Effect of 5Es with Teaching Aids on Academic Performance of Upper Primary School Pupils in Mathematics Non-Routine Problems

Frank Owusu[1], Augustina Adu[2], Dennis Offei Kwakye[3]*
[1 & 2] *Department of Mathematics and ICT, St. Loui College of Education, Kumasi, Ashanti Region, Ghana*
[3*] *Department of Mathematics and ICT Education, C. K. Tedam University of Technology and Applied Sciences, Navrongo, Upper West Region, Ghana*
**Corresponding author*

***Abstract* – The study aimed to determine the effect of 5Es with teaching aids on the academic performance of Junior High school students in mathematics non-routine problems. A sample of 48 students was randomly selected from Asawinso Methodist Upper primary school. Quasi-experimental non-equivalent pretest-posttest control group design research design was adopted for the study. A pre-test was employed to assess the academic ability equivalence and homogeneity of the two groups, while post-testing was used to examine the effect of the 5Es inquiry model with instructional aids on the performance of pupils in mathematics non-routine problems. An independent sample t-test was employed to compare the values between the experimental and control groups to evaluate the data at an alpha level of 0.05. In addition, the effects 5Es inquiry-based approach on students' mathematics non-routine problems was assessed based on gender. The results indicated that pupils taught using 5Es with teaching aids outperformed their counterparts taught using lecture method with teaching aids. Also, the results indicated that female learners perform better than male learners in mathematics non-routine problems. It is therefore recommended that when teaching pupils mathematics non-routine problems, 5Es supported with teaching aids should be adopted. A Teacher Made Test (TMT) was used to assess pupils' knowledge on non-routine problems in mathematics.**

***Keywords* - 5Es inquiry-based model, Quasi-Experimental pretest-posttest control group design, non-routine problems, teaching aids, academic performance**

I. INTRODUCTION

Mathematical education and mathematics are inextricably linked to the state of the world because mathematics is the dorsal spine of modern civilization. One society is of the view that mathematics as the foundation of scientific and technological knowledge, which is crucial to the nation's social and economic development. As a result, mathematics is mandatory in Ghana at both the primary and secondary levels. Mathematics is also required for admission to prestigious programs like medicine, architecture, and engineering at the tertiary level. Despite the importance of mathematics in society, national and international results have always been poor. Ghana, for instance, is currently ranked 45th in the world for overall mathematics achievement. The inability to solve non-routine problems is one of the reasons for Junior High School Two pupil poor performance. School mathematics curricula in general, and Primary and Junior High School mathematics curricula in particular, are essential for the overall development of students in Ghana who receive mathematical education. Despite several interventions to improve students' mathematics performance over the years, Ghanaian students continue to perform poorly in mathematics, particularly in non-routine problems at the primary school level [1]. Pupils' inability to understand approximately half of the non-routine problems accounts for their poor performance. As a result, a teaching strategy that helps students understand the processes involved in conceptualizing mathematical knowledge is required. In some South-Saharan African countries, including, Ghana, inquiry-based mathematics education is advocated in the primary school mathematics curriculum (Basic 4 - 6). Mathematics education must give students the chance to broaden, change, improve, and modify their worldviews. It should be based on learner-centered mathematics teaching and learning approaches that physically and cognitively engage learners in the process of knowledge acquisition in a rich and rigorous inquiry-driven environment [2]. Furthermore, rather than acquiring knowledge, mathematics learning is an active contextualized process of constructing knowledge based on the experiences of the learners. Learners are both researchers and creators of information. Teachers play the role of facilitators by fostering an environment in which students can build their own knowledge based on their prior experiences. This increases the learner's enthusiasm for learning and helps them develop critical thinking and non-routine problems skills [2]. As a result, the goal of this research is to see how a 5E inquiry-based approach with teaching aids affects basic four students' responses to non-routine mathematics problems. This will help teachers stay informed about the new strategy for developing students' non-routine problems abilities.

The 5Es are an instructional model encompassing the phases engage, explore, explain, elaborate, and evaluate, steps which educators have traditionally taught students to move through in phases. The 5Es model of instruction is an inquiry-based approach that differs from traditional methods of science instruction. The main one is that with the 5Es model the student leads the learning and the teacher acts as a guide.

