EUROPEAN JOURNAL OF STEM EDUCATION

European Journal of STEM Education, 2024, 9(1), 20
ISSN: 2468-4368

lectito

STEM Learning for Students Mathematical Numeracy Ability

Malik Ibrahim [1,2*], Herwin Herwin [1], Heri Retnawati [1], Fery Muhamad Firdaus [1], Umar Umar [1], Mufidah [1]

[1] *Universitas Negeri Yogyakarta*, INDONESIA
[2] *Universitas Nahdlatul Ulama Nusa Tenggara Barat*, INDONESIA

*__Corresponding Author:__ malikedu.org@gmail.com

Citation: Ibrahim, M., Herwin, H., Retnawati, H., Firdaus, F. M., Umar, U. and Mufidah (2024). STEM Learning for Students Mathematical Numeracy Ability. *European Journal of STEM Education*, 9(1), 20. https://doi.org/10.20897/ejsteme/15750

Published: December 26, 2024

ABSTRACT

This research aims to determine the effect of STEM (Science, Technology, Engineering, and Mathematics) learning on students' mathematical numeracy abilities. The research method uses descriptive quantitative research by only looking at the values displayed based on descriptive statistics, involving 40 participants during 8 meetings and using 10 essay questions as an instrument for assessing mathematical numeracy abilities. The results of the analysis obtained a t value of 12.005 which also supports the significance of the findings, indicating a substantial impact of STEM learning on students' mathematics skills. The results above show that STEM learning at universities has an effect on students' mathematical numeracy abilities.

Keywords: STEM, mathematic, numeracy ability

INTRODUCTION

The development of Science, Technology, Engineering and Mathematics (STEM) has become a major concern in the world of education and science in the contemporary era. STEM represents an interdisciplinary approach that integrates these four fields to solve complex problems and stimulate innovation in a variety of contexts (Madden et al., 2013). The STEM concept is not only an important foundation in the development of science and technology, but also plays a key role in forming the basis for the industrial, technological and economic development of a nation (He et al., 2021).

In an attempt to enhance STEM education, there has been a growing tendency in recent years for STEM education to be handled collaboratively (Dolgopolovas and Dagienė, 2021; Wei et al., 2021). The STEM approach transcends traditional disciplinary boundaries, creating space for collaboration across fields to produce innovative and effective solutions to complex challenges in contemporary society (Bektas, 2022). The importance of STEM in the educational context lies in its role in forming students' critical thinking, analytical and creative skills (Richardo et al., 2023). Through the STEM approach, students not only learn about the concepts of science, technology, engineering and mathematics separately, but also gain a deep understanding of the relationships between these fields and their application in real contexts (Bradley and Churchill, 2023).

The quality of STEM teaching approaches is still debated, and efforts are made to improve STEM learning results, despite the present attention and interest in the field (Thomson et al., 2020). In addition, STEM also provides a strong foundation for the development of technological literacy and digital skills, preparing future generations to face increasingly complex and diverse job demands (McGunagle and Zizka, 2020). STEM teachers are essential knowledge transmitters, and how well they do can directly affect students' learning experiences and acquisition of knowledge and skills (Huang et al., 2022). STEM education emphasizes real-world experience and an interdisciplinary approach to solving problems, in contrast to the conventional view of education that is

knowledge-based (Lau and Jong, 2023; Li et al., 2020). STEM education can help student develop an entrepreneurial mindset and provide the tools they'll need for national development in their future careers (Eltanahy et al., 2020). This decision was made for a few reasons. First, this paradigm is simple for educators to include into STEM curricula. Secondly, this paradigm enables educators to incorporate STEM disciplines and assist learners in applying their acquired knowledge to everyday situations (Büyükdede and Tanel, 2019; Ong et al., 2020).

