Meta-Analysis of STEM Education Influencing Learning Achievement and Thinking in Thailand from 2016 to 2020

Sanit Srikoon[1], Chansit Khamput[2], Sirikorn Bamroongkit[3] and Chalunda Podjana[4]

[1, 2,4]Faculty of Education, Khon Kaen University, Thailand

[3] School of Liberal Arts, Mae Fah Luang University, Thailand

E-mail: [1]sanitsrikoon@gmail.com

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Abstract

STEM education is one of the alternative learning approaches, and it is promoted widely in Thailand since it integrates four core subjects: science, technology, engineering, and mathematics for students to learn at once. Further, implementing STEM education might enhance students' soft skills along with hard skills. Therefore, this study aims to identify the effect-size index of STEM education influencing 1) students' learning achievement and 2) thinking skills. This study's population comprises 104 master's and doctoral theses on STEM education in Thailand. The following criteria were applied to select samples: it should be a master's or doctoral thesis on STEM education conducted in Thailand, the research design is a two-group pretest-posttest design, and it has been published on the Thai Digital Collection database between 2016-2020. Data were collected from eight theses according to the criteria mentioned above using the research evaluation form and research record form. Meta-analysis is employed in this study. The finding reveals that STEM education enhances students' learning achievement of experiment groups compared to control groups' (SMD=0.906 (95%CI;0.706 to 1.105), I^2=49.800). STEM education also enhances students' thinking skills of experiment groups compared to control groups' (SMD=0.993 (95%CI;0.745 to 1.242), I^2=0.000). The results show that STEM education helps students to level up their learning achievement and thinking skills.

Keywords: Meta-Analysis; STEM Education; Effect Size

Introduction

In the 21st Century, learners are expected to possess hard skills, soft skills, critical thinking, problem–solving, creativity, innovation, cross–cultural understanding, collaboration, teamwork, leadership, communications information and media literacy, computing, ICT literacy, career skills, and competencies. Consequently, STEM education is one of the learning approaches that promote 21st Century skills (Srikoon, et al., 2021: Khwana & Khwana, 2021).

STEM education is an approach that integrates four core scientific subjects, science, technology, engineering, and mathematics. It aims to enhance the learning process for creating practical learning explorations. However, research synthesis of STEM education is less performed (Monsang & Srikoon, 2021) to indicate its contributions. It would be helpful to synthesize information regarding STEM education research in Thailand especially, its influences on learning achievement and thinking skills. These two variations could reflect significant points of promoting 21st Century skills in Thai context.

Meta–analysis is used to gather information about common attributes and the effect–size index of a single study. The effect–size index indicates relationships between variations (Srikoon, 2019.; Palmer, Sterne, Newton, & Cox, 2016). Many researchers in Thailand are interested in performing meta–analyses regarding STEM education; for example, Apaivatin, Srikoon & Mungngam (2021) synthesized STEM education's influence regarding scientific skills. Monsang & Srikoon (2021) conducted a meta–analysis concerning STEM education affecting creative thinking skills in Thai learners as well as Khamngoen & Srikoon (2021), they explored STEM education that influences problem–solving skills. However, these studies did not mention the effects of STEM education regarding learning achievement and thinking skills. More importantly, the effect–size index and significance of STEM education were not mentioned in the mentioned studies. Recently, STATA Program is used to analyze standardized mean difference (SMD), confidence interval, heterogeneity, overall effect–size index, and graphical analyses that accompany a meta–analysis to show horizontal lines for each study (Palmer et al., 2016).

This paper aims to identify the effect–size index of STEM education that influences learners' learning achievement and thinking skills. Thus, the findings could increase validity in employing STEM education in a classroom.

Research Questions

1. To what extent STEM education enhances students' learning achievement

2. To what extent STEM education enhances students' thinking skills

Research Objectives

1. To identify the effect–size index of STEM education that influences students' learning achievement.

2.To identify the effect–size index of STEM education that influences students' thinking skills.

