Impact of STEM Learning (Science, Technology, Engineering, and Mathematics) on Students' Mathematics Thinking Ability: Systematic Literature Review

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Abstract. Many research results reveal that STEM learning can improve students' mathematical thinking skills. However, there are still few studies that comprehensively explain the impact of STEM learning on students' mathematical thinking skills that have been studied in a systematic literature review. Therefore, this study aims to examine the effect of using STEM learning on increasing students' mathematical thinking skills in terms of education level. To answer this objective, the Systematic Literature Review (SLR) method was used in this study. The stages of research with SLR in this study consist of (1) formulating the problem; (2) search for relevant literature; (3) identify the right type of research; (4) retrieve information from articles. The results of the findings indicate that the use of STEM learning is effective for improving students' mathematical thinking skills at various levels of education. In addition, the secondary school education level is the most effective level of education in using STEM learning.

Keywords: Mathematical Thinking ability, Systematic Literature Review, STEM learning

1 Introduction

Mathematical thinking ability is an ability that involves mathematical skills, such as estimation, induction, deduction, specification, generalization, analogy, reasoning, and verification [1]. In addition, students' mathematical thinking skills need to be trained in the learning process. This is because the ability to think mathematically can help students to be able to move individually based on personal experience to associate ideas they have [2]. One of the learning that facilitates students in STEM learning. STEM is integration between four disciplines, namely science, technology, engineering, and mathematics in an interdisciplinary approach and is applied based on real-world contexts and problem-based learning [3].

Many studies related to STEM have been implemented on mathematical concepts at various levels of education as has been done by [4] regarding STEM education in elementary schools, [5] related to the application of PjBL with a mind map-based STEM approach in secondary schools. In addition, research [6] uses a Systematic Literature Review to examine teachers' perceptions of the STEM approach. While his research [7] explains that STEM learning is increasingly being used from day today.

Although there are many studies that examine STEM using SLR, no one has studied the effect of STEM on mathematical thinking skills based on education level. Therefore, the

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research seeks to systematically review the results of research published in international journals related to the implementation of STEM in mathematics education and its effect on students' mathematical thinking skills at every level of education in schools.

2. Method

. The use of SLR in research is carried out by systematically reviewing and identifying articles in international journals, which in each process follow the steps or protocols that have been set. The following procedures are carried out in the SLR, consisting of several stages, namely: (1) problem formulation, (2) literature search, (3) identification of the right type of research, (4) retrieve information from articles.

Tabel 1. Problem Formulation

No	Objectives	Formulation
1	Describe the effectiveness of using STEM learning to improve students' mathematical thinking skills.	Is the use of STEM learning effective to improve students' mathematical thinking skills?
2	Describe the use of STEM learning to increase student's mathematical thinking skills.	Does the use of STEM learning have an effect on increasing students' mathematical thinking skills?
3	Describe the effect of using STEM learning on the overall improvement of students' mathematical thinking skills.	How much is the effect of using STEM learning on the overall improvement of students' mathematical thinking skills?
4	Describe the effect of using STEM learning on increasing mathematical thinking skills based on the level of education. How big is the effect of using STEM learning on increasing mathematical thinking skills based on the level of education.	How much is the effect of using STEM learning on increasing mathematical thinking skills based on the level of education?

Furthermore, to search the literature, it is in Table 2.

Table 2. Literature Search

Emerald	emerald.com
Link Springer	link.springer.com
Sciencedirect	sciencedirect.com
Taylor and Francis Journal	tandfonline.com
Google Scholar	scholar.google.com

At the literature search stage, this research uses software and databases including emerald, link springer, ScienceDirect, Taylor and Francis journal, and google scholar.

a) Emerald, the journal obtained at this stage was 22 journal articles. After being analyzed, obtained 1 that is relevant to the formulation of the problem in this study.
b) Link Springer, the journals obtained at this stage were 117 journal articles. After being analyzed, obtained 6 that are relevant to the formulation of the problem in this study.

c) Sciencedirect, journals obtained at this stage were 67 journal articles. After being analyzed, obtained 1 that is relevant to the formulation of the problem in this study.
d) Taylor and Francis Journal, the journals obtained at this stage were 69 journal articles. After being analyzed, obtained 7 that are relevant to the formulation of the problem in this study.
e) Google Scholar, searching for journal data obtained as many as 26 journal articles that are relevant to the formulation of the problem in this study.