Mathematical Numeracy, or often referred to as mathematical literacy, is an important concept in mathematics education that emphasizes the understanding and application of mathematics in various contexts of daily life (Hallström and Schönborn, 2023). The concept of mathematical numeration not only includes mastery of basic mathematical concepts such as addition, subtraction, multiplication and division, but also involves a deeper understanding of how to use and interpret mathematics in real situations (Ammar et al., 2024). This includes the ability to recognize and apply mathematical concepts in various contexts, analyse number-based information, and make decisions based on data and mathematical thinking (He et al., 2021; Lin et al., 2024) In an educational context, developing mathematical numeracy is important because it provides a strong foundation for students' critical thinking, analytical and problem-solving skills, and prepares them to face complex challenges in their personal, professional and social lives in the future (Lee-Post, 2019; Szabo et al., 2020). Thus, a deep understanding of mathematical numeracy is not only relevant in the educational context, but also plays an important role in forming competent and competitive individuals in a society that is increasingly dependent on mathematical thinking skills.

The use of STEM in mathematics learning has had a positive impact on student learning progress. Research shows that a STEM-based approach, supported by interactive learning media such as Vlogs, has succeeded in increasing student achievement in mathematics learning at the elementary school level (Şahin et al., 2024). In addition, training programs that focus on STEM approaches have also proven effective in increasing the competence of mathematics teachers, which in turn increases the use of STEM in the curriculum in secondary schools (Al-Jubouri and Al-Jubouri, 2023). Furthermore, the application of STEM-based learning through lesson studies has been proven to have a positive impact on teachers and students, including improving critical and creative thinking skills, problem-solving abilities, and learning achievement in mathematics and science (Nursyahidah and Mulyaningrum, 2022). The systematic literature review also highlights the benefits of a STEM approach in improving students' critical thinking skills and creative thinking abilities in mathematics at various educational levels (Appelbaum, 2023). The application of a STEM approach in learning has also been proven to contribute to improving students' scientific thinking skills (Ding and Cai, 2023). Thus, the application of STEM in mathematics learning not only improves student learning outcomes but also strengthens their skills in critical, creative and scientific thinking.

Furthermore, research in the field of mathematics numeracy shows that numeracy literacy skills, especially at the elementary school level, have a significant influence on learning outcomes, especially in the context of mathematics (Lowrie et al., 2017). Students' ability to formulate mathematical problems and connect mathematical concepts based on numeracy literacy is a very important factor in their learning process (Arlinwibowo et al., 2020; Mastuti et al., 2023). In addition, it was found that students who have a high level of self-efficacy in numeracy tend to have better performance in solving problems involving data and uncertainty compared to those who have a low level of self-efficacy (Nisa' et al., 2023). However, currently, numeracy literacy skills in elementary schools are still not optimal, this can be attributed to various factors such as the lack of application of HOTS (Higher Order Thinking Skills) questions and the lack of adequate training for teachers in implementing learning approaches that focus on numeracy literacy (Rohmah et al., 2022). To overcome these challenges, it is recommended that teachers create a supportive learning environment to increase students' self-efficacy and numeracy skills. Apart from that, there is a need to design curricular activities that aim to increase numeracy literacy through developing relevant learning materials, preparing evaluation questions that encourage higher level thinking, and using interactive learning media that can increase student involvement in the learning process. In this way, joint efforts between teachers, schools and various related parties are expected to improve and increase the numeracy literacy skills of students in elementary schools, so that they can face mathematical challenges more confidently and competently in the future.

The implementation of STEM in the context of numeracy mathematics involves combining the disciplines of science, technology, engineering, and mathematics to improve students' understanding and skills in mathematics. A number of studies have investigated the implementation and impact of STEM approaches in mathematics learning. For example, a study conducted by Rahmawati et al. found that the application of STEM with Project Based Learning (PBL) and Problem Based Learning (PBL) methods significantly increased students' critical and creative thinking abilities in mathematics (Richardo et al., 2023). Another study conducted by Akip and Rukli showed that the application of STEM using interactive Vlog media succeeded in improving students' mathematics learning outcomes at the elementary school level (Appelbaum, 2023). In addition, Nu'man et al. (2022) emphasizes the importance of making mathematical concepts clear and explicit in STEM education to strengthen students' understanding of mathematics. Furthermore, Bennison and Geiger state that a cross-curriculum approach to

numeracy can integrate mathematics subjects with other STEM disciplines, thereby enhancing learning in science and mathematics (De Loof et al., 2022). The results of this study demonstrate the positive effects of implementing STEM in mathematics education as well as the potential for integrating mathematics subjects thoroughly in the STEM curriculum.

