Journal of Engineering Science and Technology
Special Issue on ISCoE2023 Vol. 19, No. 4 (2024) 69 - 76

ENHANCEMENT OF HIGH SCHOOL STUDENTS' MATHEMATICAL REPRESENTATION IN POLYNOMIALS THROUGH CAME TECHNOLOGY-ASSISTED STEM APPROACH: A QUANTITATIVE STUDY

ANDINI DWI RACHMAWATI, DADANG JUANDI*, D. DARHIM

Universitas Pendidikan Indonesia, Bandung, Indonesia
*Corresponding Author: dadangjuandi@upi.edu

Abstract

This quantitative study aimed to enhance high school students' mathematical representation of polynomials through a Science, Technology, Engineering, and Mathematics (STEM) approach aided by computer-aided method engineering (CAME) technology. A one-group pretest-posttest design was employed with 35 students from grade XI. Data were collected through three essay tests on mathematical representation relevant to the topic. Validity and reliability tests were performed to ensure the quality of the research instrument. T-tests were used to analyze the significance of differences between pretest and posttest scores. The research yielded an N-Gain of 0.67, indicating a significant improvement in mathematical representation after the STEM-CAME intervention. This N-Gain suggests the approach's effectiveness in enhancing students' understanding of polynomials. Teachers and academics alike may utilize the study's findings to inform their research as well as to enhance classroom instruction.

Keywords: CAME, Mathematical representation ability, STEM approach..

1. Introduction

Enhancing high school students' mathematical representation in polynomials through the Science, Technology, Engineering, and Mathematics (STEM) approach aided by Computer-aided method engineering (CAME) technology is a critical and timely topic in contemporary education [1]. A robust mathematical representation is fundamental for students to effectively comprehend and apply mathematical concepts [2]. Incorporating STEM methodologies has gained prominence in education, fostering interdisciplinary learning and practical applications [3-6].

In this study, we delved into the intersection of mathematical education, polynomials, and technology, with a specific focus on the innovative use of CAME tools. The synergy of these elements promises a transformative impact on students' understanding of polynomials, positioning them to navigate complex mathematical concepts with confidence [7]. Teaching mathematics has been one of the hottest topics recently, making many studies well-developed [8-13].

This research centers on elevating the mathematical representation of high school students, particularly in polynomials. The study leverages the STEM approach, integrating (Science, Technology, Engineering, and Mathematics) [14]. As explained by many scholars, a deep understanding of mathematical representations is critical to students' overall mathematical abilities [15]. This research aims to explore improving STEM approaches enriched by CAME technology in the context of polynomial understanding. This research aims to contribute valuable insights into educational practice, offering a differentiated version of how this innovative pedagogical tool can reshape the mathematics learning experience for high school students. This can add new insight into the current research in mathematics education [16-21].

This study stands at the forefront of educational research by merging the realms of STEM and CAME to address a specific gap in high school mathematical education related to polynomial comprehension. While previous studies have explored the impact of STEM approaches [22-24]. or the impact of technology in mathematics education [25-27], amalgamation of these elements to enhance polynomial understanding is a unique and uncharted territory [28]. By navigating this unexplored terrain, our research aspires to provide educators, curriculum developers, and policymakers with evidence-based insights into the innovative strategies that can propel mathematical education into the future. The novel synergy of STEM and CAME in the context of polynomials is poised to improve students' mathematical representation skills and pave the way for a more dynamic.

2. Literature Review: Mathematical Representation Ability.

Mathematical representation abilities are divided into three parts, including verbal, visual, and symbolic representation abilities [29-31]. Indicators of verbal representation ability are (1) creating problem situations based on the data or representation provided. Example (Fig. 1): When adding two polynomials, what is the degree of the resulting polynomial? Explain using the general form of a polynomial function and show the steps to solve it sequentially in your language! (2) Write an interpretation of an equation. For example, for each polynomial function expressed in its graph here, determine the number of natural zero generators and unreal zero generators. Also, explain the reasons.