Literature Review

Mata–analysis is one way to assess how a set of research studies demonstrate power, homogeneous relationship, and heterogeneity (Srikoon, 2019). Mate–analysis measures and summarizes a set of studies of statistical power and overall in–depth information regarding the same research questions for further study (Wiratchai & Jetchamnongnuch, 2008). To quantify the meta–analysis, Palmer et al. (2016) concluded statistics used as follows:

1. standardized mean difference (SMD) or mean difference (MD) to measure the effect–size index with a 95% confidence interval (CI)

2. heterogeneity chi–squared to measure heterogeneity of each effect size

3. I2 – statistic to assess heterogeneity. Thresholds of I2 were interpreted concerning the magnitude and direction of effects and strength of heterogeneity's evidence. I2 values of more than 50% confirm substantial heterogeneity.

4. chi–squared to assess SMD concerning to analyze the significance of the overall effect calculated by computing a z score as the ratio of the overall effect to its standard error and comparing it with the standard normal distribution

These statistics could reveal insight on the confidence interval, statistical significance, homogeneous results, and heterogeneity in this study.

STEM education is a learning approach that invites learners to explore science, technology, engineering, and mathematics together—these multidisciplinary aims to promote learners' 21st–century skills and achievement (Srikoon et al., 2020). STEM education attributes are as follows: (Polyiem, 2018)

1. creating opportunities in integrating all knowledge and proficiency related to STEM during the learning process

2. challenging learners to solve assigned problems or scenarios

3. providing various activities based on the active learning environment

4. promoting 21st–century skills through assigned tasks

5. offering related real–life problems or scenarios

Guidelines in employing STEM education in classrooms are as follows: (Khwana & Khwana, 2021)

1. blending STEM in the regular syllabus

2. adding STEM as an elective subject

3. adding STEM as one of the extra–curricular activities

Therefore, STEM education is an integrated learning approach that is challenging, active, and useful since it could promote learning skills in the 21st Century. Additionally, positions of STEM can be varied depending on how teachers would implement.

This study advanced previous research of Khamput, Srikoon, & Bamroongkit (2021) in that examining the effect–size index of STEM education research in Thailand concerning a two–group pretest–posttest design was confirmed to ensure STEM education affects learning achievement and thinking skills. In addition, a meta–analysis could demonstrate the effect–size index of each study, heterogeneity of each effect size, overall effect–size index significance, and overall effect–size index heterogeneity (Palmer et al., 2016).

Research Methodology

The study employs meta–analysis and includes the research elements as follows:

Population and samples

The population for this study was 115 published theses of master and doctoral regarding STEM education. According to the evaluation, the 104 theses held good quality. They were applied to the further criteria as 1) it should be master or doctoral theses concerning STEM education, 2) the research design should be a two–group pretest–posttest design, and 3) it should be distributed in Thai Digital Collection database between 2016–2020. With regard to the mentioned criteria, the sample of this study comprised eight theses, as mentioned in the appendix.

Instruments

The researchers used instruments developed by the Ministry of Education (2009 as cited in Monsang, & Srikoon, 2021), which are research evaluation forms and research information records.

Data Collection

The researchers collected the data as follows:

1. identify research gaps and set objectives to analyze attributes of STEM education research in Thailand from 2016 to 2020.

2. search for master and doctoral theses regarding STEM education from Thai Digital Collection database.

3. examine related studies concerning research attributes and meta–analysis

4. collect data by gathering published research studies, evaluating the quality, selecting research that hold good quality according to the set criteria, and collecting research attributes as stated in the research of Khamput, Srikoon, & Bamroongkit (2021)

5. collect data from research studies based on the criteria of employing a two–group pretest–posttest design and analyze the effect–size index of each study

6. report and summarize the research

Data Analysis

The effect–size index of STEM education was retrieved from the learning achievement and thinking tests and compared using standardized mean difference (SMD) or mean difference (MD) with a 95% confidence interval (CI). In addition, the researchers assessed heterogeneity with the I2–statistic and interpreted its thresholds according to the magnitude and direction of effects and strength of heterogeneity's evidence. The I2 values are more than 50 percent; it is considerable heterogeneity. DerSimonian and Laird random–effects model was used to pool the data, and STATA was used to analyze the data.