The implementation of STEM in mathematical literacy is an important area of research, especially in the context of students' representation of mathematical concepts (Adikayanti and Retnawati, 2022). However, further research is needed to explore the impact of STEM on this aspect of mathematics education. Additionally, the use of information systems in education, including mathematics, has the potential to improve the delivery of STEM-related content (Arlinwibowo et al., 2020). The development of curricula that integrate STEM principles, including in the teaching of mathematics, is also an important consideration (Allan et al., 2019). Lastly, historical and cultural aspects of mathematical symbols, such as the origins of the square root symbol, can provide valuable context for mathematics teaching (Guo et al., 2021).

Based on the analysis of various studies that have been presented, it appears that the use of STEM (Science, Technology, Engineering and Mathematics) in learning mathematics and numeracy literacy has had a positive impact on student learning progress. The research results show that a STEM-based approach, supported by interactive learning media such as Vlogs, has succeeded in increasing student achievement at the elementary school level and increasing the competence of mathematics teachers at the secondary school level. In addition, the implementation of STEM-based learning through lesson studies has a positive impact on teachers and students, including improving critical and creative thinking skills, problem-solving abilities, and learning achievement in mathematics and science. The systematic literature study also highlights the benefits of the STEM approach in improving students' critical thinking skills and creative thinking abilities in mathematics at various educational levels. However, there are several gaps that need further research, such as the influence of STEM on students' mathematical numeracy abilities in higher education, as well as the influence of STEM on other aspects of mathematics education such as the representation of mathematical concepts by students and the use of information systems in mathematics learning. In addition, further research is needed to develop curricula that integrate STEM principles in mathematics teaching and to explore the historical and cultural aspects of mathematical symbols as a valuable context in mathematics teaching. Therefore, the aim of the next research is to explore the influence of STEM on students' mathematical numeracy abilities in higher education and to develop effective learning strategies in improving their mathematical numeracy abilities.

This research aims to determine the implementation of STEM on students mathematical numeracy abilities. This research responds to the lack of previous research which tends to focus on aspects such as critical, creative and scientific thinking abilities, as well as student academic achievement in the context of STEM-based mathematics learning. The lack of research that specifically explores the influence of STEM implementation on mathematical numeracy abilities is the main basis for this research. By evaluating the effectiveness of the STEM approach, identifying the most effective learning strategies, and analysing the impact of STEM implementation on mathematical numeracy abilities, this research is expected to provide deeper insight into the development of mathematics learning strategies that are relevant to the demands of the STEM era.

METHOD

This research is quantitative research with a descriptive approach. The aim of this research is to determine the influence of STEM (Science, Technology, Engineering and Mathematics) on students' mathematical numeracy abilities. The research subjects consisted of 40 students who were chosen randomly. The research instrument used was a test in the form of 10 questions which were arranged according to the indicators of the research variables. The research process was carried out in several stages. First, the preparation of the instrument is carried out by referring to the research variable indicators. Second, the test instrument questions are composed of 10 questions that are relevant to mathematical numeracy abilities. Third, the test instrument is given to respondents. Fourth, after the data was collected, data was tabulated and analysed using descriptive statistical techniques and the t-test (Student's test). Data analysis was carried out using the Jamovi program, using the conclusion criterion that if the significance value (Sig) is less than 0.05, then the null hypothesis (H_0) is rejected. The research results will be interpreted and conclusions will be drawn according to the results of the data analysis that has been carried out.

