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The Influence of a STEM-Based Approach on the Students' Academic Achievement in Genetics

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ABSTRACT

This research explored the impact of a STEM-based approach on the academic achievement of the grade 8 students in genetics. By incorporating Science, Technology, Engineering, and Mathematics (STEM) into genetics teaching, the study aimed at investigating the potential of a STEM-based approach as a teaching strategy in establishing fundamental concepts and deepen understanding of genetics, and improve their academic achievement in a specific period by using the researcher-developed and validated training packet in genetics. A quasi-experimental design was employed, featuring pre-test and post-test evaluations of two groups: one taught through conventional methods and the other with STEM-based techniques. The results revealed a notable enhancement in the academic achievement of students who were taught using the STEM method, demonstrating its effectiveness in promoting critical thinking, problem-solving, and collaboration. These findings highlighted the transformative potential of STEM approaches in reshaping science lessons and equipping students for the challenges of the 21st century.

INTRODUCTION

The integration of STEM (Science, Technology, Engineering, and Mathematics) approaches in education has gained significant attention as a transformative method for enhancing student learning outcomes. STEM-based teaching strategies emphasize interdisciplinary learning, critical thinking, and problem-solving skills, which are essential for addressing complex scientific concepts such as genetics. Genetics, a fundamental branch of biology, involves the study of heredity and variation in organisms, and its intricate nature often poses challenges for learners at the secondary education level.

Research indicates that STEM-based approaches can improve students' academic performance by fostering engagement and a deeper understanding of scientific concepts (Adeyanju, 2023). For instance, the use of innovative teaching models, such as the Johnson and Johnson Model of Learning Together, has been shown to enhance students' comprehension and retention of genetic concepts (Adeyanju, 2023). Similarly, interventions like PEPs (Puzzles, Edmodo, and Punnet Blocks) have demonstrated effectiveness in bridging learning gaps and increasing mastery of genetics topics among STEM students (Arquero, 2021).

Grade 8 students often face several challenges when learning genetics due to the complexity and abstract nature of the subject (Haskel-Ittah & Yarden, 2021). A lot of specialized vocabulary and terminology in genetics can be difficult for students to understand and remember (Knippels, Waarlo, & Boersma, 2005). Mendelian genetics requires an understanding of probability and ratios, which can be challenging for students who struggle with mathematical concepts (Knippels, Waarlo, & Boersma, 2005). Also, many genetic concepts are abstract and not directly observable, making it hard for students to grasp without hands-on activities and visual aids (Banet & Ayuso, 2000). In addition, understanding cytological processes like meiosis and mitosis can be complex due to their microscopic nature and the need for prior knowledge of cell biology (Knippels, Waarlo, & Boersma, 2005). More so, students often come with preconceived notions about genetics that can interfere with learning new concepts leading to misconceptions (Haskel-Ittah & Yarden, 2021). Using a STEM-based approach in teaching

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genetics, the concepts of Science, Mathematics, Technology, and Engineering are being integrated to address the challenges experienced by students.

METHODOLOGY

This study utilizes a quasi-experimental design static group comparison. The design establishes the comparison of the academic achievement between the experimental group (taught using the STEM-based approach) and the control group (taught with traditional methods). The participants are the seventy-four (74) grade 8 students of Rizal National High School, a junior high school of the Department of Education Schools Division of Misamis Oriental. The selection process involves random sampling, ensuring unbiased selection of participants. Parental consent is obtained before the students participate in the study. The instruments of this study are the validated researcher-made training packet in genetics, pre-test and post-test, multiple-choice and open-ended questions on genetics, aligned with the Grade 8 curriculum (MELC). Interviews are also conducted with selected students to gather qualitative insights.

RESULTS AND DISCUSSIONS

Academic Achievement of the Experimental Group before and after using STEM-Based Approach in Genetics

	N	Minimum	Maximum	Mean	Std. Deviation
ELearners	37	1	37	19.00	10.824
EPretest	37	6	17	10.86	2.859
EPosttest	37	10	26	17.19	4.142
Valid N (listwise)	37				

Table 1.
Mean of Pretest and Posttest before and after using STEM-Based Approach in Genetics

Table 1 shows the mean of the academic achievement of grade 8 students who belong to the experimental group before and after using a STEM-based approach in learning genetics. The result stipulates that conducting lessons in genetics at the grade 8 level using STEM-based approach yielded significant improvements in students' academic performance. The pre-test mean score is 10.86, while the post-test mean score increased significantly to 17.19. This notable change highlights the impact of the STEM-based instructional strategy in enhancing students' comprehension and achievement.