At the stage of identifying the right type of research based on the background of the problem that has been described, several problems can be identified as follows:

a) Articles are made by general researchers or students.
b) Articles made using experimental research methods.
c) Articles are international level originating from journals accredited by Scopus.
d) Articles published within the last 5 years starting from 2015-2020.
e) Themed article on the use of STEM-based learning to improve mathematical thinking skills.
f) The sample level of education in the article is the education level of Junior High School and Senior High School.

At the stage of concluding information from the article, the results of all concluded articles will be processed and conclusions drawn according to the formulation of the problem that has been determine

3. Results and Discussion

As previously mentioned, this literature review will describe how much influence the effective use of STEM learning has on improving students' mathematical thinking skills based on their educational level. It can be seen in Table 3 the results of the relevant literature in this study.

Table 3. Analysis Results

citation	Effectiveness	Effect	Educational level
[9]	Effective	Take effect	Junior High School dan Senior High School
[10]	Effective	Take effect	Junior High School
[11]	Ineffective	No effect	Senior High School
[12]	Ineffective	No effect	Junior High School
[13]	Ineffective	No effect	Senior High School
[14]	Effective	Take effect	Junior High School dan Senior High School
[15]	Effective	Take effect	Senior High School
[16]	Effective	Take effect	University
[17]	Effective	Take effect	Primary school
[18]	Effective	Take effect	Junior High School/Senior High School
[4]	Effective	Take effect	Primary school
[19]	Effective	Take effect	University
[20]	Effective	Take effect	Junior High School dan Senior High School
[21]	Effective	Take effect	University
[22]	Ineffective	No effect	Senior High School

In table 3 there are 11 of 15 kinds of literature that are effective and influential in their research, 4 of them are not effective and influential. There are 4 out of 11 effective and influential literature. [9] combining data from two studies, a large-scale survey and intervention, argues three main points: (1) student attitudes and teacher perceptions of these attitudes are quite

distinctly different, (2) the relationship between mathematics and STEM has an influence on students' perceptions and (3) implementation of class ability grouping based on standardized test scores can be detrimental to students who have a natural tendency towards STEM and a positive attitude towards mathematics. [11] revealed that STEM learning affects student achievement by demographic background and level of performance. [4] provides insight into how mathematical knowledge and thinking, in particular the identification of mathematical patterns and structures, can be promoted through engagement with coding activities. Studies provide evidence that learning that occurs through coding instruction can lead to higher-level students' mathematical thinking in terms of identifying mathematical patterns and structures that can lead to generalizations.

In Table 3, there are 3 of 15 pieces of literature that show how much influence the use of STEM has on improving students' mathematical thinking skills. From the three literature, some instruments are carried out, namely surveys and prospective cohorts. There is an influencing factor, namely the student factor, in the study [10] the percentage of students who said that they were not sure whether they needed STEM in their learning ranged from 12.5 to 32.6%. Overall the results show that STEM knowledge is scarce among high school students. The results revealed that students did not seem to be aware of the limitations of STEM knowledge. Perhaps a greater emphasis on authentic means of teaching and evaluating STEM content involving collaboration, problem-solving, and application of STEM knowledge might serve to engage learners in more meaningful ways, resulting in possible continuation of motivation and interest in STEM careers as students progress through education. middle and post-secondary school. [21] The percentage of 58% positive results obtained are not only knowledge and abilities but also satisfaction expressed by students. GBL activities have a structure that is very in line with the requirements of the intended action. First, by working in teams students can work together, confront ideas and gain a deep understanding of content understanding, which increases their confidence. Second, given the competitive base of activity, teams are challenged to reach the right solution as soon as possible, meaning they must find the most appropriate way to optimize time (speed matters) and resources (who does what). Third, students are familiar with the game (94% of students who took part in the first session stated that they were familiar or very familiar with the game). Thus it is easy for them to understand the elements that characterize it (goals, context, and rules). [19] using a prospective cohort of the effect of mathematical thinking skills on a stratified approach, the posttest result is 34%.