RESULTS AND DISCUSSION

This research uses quantitative research methods with a descriptive approach to explore the implementation of STEM on students' mathematical numeracy abilities. The research process was carried out in several structured

Table 1. Numeracy ability indicator

No	Indicator	Item
1	Use various kinds of numbers or symbols related to basic mathematics in solving daily life problems.	1, 2, 3
2	Analyze information displayed in various forms (graphs, tables, charts, diagrams, and so on).	4, 5, 6, 7
3	Interpret the results of the analysis to predict and make decisions.	8, 9, 10

Table 2. Descriptive statistics

Variable	Grade
Valid	40
Mode	60
Median	70
Mean	70.075
Standard error of mean	1.589
Standard deviation	10.050
Coefficient of variation	0.143
Variance	100.994
Minimum	60
Maximum	90

Table 3. One-sample test (test value = 51)

	t	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
					Lower	Upper
Data	12.005	39	.000	19.07500	15.8610	22.2890

stages. First, the preparation of research instruments is carried out by referring to the research variable indicators that have been determined (**Table 1**).

This is done to ensure that the instruments used are in accordance with the research objectives and are able to measure the variables to be studied. Second, the test instrument consists of 10 questions which are specifically designed to test students' mathematical numeracy skills. These questions were created by taking into account the diversity of mathematical numeracy material that is relevant to the student context. Third, the test instruments were then distributed to respondents, namely 40 students, to be filled in according to their mathematical numeracy skills. Respondents are expected to be able to answer test questions honestly and accurately. Fourth, after the data is collected, data tabulation is carried out to organize the results of filling in the instrument by respondents. Next, data analysis was carried out using descriptive statistical techniques to describe and summarize the characteristics of the data collected. In addition, a t-test (Student's test) was also carried out to test the significance of differences between two different groups of data. The results of this data analysis will be interpreted carefully to draw appropriate conclusions regarding the effectiveness of STEM implementation on students' mathematical numeracy abilities. The descriptive statistical results are in accordance with **Table 2**.

From the results of the descriptive statistical analysis in **Table 1**, it can be seen that the average student numeracy ability score is 70.075 with a standard error mean of 1.589. The average value obtained shows that in general, students have a level of mathematical numeracy ability that tends to be above the average value. This indicates that the majority of students have adequate understanding and skills in the context of mathematical numeracy. In addition, the variance value obtained was 100,994 indicating a relatively large level of variation or spread of data, indicating that there was significant variation between students' numeracy ability values. The minimum score of 60 indicates that the lowest score obtained by a student in numeracy is 60, while the maximum score of 90 indicates that the highest score obtained by a student is 90.

This illustrates that there is significant variation between the lowest and highest scores, indicating a gap between the students' numeracy abilities. These findings are important to consider in developing learning strategies that aim to improve students' overall numeracy abilities, as well as to pay special attention to students who have low levels of numeracy abilities. In conclusion, this descriptive statistical analysis provides a comprehensive picture of the distribution and characteristics of students' numeracy ability scores, as well as providing a strong basis for decision making regarding curriculum development and learning strategies at the tertiary level. Next, the researcher carried out a t test analysis to answer the research hypothesis, the results are according to **Table 3**.

Table 3 shows the results of hypothesis testing regarding the implementation of STEM on students' numeracy abilities using the One Sample Test. In this test, a t-test value was obtained of 12.005 with a significance level (Sig.) of 0.000. These results indicate that there is a significant difference between the sample mean (sample average) and the population mean (population average) in students' numeracy abilities. Sig value. which is close to zero indicates that the difference does not occur by chance, but is caused by the implementation of STEM in mathematics learning. In this context, the mean difference obtained was 19.075, indicating that there was a significant average

