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Research Article

Effect of 5E Learning Model on Academic Achievement in Teaching Mathematics: Meta-analysis Study

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Abstract: Active student involvement in the teaching and learning process is important in helping students strengthen their understanding of a concept better. Knowledge that is not related to existing knowledge will be easily forgotten. To strengthen understanding and knowledge, students need to build new knowledge on top of existing knowledge to ensure meaningful learning will take place. The 5E learning model is optically discerned to be able to have a positive impact on the development of student achievement. This study examines the benefits of the 5E learning model approach in teaching mathematics through a systematic review of research literature published from 2013–21 producing a total of 20 interventions (20 studies) that satisfy this study's criteria. The results show that conceptual knowledge, procedural knowledge and flexibility of procedures for the implementation of greater interventions, which can improve mathematical learning when used appropriately. This study suggests that teachers may need additional support to complete the course of mathematics using the five phases of learning in the 5E model, which in turn can assist in conducting teaching in an orderly and effective manner. In this way, it is important to implement the construction of learning modules for the fundamental topics of algebra based on the 5E model.

Keywords : Mathematics, Algebra, 5E learning model

1. Introduction

The teaching and learning of mathematics should involve the utilization of creativity and thinking skills. Mathematical skills include the competency to calculate, reasoning, creativity, problem-solving, and analysis (Elida, 2012). Mathematical learning is an abstract method for interpreting concepts, graphics, patterns, and step formats predicated on simple formulas to solve problem. This step is relevant and highly dependent on a person's thinking ability (Su et al., 2016). Studies conducted empirically on linear algebra from 2008 to 2017, show that students succeed in thinking about algebra through teaching and experimental activities in the classroom (Stewart S. et al., 2019). According to Stuhlmann (2019), there are students in institutions of higher learning who have difficulty in understanding the sundry types of measurements and fundamentals in linear algebra proof. The successful curriculum of mathematics education is when students can solve problems, implement concepts, and establish relationships between them by choosing appropriate mathematical methods, applying, and following the reasoning process. In changing the landscape of academic achievement in mathematics, sundry studies utilizing felicitous models, theories, and methods have been introduced. The 5E learning model introduced by Bybee et al. (2006) focuses on science to ameliorate student mastery in the subject. Based on previous studies, the 5E learning model has a positive effect on student achievement for certain topics in mathematics. When this learning model is implemented in algebra via the use of applied 21st century learning, it will obviously get a more preponderant effect on the students mastering algebra rudiments and further expanding their interpretation of complex algebra topics.

Principles of learning mathematics in school, students need to master mathematics with knowledge, active new knowledge from experience and understanding (NCTM, 2000). Effective mathematics learning requires students' understanding of the basic things they know and what they need to learn then gives them challenges and guidance to learn more. In a research carried out on most high school students who find it difficult to apply basic concepts of algebra to solve problems (Barbara Van Amerom, 2003). In the United States, the number of students who oppose or fear mathematics and leave school mathematically inadequate has caused massive concern (Jo Boaler, 2015). Jo Boaler (2016) found that students in the United States have been concerned about being unprepared for mathematics. Most of them left mathematics and were placed in the field of skills and rehabilitation jobs. Studies conducted with different approaches in heterogeneous groups of students given the responsibility and right to engage in mathematical training collaboratively.

The results of this study showed that student interest, accomplishment and motivation are rising. Tassell et al. (2012) clarified that in the learning process, the application of mathematics and learning through the experiences of students in life is very important. In terms of psychology, student-centered learning increases self-confidence,

decreases anxiety and develops a positive attitude towards teachers. Applying 5E and 21st century learning models would allow students to collaboratively. In terms of evaluation, collaboration class activities can be used as an alternative form of assessment. As a strategy to reinforce active learning practices and to facilitate active student engagement, collaborative activities have become increasingly necessary.

Therefore, 21st century learning is a teaching tool that is strongly promoted by the Ministry of Education (MOE) to be used in the teaching and learning process and to engage actively in student activities. Students will be more enjoyable, active and achieve academic success. According to Laal. M. & Ghodsi S.M. (2012), students who provide avail support, ideas, and information to each other can solve learning problem together. Although there are previous studies that use the 5E model in mathematics learning, it is not common and restricted to some areas of mathematics only. A simple algebra learning module can be built by integrating this 5E learning model with 21st century learning to open up the possibilities of mathematics education in the form of facilitators and student-centred teachers.