In Table 3 there are 11 of 15 pieces of literature that affect the level of education, 4 of which have no effect. At the secondary/high school level, there are 10 pieces of literature, 6 pieces of literature have an effect on the secondary/high school level, 5 of which have no effect. At the elementary school level, there is 1 literature of which is influential. Then at the university level, there are 2 pieces of literature of which are influential. While at the level of Teacher 1, literature is influential. Because the sample level of education in the article is a junior high school and high school level of education. So obtained 10 of 15 literature at the level of high school / high school, 6 influential literature and 4 of them have no effect. Then it is obtained that the influence of the use of STEM learning on increasing students' mathematical thinking skills is 60% at the high school/high school level. Therefore, in this study 60% of the effect of the use of STEM learning on increasing students' mathematical thinking skills at the secondary school level.

4. Conclusion

The results of the study indicate that the use of STEM learning is effective in improving students' mathematical thinking skills. The use of STEAM learning affects increasing students'

mathematical thinking skills. Overall the lowest ranged from 12.5 to 32.6% and by 58% affected the use of STEM learning in increasing students' mathematical thinking skills. At the high school level 60% of the use of STEM learning affects the improvement of students' mathematical thinking skills. Based on the conclusions above, the researcher can convey some suggestions that are expected to provide benefits. The suggestions that will be submitted are as follows: (a) For researchers, it is expected to be useful knowledge and add insight to researchers to become a teacher.(b) For other researchers, this research is limited by literature sources, years, and levels of education. For future researchers, the authors suggest adding literature sources, years, and levels of education. It can also be a reference, source of information and reference material so that it can be further developed to add insight and knowledge and can be used as a library guide for further research.

References

[1] A. E. and A. C. Berna Tataroglu Tasdan, "A daunting task for pre-service mathematics teachers: Developing students mathematical thinking," *Educ. Res. Rev.*, vol. 10, no. 2, pp. 2276–2289, 2015, doi: 10.5897/ERR2015.

[2] U. Layyina, "Analisis Kemampuan Berpikir Matematis Berdasarkan Tipe Kepribadian pada Model 4K dengan Asesmen Proyek Bagi Siswa Kelas VII," *Prism. Pros. Semin. Nas. Mat.*, vol. 1, pp. 1–10, 2018, [Online]. Available: https://journal.unnes.ac.id/sju/index.php/prisma/%0Ahttps://journal.unnes.ac.id/sju/index.php/prisma/article/view/20216/9592.

[3] S. M. Matondang, "Peningkatan Kualitas Pembelajaran Berbasis STEM di SMK Sebagai Upaya Dalam Menghadapi Abad 21," *Pros. Semin. Nas. Teknol. Pendidik. Pascasarj. UNIMED*, pp. 267–273, 2019.

[4] J. Miller, "STEM education in the primary years to support mathematical thinking : using coding to identify mathematical structures and patterns," *ZDM*, vol. 10, no. 1007, p. 19, 2019, doi: 10.1007/s11858-019-01096-y.

[5] N. L. Badriyah, A. Anekawati, and L. F. Azizah, "Application of PjBL with brain-based STEAM approach to improve learning achievement of students," *J. Inov. Pendidik. IPA*, vol. 6, no. 1, pp. 88–100, 2020, doi: 10.21831/jipi.v6i1.29884.

[6] K. C. Margot and T. Kettler, "Teachers' perception of STEM integration and education: a systematic literature review," *Int. J. STEM Educ.*, vol. 6, no. 1, 2019, doi: 10.1186/s40594-018-0151-2.

[7] Y. X. and J. E. F. Yeping Li, Ke Wang, "Research and trends in STEM education: a systematic analysis of publicly funded projects," *Int. J. STEM Educ.*, vol. 7, no. 1, 2020, doi: 10.1186/s40594-020-00213-8.

[8] S. Siswanto, "Systematic Review Sebagai Metode Penelitian Untuk Mensintesis Hasil-Hasil Penelitian (Sebuah Pengantar)," *Bul. Penelit. Sist. Kesehat.*, vol. 13, no. 4, 2012, doi: 10.22435/bpsk.v13i4.

[9] E. Prieto and N. Dugar, "An Enquiry into the Influence of Mathematics on Students ' Choice of STEM Careers," *Int. J. Sci. Math. Educ.*, vol. 10, no. 1007, p. 7, 2016, doi: 10.1007/s10763-016-9753-7.