Studies shows that lessons in this 5Es model promote active learning in the classroom. In comparison to passively listening to and reading about an activity, students actively participate in it [3]. Research findings reveals that students learn more effectively when they work collaboratively with others rather than working alone in a competitive study environment. It has been observed and discovered that when students collaborate, they are more successful in discovering and conducting their own experiments. Students pose scientific investigation-related questions, observe, evaluate, and explain, and draw conclusions and results. Students engage in direct experimentation as well as critical thinking to construct explanations during these inquiry-based experiences. Students require time to:

- Express and elaborate their current ideas, according to a constructivist understanding of scientific research.
- Interact with and become familiar with scientific apparatus, items, substances, and equipment, providing students with a variety of experiences from which to draw conclusions.
- Comparing your ideas to those of other students

• Using the 5Es inquiry model, students can gradually improve their conceptual thinking and comprehension. As illustrated in Figure 1, this technique walks students through five distinct learning processes beginning with the letter E: Engage, Explore, Explain, Elaborate, and Evaluate.

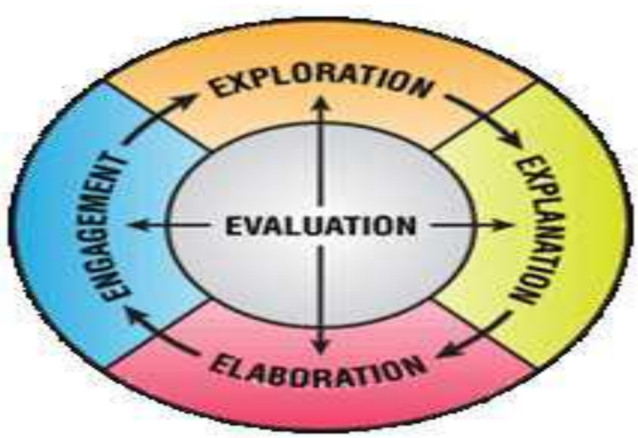

Figure 1: 5Es inquiry model Engage

This phase, doing science: the scientific inquiry process is to assesses students' prior knowledge. It helps the teacher decide which concepts should be emphasized more. Students, on the other hand, have the opportunity to learn about their instructor's current ideas and thoughts on the subject. It piques students' interest and piques their curiosity about the subject, increasing their learning capacity. During this phase, students' preconceptions, incorrect preconceptions, and naive preconceptions are elicited. It is used to determine what students know and believe about a particular subject. Activities such as reading and demonstration may be included during this phase. Teachers can gain critical insight into students' ideas, level of understanding, and potential misconceptions through a carefully planned engagement for a unit or lesson.

Characteristics:

- Determine the students' current understanding of the topic.
- Encourage students to think about and debate their own questions about the topic
- Encourage students to compare their ideas to those of others who have worked on the same topic.
- Inspire and arouse curiosity in the scientific investigation of the topic
- During the activity, establish a link between the students' prior and current learning experiences [4].

Explore

[5] explain that this phase serves as a common ground for activities that identify current concepts (misconceptions), processes, and skills, and facilitate conceptual change. Here, teachers act as a facilitator and arranges exploration activities for students as a means of constructing concepts and developing skills during this phase of the BSCS 5Es inquiry-based model. This phase gives students hands-on experiences that will be used later to formally introduce a concept, process, or skill. Additional material such as engaging students with the 5Es inquiry-based model indicates that this phase leads to an inquiry-based investigation into the topic and serves as a foundation for developing conceptual understanding. The teacher provides students with investigational equipment or materials as well as guidance without telling them what they will do or expect later.

Characteristics:

- Students debated various non-routine problems or question-framing strategies.
- Students build a common set of experiences that allows them to compare their findings and ideas to those of others.
- Students describe, document, compare, and share their ideas and experiences with their classmates.
- Students communicate their ideas while learning about testable hypotheses and scientific inquiry [4].

Explain

This phase is devoted to the discussion of the students' experiences. Throughout the investigation, students organize sequential events logically, consider cause and effect, and reflect on their learning. This phase allows students to explain their understanding thus far, and the teacher clarifies their understanding in an open and direct manner.

Characteristics:

- Encourages and motivates students to express their thoughts and ideas about the experimental subject.
- Teachers must be open to suggestions from students for revising their ideas and current comprehension.
- Teachers use simple language as well as labels, terminology, and formal language.
- Motivate and encourage students to create explanations based on their shared experiences, skills, and data from the Engage and Explore lessons.
- Following the expression of students' ideas, teachers must introduce terminology and alternative simple explanations [4].