2. Research questions

The goal of this meta-analysis is to synthesize existing studies as a guiding principle in future selection of 5E mathematical model learning. The aim of this study is to provide an overview of 5E learning in the study at different levels of the school. The study also examines the progressive enhancement in mathematical learning of the 5E model. This article aims frankly to answer to the key statement:

i. What is the theme of the 5E learning model study in mathematics?

ii. What are the benefits of the 5E learning model approach to mathematics learning?

3. Methodology

The meta-analysis design was used in this study to systematically analyse studies related to the 5E learning model approach in mathematics. An exhaustive search for manipulative and mathematical studies was conducted between 2013 and 2021 with relevant keywords and their combinations (e.g., 5E model, approaches 5E learning model, teaching mathematics, learning, mathematics). This study followed Webster & Watson's (2002) procedures, which were adapted for the purpose of selecting related articles for the study.

A study of teaching mathematics using the 5E learning model approach to mathematics was the first essential criterion in the choice of an article. The second criterion is that the sample types were based on different educational levels. As a result, a total of 20 studies that fulfilled all the criteria were reviewed in this study, as shown in Table 1.

Table 1: List of Studies Related to 5E Learning Model Approach in Mathematics

Studies	Level of Education	Sample Size	Journal
Turan, S., & Matteson, S. M. (2021)	Teacher	7	International Journal of Education in Mathematics, Science and Technology
Aini K, et al. (2020)	Secondary School	84	Journal of Physics
Cartilla, E. J., & Rondina, J. Q. (2020).	Teacher	19	American Journal of Educational Research
Estanto, D., Zaenuri, Z., & Junaedi, I. (2020)	Primary School	20	Unnes Journal of Mathematics Education Research
No, J. K. N. (2020)	Secondary School	72	Journal of Physics
Nopasari, W., Ikhsan, M., & Johar, R. (2020)	Secondary School	2 classes (No specific number of sample)	Journal of Physics
Özenc, M., Dursun, H., & ŞAHİN, S. (2020)	Primary school	16	Participatory Educational Research
Schallert, S., Lavicza, Z., & Vandervieren, E. (2020)	Teacher	22	International Journal Of Mathematical Education In Science And Technology
Vlasenko, K. et al. (2020)	Tertiary Education	49	ICHTML 2020

Zahra Kalantarnia et al. (2020)	Secondary School	30	Journal for Educators, Teachers and Trainers JETT
Magsalay, R et al. (2019)	Tertiary Education	63	American Journal of Educational Research
Ramlee, N., Rosli, M. S., & Saleh, N. S. (2019)	Secondary School	33	International Journal of Emerging Technologies in Learning (iJET)
Michael C. Simanullang & Hasratuddin (2018)	Secondary School	31	Journal of Education and Practice
Pitriani (2018)	Tertiary Education	15	Jurnal Matematika
Ranjan, S., & Padmanabhan, J. (2018)	Primary school	70	An International Journal of Education and Applied Social Science
Okafor, C. F. (2017)	Secondary School	180	The International Journal of Engineering and Science (IJES)
Omotayo, S. A., & Adeleke, J. O. (2017)	Secondary School	172	Journal of the International Society for Teacher Education
Runisah, R., Herman, T., & Dahlan, J. A. (2017)	Secondary School	173	International Journal on Emerging Mathematics Education (IJEME)
Yeni, N., Suryabayu, E. P., & Handayani, T. (2017)	Secondary School	57	Journal of Physics
Madu, B. C., & Ezeamagu, M. U. (2013).	Primary School	134	International Journal of Educational Science and Research (IJESR)

4. Finding and discussion

There are two parts to the research findings. The first part discusses the theme of 5E learning model approaches in mathematics using the sample profile to determine the different school levels used in teaching mathematics by the 5E learning model. The second part examines the advantages of the teaching-mathematics 5E learning model approach.