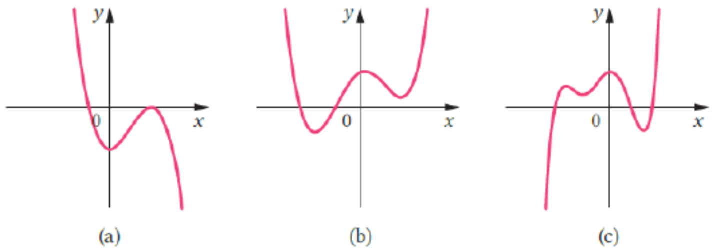

Fig. 1. Example of verbal mathematical representation ability questions.

Next, the indicator of visual representation ability is using diagrammatic, graph, and table image representations in solving problems. Example: Look at the shaded area in the following Fig. 2(a). The site is located between two circles that have the same center. Express the size of the shaded region as a function of x in the following Fig. 2(b).

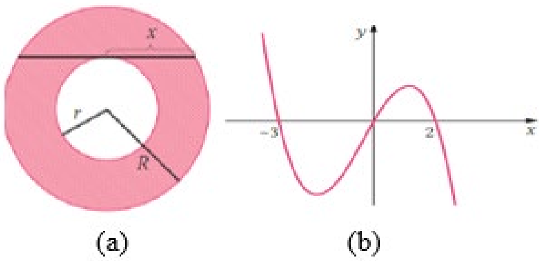

Fig. 2. (a) Example of visual mathematical representation ability questions, (b) example of symbolic mathematical representation ability questions.

Finally, indicators of symbolic mathematical representation abilities are (1) Solving problems involving mathematical expressions. For example, Use Horner's method and the Remainder Theorem to determine the value of $P(c)$ if $(x) = x^4 - 10x^3 + 84x - 28$ and c = 9; (2). Create mathematical equations or models from other given representations. Example, Fig. 2(b): Given three polynomial functions, namely $(x) = x^3 + x^2 - 6x$, $g(x) = -x^3 - x^2 + 6x$, dan $h(x) = x^3 - 4x$. Of the three functions, which one has the graph shown in the picture? Explain!

3. Methods

This quantitative research aims to improve high school students' mathematical representation of polynomial material by applying a STEM approach supported by CAME Technology. This research methodology was designed as experimental research using a one-group pretest-posttest research design. The research sample was taken from students at Senior High School in Ngunut with a student population of 35 students. Sampling was carried out purposively. Data collection was carried out by conducting a pretest and posttest. To ensure the validity and reliability of the data, the research instrument will be carried out using the Cronbach's alpha method. Next, statistical data analysis will be carried out using the t test and N-Gain values from the pretest and posttest results to test the research hypothesis and measure the increase in student understanding using SPSS [32-36].

4. Results and Discussion

Table 1 shows test and posttest scores for mathematical verbal representation abilities, which are 2.403 and 13.57 with an N-gain of 0.584. Based on the pretest and posttest, it can be seen that there was a significant increase in the average score in problem-solving ability, namely 0.584, which means that mathematical representation ability increased after being taught the CAME-assisted STEM approach with high categories. Also, with an N-gain of 0.198, the scores for mathematical visual representation ability were 6.23 on the pretest and 16.17 on the posttest. After teaching the STEM approach with the help of CAME, students demonstrated a remarkable improvement in their mathematical visual representation ability.

The pretest and posttest scores for mathematical symbolic representation abilities were 6.69 and 42.83, respectively. Based on the pretest and posttest, it was seen that there was a significant increase in the average mathematical symbolic representation abilities score, namely 0.677. which means that mathematical symbolic representation abilities increase after being taught the STEM approach assisted by CAME in the high category. Finally, in terms of mathematical representation ability, the pre-and posttest scores were 72.57 and 18.06, respectively. The average score of mathematical representation ability increased significantly from 0.46 on the pretest to 0.66 on the posttest. This indicates that after learning the medium-level CAME-assisted STEM method, students' capacity to represent mathematics improves.

Table 1. Pretest and posttest results.