The pre-test mean score reflects the baseline knowledge of students before being exposed to STEM-based teaching methods. Genetics, as a subject, often poses challenges due to its complex and abstract concepts. Conventional teaching methods may fail to engage students effectively or provide sufficient scaffolding to build their understanding. According to Yoon et al. (2007), interactive and integrative approaches like STEM encourage active participation and the application of real-world problem-solving skills, fostering deeper learning outcomes.

The post-test scores, showing a mean improvement of more than 6 points, illustrate how the STEM-based approach supports cognitive engagement. STEM emphasizes interdisciplinary learning, wherein science (Genetics) is connected to technology, engineering, and mathematics. This integrative method creates a practical context for abstract concepts, making them more relatable and easier to understand for students (Becker & Park, 2011).

Moreover, the increase in mean scores suggests that STEM-based teaching impacts not only academic achievement but also the ability to retain and apply knowledge. Studies by Freeman et al. (2014) have demonstrated that active learning strategies, such as those employed in STEM education, significantly enhance students' performance in STEM-related subjects compared to traditional lecture-based teaching.

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The remarkable improvement in academic performance post-intervention underscores the transformative potential of STEM-based approaches. The data indicate that such strategies are instrumental in overcoming learning barriers in genetics and fostering academic success among Grade 8 students.

Academic Achievement of the Control Group using the Conventional Method in Learning Genetics

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
CLearners	37	1	37	19.00	10.824
CPretest	37	6	17	10.89	2.856
CPosttest	37	7	18	11.38	2.822
Valid N (listwise)	37				

Table 2.
Mean of Pretest and Posttest of the Control Group using the Conventional Learning Methods in Genetics

Table 2 shows the mean score of pretest and posttest of the grade 8 students who belong to the control group using the conventional learning methods in genetics. The comparison of pre-test and post-test scores, with means of **10.89** and **11.38,** respectively, demonstrates a minimal increase in students' academic performance when employing the conventional learning methods in teaching genetics. This limited improvement suggests that while the conventional learning methods may provide a structured and familiar learning environment, they are potentially insufficient for engaging students with the abstract and challenging concepts of genetics.

Traditional teaching methods often rely on lectures, rote memorization, and teacher-centered approaches. Although these strategies ensure the delivery of content, they frequently lack the interactive and application-based learning opportunities needed to deepen students' understanding of complex subjects. According to Novak (2010), passive forms of learning, such as those encouraged by traditional methods, often fail to foster critical thinking and active engagement, which are essential for mastering science-related topics.

The slight increase in the post-test mean (from 10.89 to 11.38) could be attributed to the repetition of material and the students' gradual familiarity with the concepts being taught. However, genetics, as a subject, requires not only the recall of information but also the ability to apply and connect concepts, such as inheritance patterns, gene expression, and molecular processes. Trilling and Fadel (2009) argue that conventional learning methods may not sufficiently encourage students to engage in higher-order thinking, which limits the extent of knowledge retention and application.

Moreover, compared to the significant improvements often observed with more active and integrative approaches, such as STEM-based methods, the traditional approach may not fully address diverse learning styles or stimulate curiosity. As highlighted by Freeman et al. (2014), active learning approaches consistently outperform traditional methods in improving academic performance, particularly in STEM-related disciplines. The modest increase in mean scores here underlines the challenges faced when employing traditional methods to teach a subject as dynamic and complex as genetics.

