

The Development of Teaching Model based-on Educational Neuroscience to Enhance Mathematics Achievement

S Srikoon^{1*}

¹Lecturer , Curriculum and Instruction, School of Education, University of Phayao, Phayao 56000, Thailand

* Corresponding author's e-mail address: sanit.sr@up.ac.th

Abstract. The purposes of this research were 1) to develop the teaching model based on Educational Neuroscience Approaches to enhance the mathematics achievement, and 2) to compare the mathematics achievements between the experimental group and the control group. The methodology of this study was the research and development consisting of three phases as follows; Phase I Synthesis a Prototype, Phase II Developing a Prototype, Phase III Testing a Prototype. The results of this study revealed that 1) the syntax of the teaching model including Convince, Construct, Connect, and Conversant or 4Con Teaching Model, 2) the mathematics achievement mean score of the teaching model was better than the 5E model's. The findings contributed significantly to current knowledge on the effectiveness of the teaching model based on Educational Neuroscience Approaches to enhance student learning outcomes in terms of mathematics achievement.

1. Introduction

Basic education is the first learning foundation of everyone, and it is a primary learning step of future studies and work. Yet, Thailand's quality of basic education based on Mathematics achievement was low performance as 1) Ordinary National Education Test score of 2015 was slightly higher than 2014's 2) Program for International Student Assessment (PISA) score in 2013 showed that average score of Thai students was lower than other students' in Organization for Economic Co-operation and Development (OECD) countries and 3) Trends in International Mathematics and Science Study (TIMSS) score exhibited that Thai students' score was at the last three of the rank among ASEAN countries which implied that Thai basic education is not at a competitive level. Consequently, it is the urgent issue to enhance Thai students' mathematics achievement, especially grade 7 students who are primarily be prepared for the country's future [1] and for their basic foundation in daily life, and for being quality citizens to help the country reach the expecting competitive level.

Thai education experts identified the low-quality education in Thailand as it could be from having improper learning models even though various strategies, methods, techniques, and models of learning were developed [2]. Educational Neuroscience describes mechanisms of learning in one's brain and helps expand the discipline's body of knowledge [3], furthermore, it is accepted as the practical concept to develop teaching and learning in the 21st century [4]. According to the research, it was found that knowledge of educational neuroscience could highly contribute to learning achievement and learning process [5], therefore, it is crucial to employ the educational neuroscience concepts as a foundation as developing teaching models to boost mathematics achievement and enhance educational quality for Thai students to be capable to drive the country sustainably.



2. Objective of the study

- 2.1 To develop a teaching model based on education neuroscience to promote mathematics achievement
- 2.2 To compare mathematics achievement between an experimental group taught by the developed teaching model and a control group taught by 5E model

3. Research Methodology

This study was Research and Development and divided into three phases [6] as follows:

3.1 Phase 1 Synthesis a prototype of the teaching model based on educational neuroscience

3.1.1 Phase 1.1 Synthesizing a prototype was as follows:

3.1.1.1 Researcher analyzed principles, concepts and related research on teaching models, educational neuroscience and mathematics achievement

3.1.1.2 Researcher studied problems regarding educational neuroscience teaching and learning as follows:

3.1.1.2.1 Participants

12 people were selected purposively to be key performants as

1) six math teachers: three were from Dokkumtai Wittayakom School and other three were from Mae Jai Wittayakom School who currently teach grade 7 or have at least 1 year in teaching grade 7 Math.

2) six of grade 7 students: three were from Dokkumtai School and other three were from Mae Jai Wittayakom School.

3.1.1.2.2 Research instrument was Interview form about instructional situation based-on Educational Neuroscience.

3.1.1.2.3 Data collection method used the interviewing the math teachers and students.

3.1.1.2.4 Data analysis methods used the interpretation and analytic induction was employed.

3.1.1.3 Synthesized a prototype of the developed teaching model.

3.1.2 Phase 1.2 Developing the prototype was as follows:

To verify the prototype, five experts were asked to check possibilities, content validity, and appropriateness. Then, the prototype was revised accordingly.

3.2 Phase 2 Development of a teaching model based on educational neuroscience

3.2.1 Phase 2.1 Trying out the revised prototype

3.2.1.1 Research objectives

To compare mathematics achievement from the model's finding.

3.2.1.2 Research design used One Group Pretest – Posttest Design.

3.2.1.3 Population and sample

3.2.1.3.1 Population was 165 of grade 7 students studying in academic year 2019 at Dokkumtai Wittayakom School, Phayao province.