Research Findings

The meta–analysis findings concerning STEM education research in Thailand that influences students' learning achievement and thinking skills are as follows:

1. Findings regarding the effect–size index of STEM education that influences students' learning achievement

Table 1 The effect–size index of STEM education that influences students' learning achievement

ID	Study	Standardized mean difference (SMD)	95% Confidence interval (95% CI)	%Weight
1	Inpinit, L. (2016)	1.110	0.574–1.646	13.89
2	Manujum, P. (2017)	1.493	0.966–2.021	14.32
3	Tongkhang, P. (2017)	0.958	0.431–1.485	14.38
4	Suriyakamon, C. (2018)	0.339	–0.250–0.928	11.50

ID	Study	Standardized mean difference (SMD)	95% Confidence interval (95% CI)	%Weight
5	Chavarangpong, S. (2018)	0.699	0.303–1.096	25.42
6	Ranmeechai, P. (2018)	0.893	0.452–1.335	20.49
	I–C pooled SMD	0.906	0.706–1.105	100.00
Heterogeneity chi–squared = 9.97 (d.f. = 5) p = 0.076, I^2= 49.8%, Test of SMD=0 : z= 8.89 p = 0.000				

According to the set criteria, six studies were selected to do a meta–analysis. Table 1 indicates heterogeneity chi–squared no significant (X2=9.97, df=5, p=0.839, I2= 49.8%) . That is, the SMD is non– heterogeneity and shows a significant difference between STEM Education and comparators, control groups, on learning achievement (Overall achievement SMD: 0.906 (95%CI; 0.706 to 1.105), I2 = 49.8%:). As a result, STEM education is able to promote learning achievement (SMDID1=1.110, SMDID2=1.493, SMDID3=0.958, SMDID4=0.339, SMDID5=0.699, SMDID6=0.893), and a comparison of the two groups' SMD is shown in figure 1.