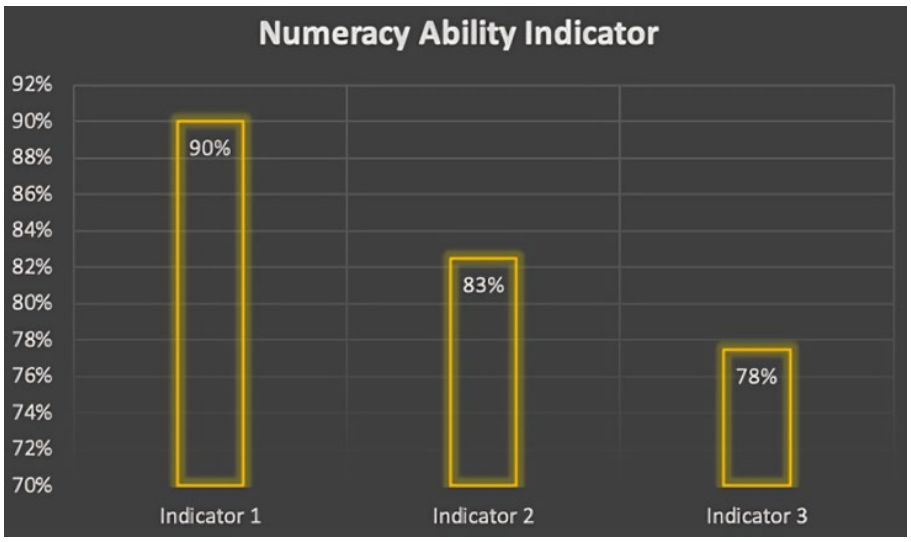

Figure 1. Result diagram numeracy ability indicator

difference between students' numeracy abilities before and after implementing STEM in mathematics learning. These results indicate that the implementation of STEM has a significant positive impact on improving students' numeracy skills. This is in accordance with the main objective of this research, which aims to identify the effect of STEM implementation on students' numeracy abilities.

From the results of this hypothesis test, it can be concluded that effective implementation of STEM can improve students' numeracy skills. These results are consistent with previous research findings which show that STEM-based learning approaches have a positive impact on student learning outcomes, especially in the context of mathematics learning. The implementation of STEM brings innovation in mathematics learning by integrating science, technology, engineering and mathematics in a learning framework that is holistic and oriented towards practical application. **Figure 1** is a diagram of the accuracy of answering each indicator of numeracy ability based on student answers.

Use Various Kinds of Numbers or Symbols Related to Basic Mathematics in Solving Daily Life Problems

In this section, almost all students answered correctly the questions given in questions number 1-3, by 90%. This indicator represents students' numeracy skills in using symbols and numbers in solving problems in everyday life. This is in line with STEM learning which trains and provides opportunities and experiences for students to develop the skills they need (Skills and Faculty, 2024; Morris et al., 2021). Students are directly involved in determining the correct symbols and formulas in answering questions.

Analyze Information Displayed in Various Forms (Graphs, Tables, Charts, Diagrams and So On)

In this section, students answered correctly the questions given in questions number 4-7, by 83%. This indicator represents students' ability to read and create graphs based on the data provided. Apart from that, students are able to utilize technology-based media such as MS. Excel to solve math problems. Students are seen exploring with group friends during the learning process in class, and are able to apply mathematical concepts well.

Interpret the Results of the Analysis to Predict and Make Decisions

In this section, students answered correctly the questions given in questions number 8-10, by 78%. This indicator shows that some students are able to make good interpretations, although there are some students who still make mistakes in interpreting data from the questions given, such as determining the formula used in solving mathematical problems. However, in the classroom process, it can be seen that groups of students discuss with each other to minimize errors in answering practice questions. This stage is in line with the concept of STEM learning, namely providing opportunities and breadth of creativity in discovering concepts with different experiences.

The positive impact of STEM implementation on students' numeracy abilities has broad implications in the context of higher education. First, this shows the importance of developing a curriculum that integrates a STEM approach in mathematics learning as an effort to improve the quality of mathematics education. Second, these findings also provide a basis for developing training programs to increase educators' competence in implementing STEM-based learning approaches. Third, these results can be used as a basis for formulating educational policies

that support the implementation of STEM in various higher education institutions. In addition, it should be remembered that these results were obtained from a sample consisting of 40 students. Therefore, these results can be considered representative of the broader student population. However, to ensure the generalisability of these results, it is recommended to conduct further research with larger and more representative samples.

The implementation of STEM (Science, Technology, Engineering and Mathematics) has a significant positive impact on improving students' numeracy skills. Studies have shown that the STEM approach is effective in improving critical and creative thinking skills in mathematics in students at various levels of education, including elementary school, middle school, high school, and university (Jung et al., 2023). The application of STEM-based learning through lesson study has also been proven to have a positive impact on teachers and students, improving critical and creative thinking skills, problem solving abilities, and learning achievement (Nursyahidah and Mulyaningrum, 2022). Furthermore, the implementation of STEM-based learning in a biology context is also known to improve student learning outcomes, scientific literacy skills, critical thinking skills, creativity and scientific thinking skills (Gunadi et al., 2023). Overall, the integration of STEM in mathematics and science learning has a positive impact on improving students' mathematics abilities (Julita et al., 2022).