Test	Mathematical Verbal Representation Ability			Mathematical Visual Representation Ability			Mathematical Visual Representation Ability		
	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
Pretest	5.14	2.403	35	6.23	3.979	35	6.69	1.922	35
Postest	13.57	3.979	35	16.17	2.844	35	42.83	3.658	35
N-gain	0.584	0.173	35	0.198	0.110	35	0.677	0.719	35

The paired sample t-test aims to determine how the STEM approach influences student performance on the mathematical representation ability test. The first step is to run prerequisite tests to see if the data is usually distributed. This test is called the Shapiro-Wilk normality test. Table 2 displays the results of the students' pretest, posttest, and normality tests.

Table 1. Normality test of mathematical representation ability.

Data	Mathematical Representation Ability	
	Sig.	**Informaton**
Pretest	0.199	Normal
Postest	0.132	Normal

The data from students' mathematical representation ability is declared to be regularly distributed since the significant value for both the pretest and posttest is more than 0.05 (Table 2). A paired sample t-test follows the assertion that the data follows a normal distribution. Table 3 displays the dependent variable in this instance, and the purpose of this test is to examine the impact of the independent variable on it.

Table 2. Paired sample t test of pretest and posttest data on students' mathematical representation abilities.

Data	Mathematical Representation Abilities		
	Std. Dev	**T**	**Sig.**
Pretest	6.68	-56.84	0.000
Posttest	5.79		

Based on the data processing findings in Table 3, the p-value is less than 0.05, which means the significance value is 0.000. Therefore, we accept H0, meaning there is a difference. Significant. The findings of the pre-and post-tests show that the STEM strategy using CAME as an adjunct improves students' problem-solving skills. In addition.

During the STEM practicum, it was evident that some students were critical thinkers who solved difficulties when the bottle boat refused to move. Students rehearse how to make the bottle boat move [37]. Implementing STEM education effectively may help students develop their mathematical representation abilities, problem-solving skills, and conceptual comprehension [38]. It is important to stress the importance of students working together to discover solutions to problems throughout the learning process. After receiving treatment in the form of a STEM approach, students will be given a posttest to make sure they have understood the subject [39].

The purpose of this is twofold: first, to assess how well students understand mathematical concepts; second, to provide them with the tools they need to develop their mathematical representations; and third, to encourage them to work together in groups to solve problems based on real-world scenarios; and finally, to demonstrate the significance of mathematical representations to students in a way that piques their interest and fosters their development as independent learners.

5. Conclusion

The findings presented lead to the conclusion that increasing mathematical representation skills in the medium category and improving mathematical representation abilities via the STEM approach with CAME support are two benefits of studying mathematics. Students' mathematical representation skills may be developed and enhanced in the classroom via the use of the STEM approach with support from CAME. The goal of mathematics education should be to develop students' skills in mathematical representation. This skill is crucial and may help pupils understand how to handle issues that arise in daily life.

References

1. Li, Y.; and Schoenfeld, A.H. (2019). Problematizing teaching and learning mathematics as "given" in STEM education. *International Journal of STEM education*, 6(1), 1-13.