[10] K. A. Blotnicky, T. Franz-Odendaal, F. French, and P. Joy, "A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students," *Int. J. STEM Educ.*, vol. 5, no. 1, p. 22, 2018, doi: 10.1186/s40594-018-0118-3.

[11] S. Han, R. Capraro, and M. M. Capraro, "How STEM PBL Affects High, Middle, and Low

Achievers Differently: The Impact of Student Factors On Achievement," *Int. J. Sci. Math. Educ.*, vol. 10, no. 1007, p. 14, 2014, doi: 10.1007/s10763-014-9526-0.

[12] R. U. Mun and N. B. Hertzog, "Teaching and Learning in STEM Enrichment Spaces: From Doing Math to Thinking Mathematically," *Roeper Rev.*, vol. 40, no. 2, pp. 121–129, 2018, doi: 10.1080/02783193.2018.1434713.

[13] A. H. Aldahmash, M. Alamri, and M. A. Aljallal, "Saudi Arabian science and mathematics teachers ' attitudes toward integrating STEM in teaching before and after participating in a professional development program," *Cogent Educ.*, vol. 6, no. 1, pp. 1–21, 2019, doi: 10.1080/2331186X.2019.1580852.

[14] A. Bicer, R. M. Capraro, and M. M. Capraro, "International Journal of Mathematical Education in Hispanic students ' mathematics achievement in the context of their high school types as STEM and non-STEM schools," *Int. J. Math. Educ. Sci. Technol.*, vol. 5211, no. 1464, p. 20, 2017, doi: 10.1080/0020739X.2017.1410735.

[15] M. J. Nathan, M. Wolfgram, R. Srisurichan, C. Walkington, and M. W. Alibali, "Threading mathematics through symbols, sketches, software, silicon, and wood: Teachers produce and maintain cohesion to support STEM integration," *J. Educ. Res.*, vol. 110, no. 3, pp. 272–293, 2017, doi: 10.1080/00220671.2017.1287046.

[16] D. Moore-Russo, K. Kornelson, M. Savic, and C. Andrews, "Considering the Evolution of the STEM Mathematical Pathway at the University of Oklahoma using Organizational Development and Change Theory," *Primus*, vol. 0, no. 0, pp. 1–14, 2020, doi: 10.1080/10511970.2020.1793852.

[17] R. Weinhandl, Z. Lavicza, and T. Houghton, "Mathematics and STEM teacher development for flipped education," *J. Res. Innov. Teach. Learn.*, vol. 13, no. 1, pp. 3–25, 2020, doi: 10.1108/jrit-01-2020-0006.

[18] C. K. Baker and T. M. Galanti, "Integrating STEM in elementary classrooms using model-eliciting activities: responsive professional development for mathematics coaches and teachers," *Int. J. STEM Educ.*, vol. 4, no. 10, pp. 1–15, 2017, doi: 10.1186/s40594-017-0066-3.

[19] S. S. Guzey, M. Harwell, M. Moreno, Y. Peralta, and T. J. Moore, "The Impact of Design-Based STEM Integration Curricula on Student Achievement in Engineering, Science, and Mathematics," *J Sci Educ Technol*, vol. 10, no. 1, pp. 8–9, 2016, doi: 10.1007/s10956-016-9673-x.

[20] X. A. Newton and E. P. T. Jr, "Studies in Educational Evaluation Building undergraduate STEM majors ' capacity for delivering inquiry-based mathematics and science lessons : An exploratory evaluation study," *Stud. Educ. Eval.*, vol. 64, no. 10, p. 8, 2020, doi: 10.1016/j.stueduc.2019.100833.

[21] D. Gil-domenech and J. Berbegal-mirabent, "Stimulating students ' engagement in mathematics courses in non-STEM academic programmes : A game-based learning," *Innov. Educ. Teach. Int.*, vol. 14, no. 7, p. 5, 2017, doi: 10.1080/14703297.2017.1330159.

[22] M. A. Gottfried and M. A. Gottfried, "The Influence of Applied STEM Coursetaking on Advanced Mathematics and Science Coursetaking," *J. Educ. Res.*, vol. 22, no. 2, pp. 5–6, 2015, doi: 10.1080/00220671.2014.899959.