CONCLUSION

Based on the results of research using STEM implementation on students' mathematical numeracy abilities, the t-test value was 12.005 and Sig. (2 tailed) of 0.000. High t-test value and Sig. value. (2 tailed) which is close to zero indicates that there is a significant influence of STEM implementation on students' mathematical numeracy abilities. The conclusion of this research is that the implementation of STEM has a significant and positive impact in improving students' mathematical numeracy skills. This shows that the STEM-based learning approach is effective in improving students' understanding and skills in the context of mathematics. These results are important because they emphasize the importance of integrating STEM in mathematics education to strengthen students' numeracy skills.

Based on these results, it is recommended that educational institutions and teachers encourage more implementation of STEM-based learning approaches in mathematics courses. Further research can also be conducted to explore the effectiveness of various STEM implementation strategies in improving students' numeracy skills. In addition, there is a need for training and support for teachers in integrating STEM approaches into the mathematics curriculum. Thus, it can be hoped that the implementation of STEM can be an effective solution in improving students' mathematical numeracy skills at the higher education level.

FUNDING SOURCE

This study was supported by the Beasiswa Pendidikan Indonesia from BPPT and LPDP.

REFERENCES

Adikayanti, L. and Retnawati, H. (2022). Is project-based learning integrated to STEM can improve creativity and problem-solving skills in mathematics learning? *AIP Conference Proceedings*, 2575(1), 080009. https://doi.org/10.1063/5.0110811

Al-Jubouri, M. S. A. and Al-Jubouri, F. S. H. (2023). The effectiveness of a training program based on STEM approaches in developing implementation competencies for mathematics teachers. *Russian Law Journal*, 11(8), 688–700. https://doi.org/10.52783/rlj.v11i8s.1414

Allan, C. N., Campbell, C. and Crough, J. (2019). *Blended Learning Designs in STEM Higher Education: Putting Learning First*. New York City: Springer. https://doi.org/10.1007/978-981-13-6982-7

Ammar, M., Al-Thani, N. J. and Ahmad, Z. (2024). Role of pedagogical approaches in fostering innovation among K-12 students in STEM education. *Social Sciences & Humanities Open*, 9, 100839. https://doi.org/10.1016/j.ssaho.2024.100839

Appelbaum, P. (2023). The rise of STEM education: Mathematics learning for STEM, in R. J. Tierney, F. Rizvi and K. Ercikan (eds), *International Encyclopedia of Education* (Fourth Edition) (pp. 28–35). Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-12-818630-5.13036-2

Arlinwibowo, J., Retnawati, H. and Badrun, K. (2020). The types of STEM education implementation in Indonesia. *Journal of Xi'an University of Architecture & Technology*, XII(VIII), 606–613.

Bektas, O. (2022). The effect of 5E-based STEM education on academic achievement, scientific creativity, and views on the nature of science. *Learning and Individual Differences*, 98, 102181. https://doi.org/10.1016/j.lindif.2022.102181

Bradley, G. and Churchill, D. (2023). STEM teachers' private theories and their learning design in international schools in Hong Kong. *European Journal of STEM Education*, 8(1), 09. https://doi.org/10.20897/ejsteme/14075

Büyükdede, M. and Tanel, R. (2019). Effect of the STEM activities related to work-energy topics on academic achievement and prospective teachers' opinions on STEM activities. *Journal of Baltic Science Education*, 18(4), 507–518. https://doi.org/10.33225/jbse/19.18.507

De Loof, H., Boeve-de Pauw, J. and Van Petegem, P. (2022). Integrated STEM education: The effects of a long-term intervention on students' cognitive performance. *European Journal of STEM Education*, 7(1), 13. https://doi.org/10.20897/ejsteme/12738

Ding, M. and Cai, J. (2023). Mathematics in STEM education, in R. J. Tierney, F. Rizvi and K. Ercikan (eds), *International Encyclopedia of Education* (Fourth Edition) (pp. 19–27). Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-12-818630-5.13035-0