2. Mainali, B. (2021). Representation in teaching and learning mathematics. *International Journal of Education in Mathematics, Science and Technology*, 9(1), 1-21.
3. Darmawansah, D.; Hwang, G.J.; Chen, M.R.A.; and Liang, J.C. (2023). Trends and research foci of robotics-based STEM education: A systematic review from diverse angles based on the technology-based learning model. *International Journal of STEM Education*, 10(1), 1-24.
4. Lestari, D.A.; Suwarma, I.R.; and Suhendi, E. (2024). Feasibility analysis of the development of STEM-based physics e-book with self-regulated learning on global warming topics. *Indonesian Journal of Teaching in Science*, 4(1), 1-10.
5. Tipmontiane, K.; and Williams, P.J. (2022). The integration of the engineering design process in biology-related STEM activity: A review of thai secondary education. *ASEAN Journal of Science and Engineering Education,* 2(1)*,* 1-10.
6. Lagcao, Y.G.D.; Dechavez, J.P.A.D.; Goleng, D.J.G.; Lagca, Y.G.D.; Tangkli, K.Y.M.; and Vicera, W.J.C. (2023). Math readiness and its Effect on the online academic performance of science, technology, engineering, and mathematics
7. Berman, A.; and Shvartsman, L. (2016). Definitions are important: The case of linear algebra. *European Journal of Science and Mathematics Education*, 4(1), 26-32.
8. Dallyono, R.; Sukyadi, D.; and Hakim, L. (2020). A mathematical model of the cognitive semantics of the English preposition on. *Indonesian Journal of Science and Technology*, 5(1), 133-153.
9. Hashim, S.; Masek, A.; Mahthir, B.N.S.M.; Rashid, A.H.A.; and Nincarean, D. (2021). Association of interest, attitude and learning habit in mathematics learning towards enhancing students' achievement. *Indonesian Journal of Science and Technology*, 6(1), 113-122.
10. Akinoso, S.O. (2023). Motivation and ICT in secondary school mathematics using unified theory of acceptance and use of technology model. *Indonesian Journal of Educational Research and Technology*, 3(1), 79-90.
11. Radiamoda, A.A. (2024). Difficulties encountered by the students in learning mathematics. *Indonesian Journal of Educational Research and Technology*, 4(1), 63-70.
12. Obafemi, K.E.; Saadu, U.T.; Yahaya, O.; Obafemi, T.O.; and Yakubu, F.M. (2024). Exploration of the effect of scaffolding instructional strategy on pupils' academic performance in mathematics. *ASEAN Journal for Science Education*, 2(2), 121-128.
13. Awofala, A.O.A.; Olabiyi, O.S.; Ojo, O.T.; Oladipo, A.J.; Fatade, A.O.; and Udeani, U.N. (2023). Personal and contextual factors as correlates of entrepreneurial intentions among pre-service science, technology, and mathematics teachers. *ASEAN Journal of Science and Engineering Education*, 3(3), 265-278.
14. Feola, S.; Lewis, J. E.; McAlpin, J.D.; Prevost, L.B.; Skvoretz, J.; Stains, M.; Couch, B.A.; Earl B.; Ziker, J.P; Lane and Shadle, S.E. (2023). STEM education institutional change projects: Examining enacted approaches through the lens of the four categories of change strategies model. *International Journal of STEM Education*, 10(1), 1-17.

15. Utomo, D. P.; and Syarifah, D. L. (2021). Examining mathematical representation to solve problems in trends in mathematics and science study: voices from Indonesian secondary school students. *International Journal of Education in Mathematics, Science and Technology*, 9(3), 540-556.
16. Awofala, A.O.A.; and Agbolade, F.O.O. (2024). Effect of peer-tutoring strategy on senior secondary school students' achievement in mathematics. *ASEAN Journal for Science Education*, 3(1), 1-12.
17. Awofala, A.O.A.; and Olaniyi, A.O. (2023). Assessing teachers' formative evaluation strategy as related to senior secondary school students' achievement in mathematics. *ASEAN Journal for Science Education*, 2(2), 77-86.
18. Dermawan, R.; Muktiarni, M.; and Mupita, J. (2022). Efforts to increase the interest of junior high school students in mathematics lessons using the tik tok learning tool. *ASEAN Journal for Science Education*, 1(2), 81-88.
19. Jose, M.T.N.S. (2022). Factors that affect the performance of selected high school students from the third district of Albay in international mathematics competitions. *ASEAN Journal for Science Education*, 1(1), 9-16.
20. Maryanti, R. (2021). Assessment of mathematical abilities of students with intellectual disabilities during the covid-19 pandemic. *Indonesian Journal of Community and Special Needs Education,* 1(2), 47-52.
21. Obafemi, K.E. (2024). Enhancing pupils' academic performance in mathematics using brainstorming instructional strategy. *ASEAN Journal of Science and Engineering Education*, 4(2), 99-106.
22. Ardianti, S.; Sulisworo, D.; Pramudya, Y.; and Raharjo, W. (2020). The impact of the use of STEM education approach on the blended learning to improve student's critical thinking skills. *Universal Journal of Educational Research*, 8(3), 24-32.
23. Astawan, I.G.; Suarjana, I.M.; Werang, B.R.; Asaloei, S.I.; Sianturi, M.; and Elele, E.C. (2023). STEM-Based scientific learning and its impact on students' critical and creative thinking skills: An empirical study. *Jurnal Pendidikan IPA Indonesia*, 12(3), 482-492.
24. Richardo, R.; Dwiningrum, S. I. A.; Wijaya, A.; Retnawati, H.; Wahyudi, A.; Sholihah, D.A.; and Hidayah, K.N. (2023). The impact of STEM attitudes and computational thinking on 21st-century via structural equation modelling. *International Journal of Evaluation and Research in Education. IJERE*, 12(2), 571.
25. Eyyam, R.; and Yaratan, H.S. (2014). Impact of use of technology in mathematics lessons on student achievement and attitudes. *Social Behavior and Personality: an international journal*, 42(1), 31S-42S.
26. Viberg, O.; Grönlund, Å.; and Andersson, A. (2023). Integrating digital technology in mathematics education: A Swedish case study. *Interactive Learning Environments*, 31(1), 232-243.
27. Saadati, F.; Tarmizi, R. A.; and Ayub, A.F.M. (2014). Utilization of information and communication technologies in mathematics learning. *Indonesian Mathematical Society Journal on Mathematics Education*, 5(2), 138-147.
28. Ozawa, N. (2013). About the connes embedding conjecture: Algebraic approaches. *Japanese Journal of Mathematics*, 8(1), 147-183.