Theme of 5E learning model approaches in mathematics

RQ 1: What is the theme of the 5E learning model study in mathematics?

Only one research topic from previous studies is relevant to the analysis based on the critical analysis of the goal and research questions, i.e. theme of study followed by the different school levels and 5E learning model approaches in mathematics teaching.

Table 2: Research Finding Related to the Theme of 5E Learning Model Approaches in Teaching Mathematics.

Research Themes	F	Studies (Year)
Geometry	3	Zahra Kalantarnia et al. (2020), Pitriani (2018), Okafor, C. F. (2017)
Trigonometry	1	Omotayo, S. A., & Adeleke, J. O. (2017)
Plane and spherical trigonometry	1	Magsalay, R et al. (2019)
Fraction	1	Madu B. C & Ezeamagu M. U (2013)
Probability	1	Michael C. Simanullang &Hasratuddin (2018)
Quadratics	1	Ramlee, N., Rosli, M. S., & Saleh, N. S. (2019)
Multiplication	1	Özenc, M., Dursun, H., & ŞAHİN, S. (2020)
Mathematical Proportional Reasoning	1	Estanto, D., Zaenuri, Z., & Junaedi, I. (2020)
Approximation Theory and Fourier Series	1	Vlasenko, K. et al. (2020)
The mathematical understanding test and the mathematical disposition questionnaires	1	Nopasari, W., Ikhsan, M., & Johar, R. (2020)

Lesson plan	3	Turan, S., & Matteson, S. M. (2021); Cartilla, E. J., & Rondina, J. Q. (2020); Schallert, S., Lavicza, Z., & Vandervieren, E. (2020).
Mathematical Communication Skill	2	No, J. K. N. (2020); Ramlee, N., Rosli, M. S., & Saleh, N. S. (2019)
No specific topics	3	Ranjan, S., & Padmanabhan, J. (2018); Runisah, R., Herman, T., & Dahlan, J. A. (2017); Yeni, N., Suryabayu, E. P., & Handayani, T. (2017)

The Research Sample Profile in Teaching Mathematics

After analysing the sample profile of the previous study of 5E learning model approaches in mathematics, four sample categories were identified, namely graduated teacher, primary schools, secondary schools and tertiary education.

Table 3: The Research Sample Profile

Sample	School Levels	F	Studies (Year)
Child	Primary	4	Estanto, D., Zaenuri, Z., & Junaedi, I. (2020); Özenc, M., Dursun, H., & ŞAHİN, S. (2020); Ranjan, S., & Padmanabhan, J. (2018); Madu, B. C., & Ezeamagu, M. U. (2013).
Teenager	Secondary	10	Aini K, et al. (2020); No, J. K. N. (2020); Nopasari, W., Ikhsan, M., & Johar, R. (2020); Zahra Kalantarnia et al. (2020); Ramlee, N., Rosli, M. S., & Saleh, N. S. (2019)Michael C. Simanullang & Hasratuddin (2018); Okafor, C. F. (2017); Omotayo, S. A., & Adeleke, J. O. (2017); Runisah, R., Herman, T., & Dahlan, J. A. (2017); Yeni, N., Suryabayu, E. P., & Handayani, T. (2017)
Young	Tertiary	3	Vlasenko, K. et al. (2020); Magsalay, R et al. (2019); Pitriani (2018)
Adult	Graduated Teacher	3	Turan, S., & Matteson, S. M. (2021); Cartilla, E. J., & Rondina, J. Q. (2020); Schallert, S., Lavicza, Z., & Vandervieren, E. (2020);

Based on the analysis carried out, the majority of previous studies related to 5E learning model in mathematics were performed among secondary school students. Many studies focus on young people because the formation of 5Elearning model is suitable for this age. This shows that the study shows that compared to primary school, secondary, higher education and teachers it is still important to do so. However, future studies can focus with a 5E learning approach on teacher lesson plans.

RQ 2: What are the benefits of the 5E learning model approach to mathematics learning?

The key results of research related to the importance of the 5E learning model method in teaching mathematics in accordance with the research objective are shown in Table 4.