Elaborate

This phase focuses on activities that assist students in understanding a concept or topic. It is a filtering phase because it removes any remaining conceptual misunderstandings. This stage helps students apply concepts in a broader context. The activities in this phase require students to apply, extend, or elaborate on previously learned concepts and skills in new contexts, resulting in a more comprehensive understanding.

The sections that follow go over the characteristics or points of the fourth lesson.

- Students' ideas are linked, problems are solved, and knowledge is applied to a new situation.
- Deepen their understanding of developing concepts and processes.
- Encourage and motivate students to use what they have learned to explain a new concept.
- Encourage students to use scientific terms and describe that they have already learned.
- Ask questions to help students conceptualize and draw reasonable conclusions from evidence and data [4].

Evaluate

This is the last stage of the 5E instructional model, and it evaluates students' understanding of a concept, process, topic, or skill. This assessment could be formative or summative, and it could provide snapshots of what students learn and comprehend. It entails assessing students using thinking maps, rubrics, teacher observations, and portfolios.

Characteristics:

- Show what students understand about a specific scientific inquiry, as well as how they investigate and evaluate in light of that knowledge.
- Discuss their current thoughts with classmates and friends.
- Monitor and record students' conceptual and skill performance.
- Give students time to talk about their ideas with their classmates and possibly revise their thinking.
- Conduct interviews with students to determine their level of understanding.

The 5Es inquiry-based approach's impact on students' academic achievement

[6] investigated the effectiveness of the 5Es inquiry learning model in improving science achievement among Malaysian Year 5 Indian students and the results showed that the mean of the experimental group was significantly higher than the mean of the control group.

[7] investigated the impact of an inquiry-based teaching approach on Senior High School (SHS) students' conceptual understanding of circle theorems. It was observed that students in the experimental groups, on the other hand, outperformed students in the control group. Furthermore, during the treatment, the experimental group's perception of motivation in the classroom learning environment was higher than that of the control group.

[8] investigated the impact of inquiry-based instruction on the attitudes and academic achievement of secondary students in Physics. The study also found that inquiry-based training is more effective than the lecture method for learning Physics.

[9] investigated the impact of a constructivist approach on the mathematics achievement of IX standard students. This was a quasi-experimental study with a pre-test-post-test phase that used both qualitative and quantitative techniques. The experimental group used the 5Es inquiry-based model (Engage-Explore-Explain-Elaborate-Evaluate), while the control group used the traditional method of teaching. A total of 60 students took part. The Mathematics Achievement Test (MAT) was used to assess students' achievement levels in both groups. The experimental results led to the following conclusions. To begin, when compared to traditional instruction, constructivist learning significantly improves students' mathematics achievement. Second, the constructivist learning approach was equally effective in improving math achievement in both boys and girls. Third, when students are taught in a constructivist learning environment, their understanding and application abilities improve significantly more than other abilities such as knowledge and skill.

Purpose

The purpose of the study was to determine the effect of 5Es inquiry-based model on the academic performance of some upper primary school pupils in mathematics on non-routine problems.

Research questions

The following major research question guided the study: What is the effect of 5Es inquiry model on pupils learning of non-routine problems in mathematics?

Hypothesis

Ho: There is no difference in the academic performance of pupils using 5Es inquiry model on non-routine problems in mathematics.

H1: There is difference in the academic performance of pupils using 5Es inquiry model on non-routine problems in mathematics.

II. METHODOLOGY

This study was conducted using the quasi-experimental pretest-posttest control group design. Two intact classes were used. The class was purposefully selected for the study from a population of students in forms one to three of the two (Asawinso Methodist Upper primary school A and B). Due to the fact that there were two Basic four classes, one of them (n = 24) was randomly chosen to receive mathematics instruction using the 5E instructional model with teaching aids. model is characterized by the engage, explore, explain, elaborate/expand, and evaluate phases.

The control group (n = 24) received traditional instruction with teaching aids and is characterized by teacher-centered instruction. Both groups received three weeks of instruction from the researcher. The experimental group consisted of 13 females and 11 males, while the control group consisted of 11 males and 11 females. The average age of the students is ten years. The pretest was administered prior to the intervention, and the posttest was administered following it.