29. Zhe, L. (2023). Survey of primary students' mathematical representation status and study on the teaching model of mathematical representation. *Journal of Mathematics Education*, 63-76.
30. Milrad, M. (2002). Using construction kits, modeling tools and system dynamics simulations to support collaborative discovery learning. *Journal of Educational Technology and Society*, 5(4), 76-87.
31. Jitendra, A.K.; Nelson, G.; Pulles, S.M.; Kiss, A.J.; and Houseworth, J. (2016). Is mathematical representation of problems an evidence-based strategy for students with mathematics difficulties?. *Exceptional Children*, 83(1), 8-25.
32. Fathoni, A.; Muslim, S.; Ismayati, E.; Rijanto, T.; and Nurlaela, L. (2020). STEM: innovation in vocational learning. *Jurnal Pendidikan Teknologi dan Kejuruan*, 17(1), 33-42.
33. Marasabessy, R. (2021). Study of mathematical reasoning ability for mathematics learning in schools: A literature review. *Indonesian Journal of Teaching in Scienc*e, 1(2), 79-90.
34. Adeniran, T.A.; and Onasanya, S.A. (2024). Impact of e-learning on college of education lecturers' knowledge of quantitative data analysis in SPSS. *Indonesian Journal of Educational Research and Technology*, 4(2), 121-128.
35. Fiandini, M.; Nandiyanto, A.B.D.; Al Husaeni, D.F.; Al Husaeni, D.N.; and Mushiban, M. (2024). How to calculate statistics for significant difference test using SPSS: Understanding students comprehension on the concept of steam engines as power plant. *Indonesian Journal of Science and Technology*, 9(1), 45-108.
36. Al Husaeni, D.F.; Al Husaeni, D.N.; Fiandini, M.; and Nandiyanto, A.B.D. (2024). The research trend of statistical significance test: Bibliometric analysis. *ASEAN Journal of Educational Research and Technology*, 3(1), 71-80.
37. Afifah, S.; Mudzakir, A.; and Nandiyanto, A.B.D. (2022). How to calculate paired sample t-test using SPSS software: From step-by-step processing for users to the practical examples in the analysis of the effect of application anti-fire bamboo teaching materials on student learning outcomes. *Indonesian Journal of Teaching in Science*, 2(1), 81-92.
38. Azmidar, A.; and Husan, H. (2022). Enhancing students'mathematical representation ability through mathematics learning. *Hipotenusa Journal of Research Mathematics Education (HJRME)*, 5(2), 35-49.
39. Watkins, J.; and Mazur, E. (2013). Retaining students in science, technology, engineering, and mathematics (STEM) majors. *Journal of College Science Teaching*, 42(5), 36-41.