Table 4: Research Findings Related to the Benefit of Learning 5E Model Approach in Teaching Mathematics.

Studies	Research Objective	Methodology	Research Findings
Turan, S., & Matteson, S. M. (2021)	To examine how middle-level math teachers designed and implemented their instruction on the basis of the 5E instruction model.	Case Study	The findings of this study inform educators of the difficulties teachers have in implementing the 5E model with fidelity. The quality of teachers' math lessons based on the 5E instructional model was examined by a limited number of studies.
Aini K, et al. (2020)	This investigation sought to develop the Mathematical Instrumentation by using	Mixed Method	The results of this study systematively showed that the learning cycle 5E model based on caring community met all the criteria for acceptable, practical and

	the careful community-based learning cycle 5E on the Matrix Operations.		effective use. The 5E learning cycle model based on caring community has an effect on the communication skills of students.
Cartilla, E. J., & Rondina, J. Q. (2020).	To determine the educational background of the teachers and the effectiveness of the LAC session in the performance of the teacher.	Observation	The findings have shown that teachers have outstanding performance in the planning and delivery of lessons. The results also showed that teachers strongly agree that the Learning Action Cell (LAC) sessions help to improve their teaching performance.
Estanto, D., Zaenuri, Z., & Junaedi, I. (2020)	The aim of this study is to determine the stage of mathematical reasoning of students in the 5th cycle of nuanced ethnomathematics.	Mixed Method	The findings of this study show that learning with a 5e cycle of nuanced ethnomathematics is effective in increasing the proportion of mathematical reasoning of students.
No, J. K. N. (2020)	The purpose of this study is to measure the effectiveness of the 5E Learning Cycle model in developing mathematical communication skill of junior high school students.	Quasi Experimental	The mathematical communication skills of students using the 5E LC model are better than conventional learning.
Nopasari, W., Ikhsan, M., & Johar, R. (2020)	The aim of this study is to determine the increase in the ability of mathematical understanding and mathematical disposition learned through this model, as well as the correlation between mathematical understanding and mathematical disposition in mathematical learning.	Experimental	The application of the 5E learning cycle model could improve students' mathematical understanding and disposition skills by developing mathematical understanding and mathematical layout for students who learned with the 5E learning cycle model was better than those who learned with the conventional learning model. Apart from that, the increase in mathematical disposition of those who learned with the 5E learning cycle model was better than that of those who used the conventional learning model and, last but not least, there was a significant correlation between mathematical understanding and mathematical disposition of students who learned with the 5E learning cycle model.
Özenc, M., Dursun, H., & ŞAHİN, S. (2020)	This study examines the effects of activities developed with WEB 2.0 tools on the multiplication achievement in grades 4.	Quasi Experimental	A major finding from this study and other studies was that the 5E Learning Cycle model and WEB 2.0 learning activities positively increased student achievement.
Schallert, S., Lavicza, Z., & Vandervieren, E. (2020)	The aim of this study was to evaluate a heuristic design aimed at encouraging teachers to develop flipped classroom lesson plans aligned with the 5E study model.	Case Study	Findings indicate that participants planned to use pre-out-of-class phases for engagement, post-out-of-class phases for consolidation, and in-class phases primarily for the implementation of student-centered activities.
Vlasenko, K. et al. (2020)	The study focuses on the feasibility of involving the 5E Instructional model for organizing the scientific research of students during the Approximation Theory	Survey	Positive influence of environmental improvement through 5E Instructional Model on students' emotional state and strengthening their interest in scientific research and the organization of workshop classes.