A Teacher Made Test (TMT) was used to assess students' knowledge of non-routine mathematics problems. At the pretest stage of the study, learners were given ten mathematics non-routine problems to solve. Each student was provided with a printed question paper and an answer booklet, and the examination lasted 40 minutes. A post-test was conducted following the experiment to determine the efficacy of the two approaches. The researchers repeated the pre-test questions in the post-test. All examination conditions and instructions used for the pretest were also used for the posttest, which was administered to all students. Pre-test assessments established whether there was a difference in academic performance between the two groups at the time of the analysis.

The Statistical Package for Service Solutions (SPSS) software version 21.0 was used to analyze the data. The pretest and posttest mean and standard deviations were computed as descriptive statistics. Additionally, the independent sample t-test was used to compare the differences between the control and experimental groups' marks. Finally, the performance of male and female students was compared using the independent sample t-test.

III. RESULTS

Data collected was presented in tables and interpreted based on research questions and hypothesis.

Table 1: Comparison of the Pretest score of the control and Experimental Group

Group	N	Mean	SD	T	P
Pretest	24	2.21	1.14	0.13	0.90
Posttest	24	2.17	1.13		

After the treatment, posttest scores of the control group and the experimental group are compared. The results indicated that there is a significance difference between pupils taught through the lecture method with manipulative and pupils taught using 5Es with teaching materials. This means that, pupils taught using 5Es inquiry-based approach with materials performed better (mean = 5.71, SD = 1.23) than pupils taught using the lecture method with materials (mean = 3.54, SD = 1.14). It can therefore be deduced that 5Es inquiry approach have significance influence on the academic performance of pupils in problem solving in mathematics.

Effectiveness of 5Es inquiry-based model with materials and lecture with materials method on performance of junior high school pupils in mathematics non-routine problems

To ascertain the effects of 5Es inquiry-based model with materials and lecture with materials method on performance of junior high school pupils in mathematics non-routine problems. To achieve this, independent sample t-test was used to compare the performance pupils taught using 5Es inquiry-based model with materials and pupils taught using lecture with materials in mathematics word problem. The results of the mathematics word for the two groups revealed that pupils in both groups showed an increased in their understanding of mathematics word problem in the post test as compared to the pre-test. The results indicated that there are significance difference pupils taught using 5Es inquiry approach with materials and lecture method with materials performance in mathematics word problem. The mean score of pupils taught using 5Es inquiry-based approach with materials in the post test exams (mean = 5.71, SD = 1.23) is higher than the mean score of pupils taught lecture method with materials (mean = 3.54, SD = 1.14) in the posttest exams as shown in Table 2. Notwithstanding this, the effect of materials on the lecture method was realized as the mean score of the pupils taught lecture with materials was higher than the mean score of the pretest results. This indicated that teaching aids help pupils to conceptualized and understand mathematical concepts with ease.

Table 2: Comparison of the Pretest score of the control and Experimental Group

Group	N	Mean	SD	T	P
Posttest Lecture	24	3.54	1.14	-6.32	0.00
Posttest Experimental	24	5.71	1.23		

To ascertain the effects of 5Es inquiry approach with materials on the academic performance of male and females. To achieve this, independent sample t-test was used to compare the performance of male and female pupils in mathematics problem solving after exposing them through 5Es inquiry-based approach with materials. The results indicated that there is significance difference between female and male pupils' performance in mathematics word problem. The mean score of the females in the post test exams (mean = 6.36, SD = 1.21) is higher than the mean score of male pupils (mean = 5.15, SD = 0.99) in the posttest exams as shown in Table 3. This is surprising because a lot of researchers have indicated that, females especially in Africa have poor attitude towards mathematics and they perform poorly in mathematics than their male counterparts. Others even think that mathematics is a male dominated subject as males perform better than females in most of mathematics exams. This indicated that when females are fully engaging in the teaching and learning situation, they are motivated to learn and develop interest in the subjects. Also, the use of the teaching aids helps to remove the abstract nature of mathematics and make it more practical and interesting. This is in consonance with the finding that achievement in mathematics was strongly associated with gender differences, and it shown that female's achievement was significantly upper than that of the males [10].