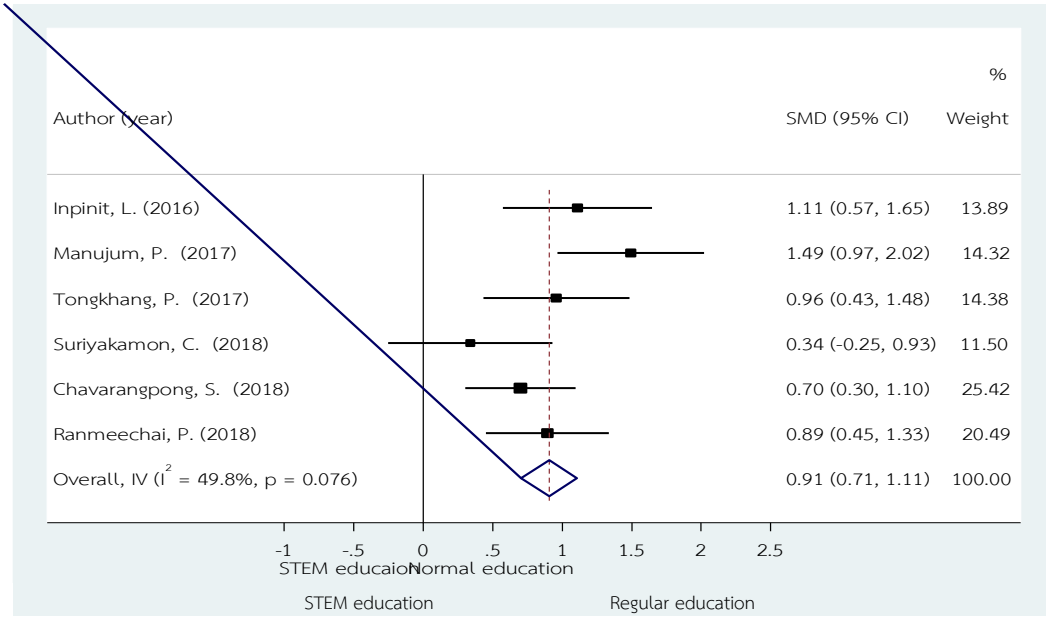

Figure 1 Comparing SMD (95% CI) between 2 groups of the six studies

2. Findings regarding the effect–size index of STEM education that influences thinking skills.

Table 2 The effect–size index of STEM education that influences thinking skills

ID	Study	Standardized mean difference (SMD)	95% Confidence interval (95% CI)	% Wight
1	Swang, O. (2017)	1.004	0.425–1.582	18.45
2	Prapasee, W. (2017)	1.128	0.655–1.601	27.64
3	Tongkhang, P. (2017)	1.046	0.514–1.578	21.81

ID	Study	Standardized mean difference (SMD)	95% Confidence interval (95% CI)	% Wight
4	Ranmeechai, P. (2018)	0.836	0.397–1.275	32.09
	I–C pooled SMD	0.993	0.745–1.242	100.00
Heterogeneity chi–squared = 0.84 (d.f. = 3) p = 0.839, I^2= 0.000%, Test of SMD=0 : z= 7.84 p = 0.000				

According to the set criteria, four studies were selected to do a meta–analysis. Table 2 indicates heterogeneity chi–squared no significant (X^2=9.97, df=5, p=0.839, I^2= 0.0%,). That is, the SMD is non– heterogeneity and shows a significant difference between *STEM Education* and comparators, control groups, on thinking skills (Overall achievement SMD: 0.993 (95%CI; 0.745 to 1.242), I^2 = 0.000%:). As a result, STEM education is able to promote thinking skills (SMD_{ID1}=1.004, SMD_{ID2}=1.128, SMD_{ID3}=1.046, SMD_{ID4}=0.836), and a comparison of the two groups' SMD is shown in figure 2.