3.2.1.3.2 Sample was 35 of grade 7 students studying at Dokkumtai Wittayakom School, Phayao province, academic year 2019. Cluster random sampling was used to get the target group.

3.2.1.4 Research instruments were as follows:

3.2.1.4.1 Research instrument

Research instrument was the prototype of teaching model based on educational neuroscience.

3.2.1.4.2 Research data collection instrument

Achievement test which developed and verified content validity and reliability.

3.2.1.5 Data collection

The process was as follows:

3.2.1.5.1 Researcher prepared lesson plans according to the prototype and taught the experimental group for 1 week.

3.2.1.5.2 Researcher collected data before conducting the research by using the mathematics achievement test as a pretest spending 1 hour.

3.2.1.5.3 Researcher taught according to the developed model by the researcher for 10 hours.

3.2.1.5.4 Researcher collected data after conducting the research by using the mathematics achievement test as a post-test spending 1 hour.

3.2.1.6 Data analysis dependent sample T-Test was used to analyze the difference in average score of pretest and posttest math achievement test.

After the prototype was approved by the experts and then tried out the researcher began to develop the final version on phase 2.2.

3.2.2 Phase 2.2 Development of the prototype

The researcher developed the teaching model based on educational neuroscience to enhance mathematics achievement and reported the tryout findings and the prototype to the experts to verify content validity, reliability, appropriateness. Then, the researcher continued developing the prototype of the teaching model as the final version.

3.3 Phase 3 Effectiveness testing of the teaching model based on educational neuroscience

3.3.1 Phase 3.1 Studying the findings of the developed model

3.3.1.1 Research objective

To compare the mathematics achievements between the developed model and the 5E model.

3.3.1.2 Research design used Randomized Pretest – Posttest Control Group Design.

3.3.1.3 Population and sample

3.3.1.3.1 Population was 109 of grade 7 students who studied at Mae Jai Wittayakom School, second semester, academic year 2019.

3.3.1.3.2 Sample is 70 of grade 7 students selected randomly with mixed proficiency. They were divided into two groups: 35 students for an experimental group and other 35 students for a control group.

3.3.1.4 Research instruments are as follows:

3.3.1.4.1 Research instruments

There were the teaching model based on educational neuroscience and 5E teaching model.

3.3.1.4.2 Data collection instrument

The developed mathematics achievement test which was approved and verified on content validity and reliability

3.3.1.5 Data collection

The process was as follows:

3.3.1.5.1 Researcher prepared lesson plans and materials according to the prototype and taught the experimental group for 1 week.

3.3.1.5.2 Researcher collected data before conducting the research by using the mathematics achievement test as a pretest for 1 hour.

3.3.1.5.3 Researcher taught both groups for 14 hours by the researcher.

3.3.1.5.4 Researcher collected data after conducting the research by using the mathematics achievement test as a post-test spending 1 hour

3.3.1.6 Data analysis

One Way ANOVA was used to analyze the differences of mathematics achievement score between the experimental and the control group.

3.4 Phase 3.2 Lesson learned from the developed model

3.4.1 Participant

Purposive sampling was used to get six key informants as (1) three math teachers, grade 7 level, Mae Jai Wittayakom School (2) three of grade 7 students of Mae Jai Wittayakom School.

3.4.2 Research instrument

An interview form to gather lesson learned from the teaching model.

3.4.3 Data collection

The data was gathered from documents regarding practices and interview.

3.4.4 Data analysis

Interpretation and analytic induction were used to analyze data.

4. Results

4.1. Finding on synthesis of the developed teaching model prototype

4.1.1 Findings on synthesis of the developed teaching model

The researcher applied teaching model principles and concepts from Joyce, Weil and Calhoun [7] as a framework to develop the teaching model also theories on educational neuroscience from Anderson [8] and Liu & Chiang [9]. Moreover, the researcher gathered information regarding teaching principles of neuroscience from Moghaddam & Araghi [10], Schachl [11] and Quinlan [12] and the researcher conducted interview with target groups. The findings on examining problems of educational neuroscience teaching and learning are as follows:

4.1.1.1 Teaching preparation Teachers analyzed students individually based on last semester's learning achievement, pretest and previous exercises. Additionally, the researcher studied curriculum and research to prepare lessons and learning materials. Students also prepared themselves and would like to learn mathematics which they could apply in daily life.

4.1.1.2 Learning activities Teachers studied educational psychology, Bruner's theory, but were not familiar with educational neuroscience theory. Teachers applied some learning activities for example, exercises, group work, extra teaching, games, and recreation activities. Teachers used observation form, test, and evaluation form as instruments. Students would like to learn comfortably, play games, take notes and do exercises, work in groups, and do activities that related to their daily life.