Effect of 5Es inquiry with materials on Upper primary school pupils in mathematics non-routine problems problem based on gender

Table 3: Comparison of the Posttest score of the Experimental Group based on Gender

Group	N	Mean	SD	T	P
Male	13	5.15	0.99	-2.70	0.01
Female	11	6.36	1.21		

Major Findings of the Study

The analysis and interpretation of the data revealed significant results which have been consolidated and presented in the form of major finding as follows:

1. The 5Es inquiry-based approach with materials has a positive effect on the achievement of pupils in Mathematics. It is evident from the analysis that the pupils taught by 5Es inquiry-based approach with materials scored higher than those taught by lecture method with materials.

2. Constructivist Approach was found more effective for girls than boys in improving their achievement towards mathematics.

Discussion of the Results

According to the studies, constructivism-based materials-based instruction significantly improved academic achievement when compared to the traditional method of teaching mathematics non-routine problems. Numerous studies corroborate this conclusion. According to [11] concrete models significantly improved eighth-grade students' geometry achievement and attitudes toward geometry. The study enrolled 106 students from an Ankara private school. The study's subjects were instructed through the use of concrete models and the traditional method. She discovered a significant achievement gap between students who were taught geometry using concrete models and those who were taught using traditional methods.

This finding is corroborated by [12], who conducted research on the 5Es constructivist approach to upper primary mathematics achievement. The purpose of this study is to ascertain the efficacy of the constructivist 5Es approach on the mathematics achievement of upper primary students. The study was quasi-experimental in nature, with a control and an experimental group. The experimental group used the 5Es inquiry-based model, which consists of Engage, Explore, Explain, Elaborate, and Evaluate, while the control group used conventional teaching. A purposive sampling technique was used to select a sample of 70 students (35 in the experimental and 35 in the control groups, respectively). The study's findings indicate that, when compared to the traditional method, teaching upper primary mathematics using the constructivist 5Es approach is more effective at improving achievement.

[13] examined the 5Es inquiry-based model as a constructivist approach for enhancing students' mathematical learning outcomes. The purpose of this study is to determine the efficacy of the 5Es inquiry-based model in improving mathematics learning outcomes. The study employed a pretest-posttest, quasi-experimental design, with 172 participants (96 males and 76 females, M = 15 years) randomly selected using a simple random sampling technique. The findings indicated that treatment had a significant posttest effect on students' mathematics achievement.

[14] investigated the effect of the teaching model 'Learning Cycles 5Es' on students' achievement in mathematics at X Years Class SMA Negeri 1 Banuhampu in the 2013/2014 academic year. The purpose of this study was to determine whether the 'Learning Cycles 5Es inquiry-based model is superior to more traditional methods of mathematics instruction. The study, which used a quasi-experimental Randomized Control test Group Only Design, included all X years class students. The sample for this study consisted of X.7's class, which used the teaching model learning cycles 5Es, and X.8's class, which used conventional teaching. The results indicated that students' achievement was higher in the class that utilized the 'Learning Cycles 5Es' teaching model than in the class that did not.

[15] examined the effect of education on students' mathematical achievement, non-routine problems abilities, and perspectives on the 5Es inquiry-based model and mathematical modeling method used in the "Geometric Objects" unit. Students in the eighth grade of a secondary school in Northern Cyprus were chosen at random. The experimental group was taught using the 5Es instructional model, whereas the control group was taught using mathematical modeling. As a data collection tool, the experimental groups were given the "Geometrical Objects

Multiple Choice Achievement Test." The study discovered that when students were taught using the 5Es inquiry-based model in Experimental Group 1 and the Mathematical Modeling Method in Experimental Group 2, academic achievement increased.

According to [16] the 5Es inquiry-based model must be visually discernible in order to have a positive effect on student achievement development. Through a systematic review of research published between 2013 and 2016, the study examined the benefits of the 5Es inquiry model approach in mathematics instruction. The review identified a total of 20 interventions (20 studies) that met the study's criteria. The findings indicate that, when used appropriately, conceptual knowledge, procedural knowledge, and the adaptability of procedures for implementing larger interventions can all help to improve mathematical learning.