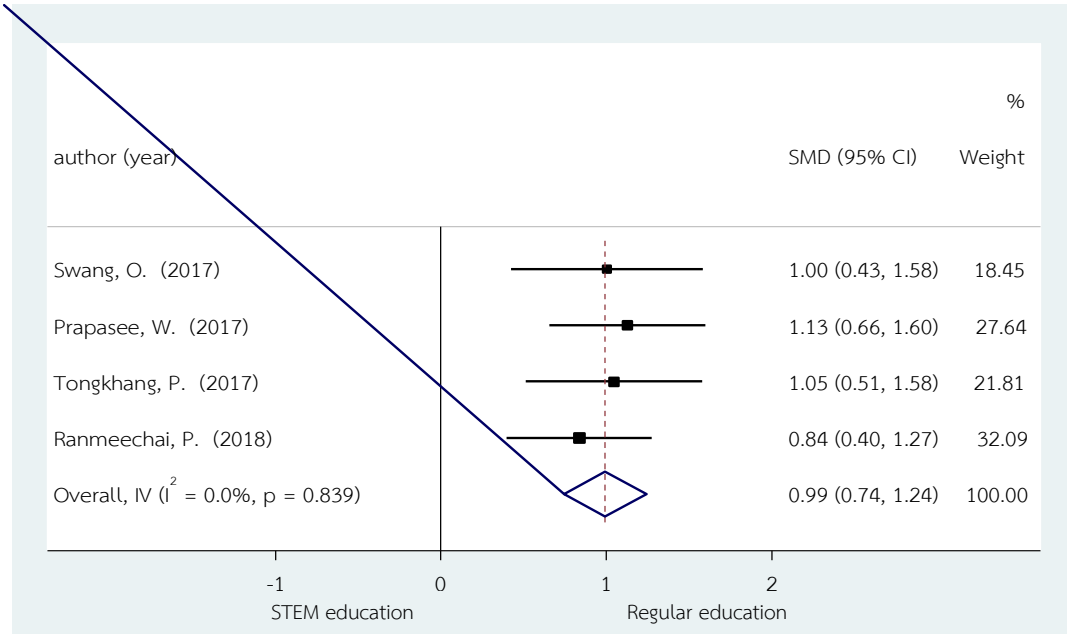

Figure 2 Comparing SMD (95% CI) between 2 groups of the four studies

Research Discussion

The study was to identify the effect–size index of STEM education that influences students' learning achievement and thinking skills. The researchers found that only eight from 104 published theses fit the set criteria. That is, STEM education research with a two–group pretest–posttest design is less interesting among researchers. The research of Khamput, Srikoon, & Bamroongkit (2021) found that STEM education research in Thailand between 2016–2020 employed one group pretest–posttest design for 33.65 percent. This may not support whether STEM education helps to enhance

students' performance. Moreover, Thitipong & Srikoon (2021) mentioned that most STEM education research in Thailand between 2009–2019 employed a one–group pretest–posttest design for 77.27 percent, whereas one research employed a two–group pretest–posttest design (4.45 percent). Therefore, it is plausible that using a two–group pretest–posttest design in STEM education research might be beneficial to the body of knowledge since the design could better show the influences of STEM education.

With regard to the effect–size index of STEM education that influences students' learning achievement, six studies revealed that STEM education could enhance students' learning achievement (Test of SMD = 0: z= 8.89 p = 0.000). In addition, Thitipong & Srikoon (2021) found that the only one STEM education research between 2009–2019 showed the effect–size index of 0.445, and it could improve students' learning achievement as Khwana & Khwana (2021) proposed that STEM education should be implemented in class to build up students' 21st–century skills.

According to the effect–size index of STEM education that influences students' thinking skills, four studies revealed STEM education could better students' thinking skills (Test of SMD = 0: z = 7.84 p = 0.000). Khwana & Khwana (2021) and Polyiem (2018) claimed that thinking skills, for example, creative, innovative, critical thinking, and problem–solving, could be promoted if STEM education is applied in classrooms. Moreover, Monsang & Srikoon (2021) found that STEM education could promote creative thinking skills.

Research Summary

The research is a meta–analysis regarding STEM education that influences learning achievement and thinking skills in Thai context from 2016 to 2020. The result shows that STEM education helps to level up learning achievement and thinking skills of Thai learners.

Limitations

This study only collected the data from STEM education research conducted in Thailand and published in the Thai Digital Collection database between 2016 to 2020. As a result, it appears that the sample size is small and may not reflect the influences of STEM education clearly.

Suggestions

1. Implications

Teachers and educators could consider bringing STEM education to their contexts to level up students' learning achievement and thinking skills that are 21st–century skills.

2. Further Study

This study conducts a meta–analysis regarding STEM education. Therefore, further studies could focus on conducting a meta–analysis of other teaching approaches, for example, research–based learning, problem–based learning, or open approach. Further, it would be beneficial to include data from international works.

References

Apaivatin, A., Srikoon, S. & Mungngam, P. (2021). Research synthesis of STEM Education effected on science process skills in Thailand. *Journal of Physics: Conference Series, 1835*(012087), 1–10.

Chakphet Suriyakamol. (2016). *The Effects of STEM Integration Based Extra–Curricular Activities on Literacy and Collaborative Problem Solving Behavior for Prathomsueksa Six Students.* (Doctoral Dissertation). Srinakharinwirot University.

Chavarangpong, S. (2018). *Comparison of 21st Century Skills and Learning Achiement of Grade 3 Student on the Topic "Materials Around Us" Using STEM Education Approach and Tradition Instruction* (Doctoral Dissertation). Thepsatri Rajabhat University.