Dolgopolovas, V. and Dagienė, V. (2021). Computational thinking: Enhancing STEAM and engineering education, from theory to practice. *Computer Applications in Engineering Education*, 29(1), 5–11. https://doi.org/10.1002/cae.22382

Eltanahy, M., Forawi, S. and Mansour, N. (2020). Incorporating entrepreneurial practices into STEM education: Development of interdisciplinary E-STEM model in high school in the United Arab Emirates. *Thinking Skills and Creativity*, 37, 100697. https://doi.org/10.1016/j.tsc.2020.100697

Gunadi, F., Sudirman, S., Runisah, R., Senjaya, A. and Mustari, S. (2023). Impact of STEM learning (science, technology, engineering, and mathematics) on students' mathematics thinking ability: Systematic literature review, in *Proceedings of the 2nd Multidisciplinary International Conference*. https://doi.org/10.4108/eai.12-11-2022.2327381

Guo, L., Xu, X., Dai, D. Y. and Deng, C. (2021). Foundations for early mathematics skills: The interplay of approximate number system, mapping ability, and home numeracy activities. *Cognitive Development*, 59, 101083. https://doi.org/10.1016/j.cogdev.2021.101083

Hallström, J. and Schönborn, K. J. (2023). Models and modeling in STEM education: Nature, roles, and implementation, in R. J. Tierney, F. Rizvi and K. Ercikan (eds), *International Encyclopedia of Education* (Fourth Edition) (pp. 112–116). Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-12-818630-5.13038-6

He, X., Li, T., Turel, O., Kuang, Y., Zhao, H. and He, Q. (2021). The impact of STEM education on mathematical development in children aged 5-6 years. *International Journal of Educational Research*, 109, 101795. https://doi.org/10.1016/j.ijer.2021.101795

Huang, B., Siu-Yung Jong, M., Tu, Y.-F., Hwang, G.-J., Chai, C. S. and Yi-Chao Jiang, M. (2022). Trends and exemplary practices of STEM teacher professional development programs in K-12 contexts: A systematic review of empirical studies. *Computers & Education*, 189, 104577. https://doi.org/10.1016/j.compedu.2022.104577

Julita, W., Fitri, R. and Arsih, F. (2022). Meta-analysis: The effect of implementing the STEM (science, technology, engineering, mathematics) approach on biology learning. *Journal of Digital Learning and Education*, 2(3), 178–186. https://doi.org/10.52562/jdle.v2i3.442

Jung, Y. J., Choi, G. W. and Kim, S. H. (2023). Design-based education in STEM: For learners of the 21st century, in R. J. Tierney, F. Rizvi and K. Ercikan (eds), *International Encyclopedia of Education* (Fourth Edition) (pp. 198–206). Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-12-818630-5.13077-5

Lau, W. W. F. and Jong, M. S. Y. (2023). Typology of teachers' stages of concern for STEM education. *Research in Science & Technological Education*, 41(4), 1560–1578. https://doi.org/10.1080/02635143.2022.2064447

Lee-Post, A. (2019). Developing numeracy and problem-solving skills by overcoming learning bottlenecks. *Journal of Applied Research in Higher Education*, 11(3), 398–414. https://doi.org/10.1108/JARHE-03-2018-0049

Li, Y., Schoenfeld, A. H., DiSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D. and Duschl, R. A. (2020). On computational thinking and STEM education. *Journal for STEM Education Research*, 3(2), 147–166. https://doi.org/10.1007/s41979-020-00044-w

Lin, X.-F., Chiu, T. K. F., Luo, S., Wong, S. Y., Hwang, H., Hwang, S., Li, W., Liang, Z.-M., Peng, S. and Lin, W. (2024). Teacher learning community for AR-integrated STEM education. *Teaching and Teacher Education*, 141, 104490. https://doi.org/10.1016/j.tate.2024.104490

Lowrie, T., Downes, N. and Leonard, S. (2017). STEM Education for All Young Australians, *VOCEDplus*. Available at: https://www.voced.edu.au/content/ngv%3A78924.