IV. CONCLUSION

The lecture method, according to a lot of studies, is ineffective in improving students' mathematics achievement. Others claimed that instructional materials can aid students in improving their mathematics grades. In Ghana, however, students' interest in and performance in mathematics remain a source of concern. As a result, we must urgently reform our instructional practices in order to boost student engagement in mathematics. As a result, the current study used a 5Es inquiry-based approach, as well as teaching aids, to help students improve their mathematics academic performance. The child is viewed as a "discoverer" who, through the process of meaning making, constructs his or her own knowledge and understanding. As a result, the framework encourages constructivism and instructional aids to be integrated throughout the mathematics learning process. Teachers must however not only be well-trained in constructivist pedagogy, but also patient enough to adhere to its requirements in order for it to succeed. This strategy takes a long time to implement and requires a lot of patience from teachers and administrators. Teachers must be well-trained and knowledgeable about the subject in order to implement effective teaching strategies that meet the educational system's current needs, particularly in mathematics. They must also be capable of deciphering the psychology at work behind a pupil's ability to take up or comprehend what is being taught. Teachers should also receive training on how to use instructional aids effectively. All of this required widespread support from educational stakeholders.

REFERENCE

[1]. Wilmot, E. M., Davis, E. K., & Ampofo, C. B. (2015). Why are non-routine mathematics non-routine problems difficult? Lessons from pre-service basic school teachers in Ghana.

[2]. Ministry of Education (2019). Teaching syllabus for mathematics (junior high school 1-3) Accra: Curriculum Research and Development Division, GES.

[3]. Bybee, R.W., Taylor, J. A., Gardner, A., Scotter P.V., Powel, J.C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model Origins and effectiveness. Retrieved from http://bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_Model- Full_Report.pdf.

[4]. Shah, K., & Muhmmad, Y. (2019). Using 5Es Instructional Model to Study the Concept of Magnetic Hysteresis Curve in Physics Kiramat Shah. October.

[5]. Wilson, C.D., J.A. Taylor, S.M. Kowalski, and J. Carlson. 2010. The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. Journal of Research in Science Teaching. 47 (3): 276-301.

[6]. Ong, E. T., Govindasay, A., Salleh, S. M., Mohd, N., Rahman, N. A., & Borhan, M. T. (2018). 5E Inquiry Learning Model : Its Effect on Science Achievement among Malaysian Year 5 Indian Students 5Es Inquiry Learning Model : Its Effect on Science Achievement among Malaysian Year 5 Indian Students. 8(12), 348–360. https://doi.org/10.6007/IJARBSS/v8-i12/5017.

[7]. Adu, E. (2016). Effect of the inquiry-based teaching approach on students ’ understanding of circle theorems in plane geometry. 12, 61–74.

[8]. Choudhary, F. R. (2016). Effect of Inquiry based Instruction on Student’s Attitude. 28(4), 91–94.

[9]. Chowdhury, S. R. (2016). A Study On The Effect Of Constructivist Approach On The Achievement In Mathematics Of IX Standard Students. 21(2), 35–40. https://doi.org/10.9790/0837-21223540

[10]. [10] Tezer, M. & Cumhur, M. (2017). Mathematics through the 5Es Instructional Model and Mathematical Modelling : The Geometrical Objects. 8223(8), 4789–4804. https://doi.org/10.12973/eurasia.2017.00965a

[11]. Bayram, S. (2004). The effect on instruction with concrete models on eighth grade students' geometry achievement and attitudes toward geometry.

[12]. Ranjan, S., & Padmanabhan, J. (2018). 5E approach of constructivist on achievement in mathematics at upper primary level. Educational Quest-An International Journal of Education and Applied Social Sciences, 9(3), 239-245.

[13]. Omotayo, S. A., & Adeleke, J. O. (2017). The 5Es Instructional Model: A Constructivist Approach for Enhancing Students' Learning Outcomes in Mathematics. Journal of the International Society for Teacher Education, 21(2), 15-26.

[14]. Yeni, N., Suryabayu, E. P., & Handayani, T. (2017). The Effect of teaching model ‘learning cycles 5E’toward students’ achievement in learning mathematic at X years class SMA Negeri 1 Banuhampu 2013/2014 Academic Year. In Journal of Physics: Conference Series (Vol. 812, No. 1, p. 012107). IOP Publishing.1(December), 1–28.

[15]. Tezer, M., & Cumhur, M. (2017). Mathematics through the 5Es instructional model and mathematical modelling: The geometrical objects. Eurasia Journal of Mathematics, Science and Technology Education, 13(8), 4789-4804.

[16]. Bakri, S. (2021). Effect of 5Es Learning Model on Academic Achievement in Teaching Mathematics: Meta-analysis Study. Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12(8), 196-204.