DerSimonian, R. & Laird, N. (1986). Meta–analysis in clinical trials. *Control Clin Trials, 7*, 177–188.

Khamngoen, S. & Srikoon, S. (2021). Research synthesis of STEM Education approach effected on students' problem–solving skills in Thailand. *Journal of Physics: Conferences, 1835* (012086), 1–8.

Khamput, S., Srikoon, S., & Bamroongkit, S. (2021). The Research Synthesis of STEM Education in Thailand. *Journal of Buddhist Studies, 12*(1), 187–204.

Khwana, T & Khwana, K. (2021). STEM Education for Learning Management to Work Skills in the 21st Century. *Journal of Graduate School Sakon Nakhon Rajabhat University, 16*(73), 1–12.

Manujum, P. (2017). *The Study on Reflective Thinking using Problem–Based Learning with STEM Education Concept* (Doctoral Dissertation). Ubon Ratchathani University.

Monsang, P. & Srikoon, S. (2021). Meta–Analysis of STEM Education Approach effected on Student' Creative thinking skills in Thailand. *Journal of Physics: Conferences, 1835*(012085), 1–8.

Onthida Swang. (2017). T*he Study on Mathematical Creative Thinking in Originality Aspect Using Problem–Based Learning with Stem Education Concept* (Doctoral Dissertation). Ubon Ratchathani University.

Palmer, T.M., Sterne, J.A.C., Newton, H.J., and Cox, N.J. (2016). *Meta–Analysis in Stata: An Updated Collection from the Stata Journal.* (2nd ed.). United States of America: Stata Press.

Phuripong Tongkhang. (2017). *The Development of an Online Integration Learning Model Based on STEM Education to Enhance Critical Thinking Ability of High School Student* (Doctoral Dissertation). Rajabhat Maha Sarakham University.

Polyiem, T. (2018). STEM Education: Introduction to Integrated Classroom. *Journal of Faculty of Education Pibulsongkram Rajabhat University, 5*(2), 122–135.

Prapasee, W. (2017). *The Study on Mathematics Analytical Thinking using Problem–Based Learning with STEM Education Concept* (Doctoral Dissertation). Ubon Ratchathani University.

Ranmeechai, P. (2017). *Comparison of Learning Activities in Cording to the Guidelines of the STEM Education on Electrochemistry Issue of Secondary student at the 11th Grade Level.* (Doctoral Dissertation). Maha Sarakham University.

Srikoon, S. (2019). Meta–Analysis of Teaching Model based–on Educational Neuroscience influencing on Science Learning Outcomes in Thailand. *Journal of Graduate Studies Review Mahachulalongkornrajavidyalaya University, Phare Campus, 5*(2), 127–146.

Srikoon, S., Apaivatin, R., Monsang, P., Khamngoen, S., & Malaitao, T. (2020). *Construct validity of Assessing Interest in STEM Content Scale. Education Research International, 2020*(1), 1–7.

Srikoon, S., Bunterm, T., Samranjai, J., & Wattanathorn. (2014). Research Synthesis of Research Based Learning for Education in Thailand. *Procedia Social and Behavioral Sciences, 116*(1), 913–917.

Srikoon, S., Punsrigate Khongjaroen, K., Apaiyatin, R., Apaikawee, D., & Khamput, C. (2021). A Study of Influences of the Research Ethic Affecting the Attitudes towards STEM Education. *Journal of Social Academic, 14*(1), 70–80.

Thitipong, L. & Srikoon, S. (2021). Meta–analysis of STEM Education approach effected on students' learning achievement in Thailand. *Journal of Physics: Conferences, 1835*(012084), 1–7.

Wiratchai, N. & Jetchamnongnuch, W. (2008). Meta–Evaluation and Meta–Analysis of External Quality Evaluation Reports, Higher Education Level. *Journal of Research Methodology, 21*(2), 125–145.