4.1.1.3 Teaching materials development Teachers had studied documents and research to develop materials. Also, teachers participated in materials development workshops, learned to operate online learning system, learned to apply Professional Learning Community process to develop materials with community. Students used materials in learning math lessons as dividers, mobile phones, TV, books and computers.

4.1.1.4 Assessment and evaluation Teachers used assess students by observing behavior, for example, in presentation and demonstration, pretest and posttest, exercises, and tasks. Teachers assessed students before, during, and after class. For students, they always took a test and got the result after classes. They did exercise, unit test, and online test on computers or mobile phones.

4.1.2 Results of the teaching model development

The researcher combined findings of problems to develop the prototype and it was approved by 5 experts. There were suggestions on learning activity as the language should be easy to remember by using rhyme and homophones. Then, the researcher revised and proposed the final version of the teaching model on phase 2.2.

4.2 Results on development of the teaching model

4.2.1 Results on the prototype tryout

According to table 1 mathematics achievement test score on pretest and posttest was statistical significance as 0.05 and the achievement test score of posttest ($\bar{x}=18.371$, $S.D.=5.292$) was higher than pretest ($\bar{x}=14.743$, $S.D.=4.859$).

Table 1 Mathematics achievement test score on pretest and posttest

Mathematics achievement test score	\bar{x}	S.D.	N	t	df
Pretest	14.743	4.859	35	17.330*	34
Posttest	18.371	5.292	35		

*p<0.05

4.2.2 Results on development of the teaching model were as follows:

4.2.2.1 Principles of the model were as follows:

- 1) Prior knowledge, perception, attention, working memory, and emotion.
- 2) Learning must be from easy to difficult or simple to complex.
- 3) Learning must be related to authenticity.
- 4) Positive learning environment enhances amygdala which is the center of emotion and helps deliver input to the brain better, therefore, it helps students learn better.
- 5) Repeating delivers inputs to long-term memory.
- 6) Social learning is to let learners interact, exchange ideas and experience.

4.2.2.2 Objectives of the model are as follows:

- 1) to enhance students' mathematics learning achievement.
- 2) to promote students' problem-solving skills.
- 3) to enhance students' reasoning skills.

4.2.2.3 Syntax

The developed teaching model consisted of Convince, Construct, Connect, and Conversant or 4Con teaching model.

Step 1 Convince

Learners reviewed their previous lessons and asked to explore learning materials which stimulate five senses as hearing, seeing, tasting, smelling, and moving. Moreover, the learners were stimulated their cognitive skills as attention and working memory.

Step 2 Construct

Learners explored new content individually by encountering problems, analyzing situations, searching for information, planning and solving problems, summarizing, and reviewing the whole process again.

Step 3 Connect

Learners were in groups and examined problems in their own contexts, discussed and exchanged ideas on solving the problems, presented the suggestions, and discussed with the whole class.

Step 4 Conversant

Encountering the selected cases individually was sufficient for learners as they could practice and develop skills in their long-term memory.

4.2.2.4 Social System

Learners could learn individually and in groups of 4-5. Teachers have to talk to learners politely since positive learning emotion needs to be created. Learners have to have positive interaction, discussion, and information exchange creatively. Learners have to help one another effectively.

4.2.2.5 Principles of Reaction

Principles of reaction Teachers promote learners to have senses and cognitive stimulation. Learners are able to face problems and analyze the solutions. Additionally, teachers have to facilitate and suggest on discussing, debating, and exchanging ideas.

4.2.2.6 Support System

The systems used in this model were as follows:

- 1) Teachers must prepare learning materials which stimulate senses and cognitive skills so that students could be ready and the classroom environment more positively.
- 2) Learners must encounter at least three problematic situations as
 - 2.1) individual problem which is easy to understand

2.2) problem in context which is related to real context or daily life and

2.3) selected problem which is complex and requires knowledge and skills, in this case, teachers must select problems according to students' capability.

3) Teachers must create positive learning environment as facilitator, hence, students could have good relationship. Teachers must let students discuss, debate, and exchange ideas freely.

4.2.2.7 Assessment and evaluation

There were three phases as follows:

Phase 1 Assessing prior knowledge Students was assessed by a test or questions.

Phase 2 Assessing during the teaching procedure Students was assessed from problem-solving skills individually and in groups.

Phase 3 Assessing after the teaching procedure Students was assessed by the achievement test.