	and Fourier Series workshop.		
Zahra Kalantarnia et al. (2020)	The present research aims to investigate the effect of Bybee and Synectics on the creative, creative problem solving, and performance of 9 th grade students in geometry .	Quasi Experimental	Bybee's techniques performed more positively in comparison to the traditional method. Also, the use of Bybee's techniques had positive influences on geometry students' performance and innovative thinking.
Magsalay, R et al. (2019)	This study investigated the impact of EMI-RMT, 5E's instructional model, and explicit mathematics instruction in mathematics achievement.	Quasi Experimental	The result was evident in their post-test score, which had the same level of approaching proficiency. This means that the EMI-RMT approach and the 5E instructional model were comparability effective in improving student scores in mathematics.
Ramlee, N., Rosli, M. S., & Saleh, N. S. (2019)	To study the cognitive effect of 5E online learning on HOTS improvement among samples	Experimental	This research shows that human HOTS abilities can be fostered with the appropriate pedagogy approach by the use of an enhanced technological learning environment.
Michael C. Simanullang & Hasratuddin (2018)	This study aims to improve students' understanding of mathematical objects through the implementation of the 5E Learning Cycle Model using virtual manipulative probabilities.	Case Action Research	The implementation of the 5E Learning Cycle using virtual manipulatives can improve students' understanding of mathematical objects in probability material.
Pitriani (2018)	The aim of the study is to describe the learning achievement and learning independence of students with the help of software through Learning Cycle 5E.	Observation	The student's independence from learning shows positive results. Students are showing positive responses to learning. Students are also excited and motivated to take part in learning. Students are able to identify the right learning strategy so that it has a positive impact on student achievement.
Ranjan, S., & Padmanabhan, J. (2018)	The present study aims to find the effectiveness of the Constructivist's 5E approach to achievement in mathematics for upper primary students.	Quasi Experimental	The study shows that teaching constructivism through the 5E approach is effective in improving achievement in upper primary level mathematics compared to traditional methods. Various types of practical examples and real life examples, innovative activities have made the constructivist approach more effective and interesting.
Okafor, C. F. (2017)	The purpose of this paper is to show the effect of 5E-Learning Cycle on SS1 students' outcome and retention in geometry in Onitsha Education Zone of Anambra State.	Quasi Experimental	The results of the study found that 5E had a significant effect on student achievement and retention in geometry. Gender was a significant factor in determining the geometry students' retention.
Omotayo, S. A., & Adeleke, J. O. (2017)	The aim of this study was to determine the effects of the 5E instructional model on student learning outcomes in mathematics.	Quasi Experimental	The findings of this study showed that the 5E educational approach significantly improved the performance of students in mathematics compared to their peers who received traditional instruction.

Runisah, R., Herman, T., & Dahlan, J. A. (2017)	The aim of this study is to describe the enhancement and achievement of critical mathematical thinking skills of students who have completed the 5E Learning Cycle with Metacognitive Technique, the 5E Learning Cycle and conventional learning.	Experimental	The mathematical critical thinking skills of students who have received the 5E Learning Cycle are better than those of students who have received conventional learning. There is no interaction between the learning model and the school level to enhance and improve students' critical mathematical thinking skills.
Yeni, N., Suryabayu, E. P., & Handayani, T. (2017)	The aim of his research is to know whether the teaching model 'Learning Cycles 5E' is better than conventional mathematical teaching.	Quasi Experimental	The result showed us that the student achievement in the class that used the teaching model 'Learning Cycles 5E' is better than the class that did not use the model.
Madu, B. C., & Ezeamagu, M. U. (2013).	The study investigated the efficacy of 5Es at primary school level.	Experimental	The results show promising occasionally robust trends in numbers and numbering outcomes, thus contributing to a growing body of evidence, suggesting that the 5Es approach not only facilitated student mathematics learning outcomes, but also supported student numbers and numeracy development.

Based on the analysis, the study in 5E model study focuses on just a few subjects in mathematics. Studies on the fundamentals of algebra were not widely investigated and this is a clear study gap which has to be carried out in order to help high school students master the basics of algebra early in school. With the 5E model learning approach in mathematics teaching, the results show increased flexibility and knowledge.

5. Conclusion

This study shows that adapting the 5E learning model and learning in teacher education is considered important in enhancing student mastery in algebra. Focusing on basic algebra subjects taught in Form One will enhance students' knowledge of other areas of algebra. Teachers should emphasize early exposure to basic topics in the algebra in order to strengthen and prevent students from easily forgetting the knowledge. According to Su et al. (2016), at a high level students should be able to demonstrate innovative and critical thinking abilities. In conclusion, a learning module should be developed to adapt the 5E learning models and 21st century learning to help students improve their knowledge of basic algebra topics and then master other algebra fields.

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