Madden, M. E., Baxter, M., Beauchamp, H., Bouchard, K., Habermas, D., Huff, M., Ladd, B., Pearon, J. and Plague, G. (2013). Rethinking STEM education: An interdisciplinary STEAM curriculum. *Procedia Computer Science*, 20, 541–546. https://doi.org/10.1016/j.procs.2013.09.316

Mastuti, A. G., Kaliky, S., Siolimbona, A. and Rano, J. (2023). Mathematical connection of geometry problems based on numeracy literacy through the polya framework. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 12(1), 269–280. https://doi.org/10.24127/ajpm.v12i1.5924

McGunagle, D. and Zizka, L. (2020). Employability skills for 21st-century STEM students: The employers' perspective. *Higher Education, Skills and Work-Based Learning*, 10(3), 591–606. https://doi.org/10.1108/HESWBL-10-2019-0148

Morris, J., Slater, E., Fitzgerald, M. T., Lummis, G. W. and van Etten, E. (2021). Using local rural knowledge to enhance STEM learning for gifted and talented students in Australia. *Research in Science Education*, 51(S1), 61–79. https://doi.org/10.1007/s11165-019-9823-2

Nisa', T. K., Ekawati, R. and Kohar, A. W. (2023). Student's numeracy on solving data and uncertainty problems in term of self-efficacy. *Jurnal Mathedunesa*, 12(1), 240–258. https://doi.org/10.26740/mathedunesa.v12n1.p240-258

Nu'man, M., Retnawati, H., Sugiman and Jailani. (2022). Strengthening m(athematics) in the implementation of STEM education in Indonesia. *AIP Conference Proceedings*, 2566(1), 080001. https://doi.org/10.1063/5.0116680

Nursyahidah, F. and Mulyaningrum, E. R. (2022). The impacts of STEM on mathematics and science through lesson study: A systematic literature review. *Kalamatika: Jurnal Pendidikan Matematika*, 7(2), 125–142. https://doi.org/10.22236/kalamatika.vol7no2.2022pp125-142

Ong, E. T., Luo, X., Yuan, J. and Yingprayoon, J. (2020). The effectiveness of a professional development program on the use of STEM-based 5E inquiry learning model for science teachers in China. *Science Education International*, 31(2), 179–184. https://doi.org/10.33828/sei.v31.i2.7

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*, 12(2), 571–578. https://doi.org/10.11591/ijere.v12i2.24232

Rohmah, A. N., Sutama, S., Hidayati, Y. M., Fauziati, E. and Rahmawati, L. E. (2022). Planning for cultivation numerical literacy in mathematics learning for minimum competency assessment (AKM) in elementary schools. *Mimbar Sekolah Dasar*, 9(3), 503–516. https://doi.org/10.53400/mimbar-sd.v9i3.51774

Şahin, E., Sarı, U. and Şen, Ö. F. (2024). STEM professional development program for gifted education teachers: STEM lesson plan design competence, self-efficacy, computational thinking and entrepreneurial skills. *Thinking Skills and Creativity*, 51, 101439. https://doi.org/10.1016/j.tsc.2023.101439

Skills, T. and Faculty, E. (2024). STEM professional development program for gifted education teachers: STEM lesson plan design competence, self-efficacy, computational thinking and entrepreneurial skills. *Thinking Skills and Creativity*, 51, 101439. https://doi.org/10.1016/j.tsc.2023.101439

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D. and Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability*, 12(23), 10113. https://doi.org/10.3390/su122310113

Thomson, M. M., Walkowiak, T. A., Whitehead, A. N. and Huggins, E. (2020). Mathematics teaching efficacy and developmental trajectories: A mixed-methods investigation of novice K-5 teachers. *Teaching and Teacher Education*, 87, 102953. https://doi.org/10.1016/j.tate.2019.102953

Wei, X., Lin, L., Meng, N., Tan, W., Kong, S.-C. and Kinshuk. (2021). The effectiveness of partial pair programming on elementary school students' computational thinking skills and self-efficacy. *Computers & Education*, 160, 104023. https://doi.org/10.1016/j.compedu.2020.104023