4.2.2.8 Application

Teachers could proceed as follows:

1) Teachers have to study the teaching model thoroughly.

2) Teachers should follow the syntax since it is set from easy to difficult tasks as in educational neuroscience framework.

4.2.2.9 Instructional and Nurturant Effects

1) Direct effects

1.1) Learners have better learning achievement.

1.2) Learners have better problem-solving skills.

1.3) Learners have retentions on learning achievement and problem-solving skills.

1.4) Discussion, negotiation, debate, and reasonable information exchange allow learners to be better in their reasoning skills.

2) Indirect effects

2.1) Working in group Learners learn how to work together as they listen to others which lead to live happily in society.

2.2) Learners are stimulated senses and cognitive skills to be ready for learning.

4.3. Results on the teaching model's effectiveness testing

Phase 3.1 Findings on the teaching model study as in Table 2 and 3

4.3.1 basic statistic data and basic statistical agreement

Table 2 showed average and standard deviation of mathematic achievement test score on pretest and posttest of an experimental and a control group. Normal distribution was tested with Kolmogorov-Smirnov Statistic and found that the pretest and posttest of both groups has significance value higher than statistical significance value at 0.05. It meant the pretest and posttest achievement test score of both groups was in normal contribution. Moreover, homogeneity of variance results tested by Levene Statistic showed that significance value was higher than statistical significance value at 0.05. It implied that variance of each group was equal and agrees to the rules.

Table 2 Basic statistic and agreement testing

Testing period	Groups	\bar{x}	S.D.	Kolmogorov-Smirnov Statistic	df	Sig.
Pretest	Control group	13.686	0.998	0.130	35	0.139
	Experimental group	13.857	0.912	0.127	35	0.168
Posttest	Control group	15.029	0.984	0.135	35	0.105
	Experimental group	20.057	0.956	0.104	35	0.200
Levene Statistic _{pre test} =0.460, df ₁ =1, df ₂ =68, Sig.=0.500,						
Levene Statistic _{posttest} =0.133, df ₁ =1, df ₂ =68, Sig.=0.717						

4.3.2 Results of average score on the mathematic achievement test of a control and an experimental group

Table 3 showed that the average score on mathematic achievement test of the control and experimental group was $F = 0.016$ and significance value = 0.899 which was higher than statistical significance of 0.05. This implied that the pretest average score of both groups was not different at the 0.05 statistical significance and the posttest average score of both groups was $F = 13.428$ and significance value was 0.000 which was less than statistical significance on 0.05. This showed that the posttest average score of both groups was at statistical difference on 0.05. It was concluded that the developed teaching model was able to enhance mathematics achievement more than 5E teaching model.

Table 3 Differences of average achievement test score of the control and experimental group

Period	Variance	SS	df	MS	F	p
Pretest	Between Group	0.514	1	0.514	0.016	0.899
	Within Group	2175.829	68	31.997		
	Total	2176.343	69			
Posttest	Between Group	442.514	1	442.514	13.428	0.000
	Within Group	2240.857	68	32.954		
	Total	2683.371	69			

Phase 3.2 Lesson learned from implementing the developed teaching model, it was found that teachers thoroughly understood and implemented the teaching model in the classroom. This 4Con teaching model was challenging and interesting since it combined educational neuroscience in learning activities, for examples, activities to stimulate senses, attention, and working memory. What's more, learners would be able to analyze given situations from simple to complex which allow them to work from easy to difficult level. The teaching model also enhanced positive learning environment which let learners feel more comfortable and motivated as there were games, various learning materials, and challenging problems to experience.

5. Discussion

According to the research findings, it was found that the 4Con teaching model applied relevant knowledge and authentic contexts regarding senses, attention, working memory, and emotions to the teaching model development process. This concept related to Anderson's approach as learning process of learners requiring those factors [8]. It also found that concepts of repeating and learning from simple to complex tasks were applied to the teaching model as retaining inputs in long-term memory relating to Anderson [8] and Schachl [11] concepts as repeating inputs lead to better long-term memory retention or learning achievement. Furthermore, the 4Con model pays attention on social learning, and positive learning environment as learners are encouraged to interact and exchange ideas and this relating to Quinlan's approach [12]. This teaching model, 4Con model, consists of Convince, Construct, Connect, and Conversant teaching procedures. It also found that the model could enhance mathematic achievement as it combines stimulants on senses, cognitive skills, and positive emotion, and simple to complex tasks in learning process. These learning activities could affect learning outcomes positively, therefore, the development of teaching model based on educational neuroscience is challenging in expanding knowledge of education's field definitely [3].

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