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The Academic Achievement of the Experimental and Control Group using STEM-Based Approach and Conventional Learning Method in Genetics

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 2	EPretest - CPretest	.000	.236	.039	-.079	.079	.000	36	1.000
Pair 3	EPosttest - CPosttest	5.811	3.134	.515	4.766	6.856	11.277	36	.000

Table 3.
Comparison of the Academic Achievement between the Experimental and Control Group

Table 3 shows the difference in the academic achievement of both the experimental and control groups taught with a STEM-based approach and traditional learning methods in genetics. A t-value of **11.277** represents a substantial and statistically significant difference between the effectiveness of a STEM-based approach and the traditional teaching method in learning genetics. This outcome has important implications in science, as it strongly supports the adoption of more innovative and integrative strategies. The t value indicates that the observed difference between the two teaching methods (STEM-based and traditional) is significantly larger than what could occur by chance. This suggests that the STEM-based approach has a considerable impact on students' academic achievement in genetics, far exceeding the results seen with traditional methods. The result also implies a large mean difference with relatively low variability in scores, demonstrating the consistency and effectiveness of the STEM-based approach across students (Cohen, 1988).

STEM education integrates science, technology, engineering, and mathematics, creating a multidisciplinary and active learning environment. This approach encourages students to engage with material in a practical and applied context, enhancing their understanding of abstract and complex concepts in genetics (Becker & Park, 2011). For instance, activities such as simulations of genetic inheritance or problem-solving tasks enable students to relate their learning to real-world applications, which likely contributed to the substantial improvement reflected in the t-value.

Conventional teaching methods, which often rely on lectures and rote memorization, are less interactive and may fail to capture students’ interest or facilitate critical thinking (Novak, 2010). The relatively poor performance of students under traditional methods, in contrast with the marked success of STEM-based learning, highlights the limitations of outdated pedagogies in modern science education. Freeman et al. (2014) found that active learning strategies, like those used in STEM, can significantly enhance academic performance in STEM subjects compared to lecture-based approaches.

The result not only underscores the statistical superiority of the STEM-based approach but also provides strong practical evidence for its adoption in classrooms. Teachers and educators may consider integrating STEM principles to foster a deeper understanding of science concepts and improve overall student outcomes.

CONCLUSIONS AND RECOMMENDATIONS

The results of the study notably indicate that the STEM-based approach in teaching genetics significantly improves students' academic achievement compared to the traditional method. The statistical significance of the academic achievement of the grade 8 students in learning genetics highlights the transformative potential of the STEM-based methodology in engaging students, enhancing their understanding of complex concepts, and fostering improved academic achievement. By integrating Science, Technology, Engineering, and Mathematics into an interdisciplinary and applied learning context, the STEM-based approach not only addresses abstract topics in genetics but also supports active participation, critical thinking, and real-world problem-solving skills. These findings provide compelling evidence that STEM strategies are more effective in delivering educational outcomes than conventional, lecture-based teaching approaches.

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The limited success of the traditional method, which often relies on passive learning strategies, underscores its inability to keep up with the dynamic and evolving nature of modern education, particularly in science subjects. This contrast between the effectiveness of the two teaching approaches emphasizes the need for a paradigm shift toward innovative and interactive methods to meet the demands of 21st-century learners.

Recommendations:

Based on the results of the study, which highlight the significant improvement in students' academic achievement in genetics through the STEM-based approach, it is therefore recommended that educators and institutions consider adopting this innovative teaching methodology. The findings underscore the effectiveness of STEM education in fostering deeper understanding, active engagement, and higher academic performance compared to conventional methods. By integrating interdisciplinary and applied learning strategies, the STEM-based approach can transform science education and better prepare students for the challenges of the modern world.

Governments and educational institutions should allocate resources to support STEM initiatives, such as providing access to technology, laboratory equipment, and training materials. Ensuring equitable access to these resources will help address disparities in learning outcomes. While this study highlights the potential of the STEM-based approach in improving academic achievement in genetics, additional research could explore its impact across other science topics and grade levels. Longitudinal studies could examine its long-term effects on knowledge retention and career readiness in STEM fields.

Schools could foster partnerships with industries, universities, and research institutions to enrich STEM education. These collaborations can provide students with access to experts, advanced tools, and opportunities for real-world applications of their learning. By shifting toward STEM-based approaches, teachers can cultivate a generation of learners who are not only well-versed in scientific concepts but also prepared to tackle complex global challenges with creativity and innovation.

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