 5. Performance task results of students in plant propagation, Grade 7 students, Iligan City public secondary school, school year 2024–2025

Group	Total Score	Performance Level
Group 1	16	Advanced
Group 2	19	Advanced
Group 3	13	Beyond
Group 4	20	Advanced
Group 5	14	Beyond
Group 6	20	Advanced
Group 7	9	Competent
Group 8	17	Advanced
Group 9	18	Advanced
Group 10	19	Advanced
Group 11	20	Advanced
Group 12	15	Beyond
Group 13	20	Advanced
Group 14	19	Advanced
Group 15	20	Advanced

Table 5 indicates that the majority of student groups achieved high performance, with 66,67 % rated as Advanced. This demonstrates students' ability to apply their conceptual understanding to practical plant propagation tasks, reflecting the approach's effectiveness in bridging theory and practice.

Table 6. Students' perception of the contextualized STEM lesson on plant asexual reproduction, Grade 7 students, Iligan City public secondary school, school year 2024–2025

Statements	Mean	Descriptions
1. The contextualized STEM lesson helped me understand the lesson.	3,50	Strongly Agree
2. The presentation of concepts in the contextualized STEM lesson is clear and appropriate to my needs.	3,52	Strongly Agree
3. I could easily understand the explanations provided by the contextualized STEM lesson.	3,46	Strongly Agree
4. I learned some useful information not mentioned in the worksheet after using the contextualized STEM lesson.	3,39	Strongly Agree
5. The time allotment is adequate for each lesson.	3,43	Strongly Agree
6. Activities and tasks given in the contextualized STEM lesson were very easy.	3,37	Strongly Agree
7. I had fun reading and doing all activities required in the contextualized STEM lesson.	3,64	Strongly Agree
8. Contextualized STEM lessons used words and terms suited to my reading comprehension.	3,49	Strongly Agree
9. Contextualized STEM lessons inspired and encouraged me to learn more topics in Biology.	3,60	Strongly Agree
10. I want to use Contextualized STEM lessons for learning next time.	3,56	Strongly Agree

Table 6 reveals that students strongly agreed the lessons were clear, engaging, and relevant, with the highest rating ($M = 3,64$) given for enjoying the activities. Overall, the survey confirms that the Contextualized STEM Approach was positively received and fostered motivation and interest in learning biology.

DISCUSSION

The integration of a contextualized STEM approach in teaching offers significant educational benefits, particularly in enhancing students' conceptual understanding, engagement, and skill development when tackling complex scientific topics. By grounding lessons in real-life contexts, this approach bridges the gap between abstract theories and practical applications, thereby making learning more relevant and meaningful. For example, in teaching plant asexual reproduction, educators can connect lessons to local agricultural practices, such as vegetative propagation in backyard gardening or nearby farms. This not only contextualizes scientific content but also allows learners to examine the ecological and societal implications of asexual reproduction within their communities.[27]

A key strength of this approach lies in its ability to develop students' critical thinking and problem-solving skills. Contextualized STEM instruction challenges learners to analyze real-world scenarios, evaluate possible solutions, and make evidence-based decisions—cognitive abilities essential in biology. Mastery of concepts such as apomixis or vegetative propagation requires more than rote memorization; it demands connecting these processes to broader issues like food security, agricultural sustainability, and ecological adaptation.[28]

Equally important, the approach fosters collaboration and communication through group-based problem-solving tasks. Such cooperative learning not only enhances interpersonal skills but also mirrors the interdisciplinary nature of real-world challenges, aligning well with the expectations of modern workplaces that emphasize cross-functional teamwork.[29]

Another advantage is the increased student motivation and engagement it brings. When learners recognize the relevance of lessons to their daily lives and future aspirations, their interest and participation increase. This sense of ownership over learning often translates into deeper involvement and sustained exploration of the subject matter.[27]

Recent studies further support the effectiveness of contextualized STEM approaches in teaching asexual reproduction. For instance, a study on the annelid *Pristina leidyi* provided insights into gene expression during regeneration and asexual reproduction, enriching students' understanding by linking molecular biology with evolutionary and ecological principles, thereby fostering scientific inquiry.[30] Similarly, research on *Potamogeton crispus* revealed how ecological conditions shape reproductive strategies, underscoring the importance of contextualized examples to illustrate the interplay between environment and reproduction.[31] Complementary findings on freshwater cnidarians highlighted how biological adaptations can be woven into teaching materials to enhance conceptual depth.[32]

Beyond content integration, teacher preparedness is crucial for successful implementation. In Vietnamese high schools, educators' perceptions and competencies were shown to strongly influence the effectiveness of STEM approaches, pointing to the need for sustained professional development.[33] Moreover, the integration of technology, such as Arduino-enhanced teaching materials, offers innovative ways to engage learners in complex topics like asexual reproduction through hands-on, interactive experiences.[34]

Finally, the role of cognitive factors must not be overlooked. Studies in STEM education highlight that understanding learners' cognitive engagement supports the design of instructional strategies that enhance motivation and performance.[34] Tailoring STEM lessons with these insights can further strengthen outcomes in biology education.

In sum, the contextualized STEM approach provides a robust framework for teaching plant asexual reproduction by combining ecological contexts, technological tools, and collaborative strategies. The evidence demonstrates its potential to enhance not only conceptual understanding but also student motivation, critical thinking, and problem-solving skills. As research on this pedagogy expands, educators are encouraged to integrate these insights into practice to create more engaging, relevant, and impactful biology instruction.

CONCLUSIONS

This study set out to examine the effectiveness of the Contextualized STEM Approach in teaching plant asexual reproduction among Grade 7 students. In relation to the first objective, the significant improvement in posttest scores confirms that the intervention effectively enhanced students' conceptual understanding of the topic. Addressing the second objective, students' high-performance levels in plant propagation tasks demonstrate their ability to apply theoretical knowledge to practical contexts, reflecting the approach's capacity to promote meaningful learning. Regarding the third objective, the perception survey revealed strong agreement that the lessons were clear, engaging, and relevant, highlighting the positive reception of the instructional strategy.

Taken together, these findings indicate that the Contextualized STEM Approach is an effective pedagogical method for addressing conceptual difficulties in biology, as it simultaneously improves understanding, supports application, and fosters motivation. However, the presence of students who remained in the Needs Improvement and Unsatisfactory categories suggests the necessity of incorporating differentiated instruction to ensure more inclusive learning gains. Future research may build on these results by testing the approach across other topics, grade levels, and learning environments to establish its broader applicability and long-term impact.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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