



## **The Effectiveness of 4MATE Teaching Model in Enhancing Creative Thinking, Attention, and Working Memory in Thai Context**

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Creative thinking is the most crucial skill in the 21st century in Thailand. Moreover, learners' attention and working memory are the most special abilities affecting creative thinking. This research was intended to investigate the effectiveness of the 4MAT teaching model integrated with executive function training (4MATE) in enhancing creative thinking, attention, and working memory in Thai context. It was particularly focused on examining the significant change in creative thinking, attention, and working memory among grade 4 students after the intervention of a 4MATE and a 5E teaching model in an experimental group and a control group, respectively. 40 of 104 grade 4 students were randomly selected from a primary school in Chiang Mai, Thailand. A pre-test and post-test control group design was adopted in this study. 4MATE teaching model consisted of eight steps, including experience concentration, experience analysis, experience development, thinking development, performance development, creative innovation, innovative analysis, and battle ideas. The 4MATE teaching model was implemented in the experiment group, while the 5E teaching model was employed in the control group. Two types of psychological tests were utilized as the research instruments, namely the creative thinking test and the cognitive ability test software: attention and working memory. The findings revealed that the mean scores, covering creative thinking, attention, and working memory, of the 4MATE intervention were higher than those of the 5E teaching model. In conclusion, creative thinking, attention, and working memory can be improved with the 4MATE teaching model derived from a combination of the 4MAT teaching model and executive function training.

**Keywords:** executive function, 4MAT, creative thinking, attention, working memory

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## INTRODUCTION

In the 21st century, the world has changed rapidly and undergone development in all dimensions, such as technology, economy, and society. This stresses that humans must be aware of these changes to prepare themselves to live in the world where changes constantly take place. Therefore, the Ministry of Education (Thailand) has reformed the Twelfth Education Development Plan (2017-2021) based on the Twelfth National Economic and Social Development Plan (2017 - 2021). The essential principle, "Take people as the center of development," aims to improve a quality of life for Thai people, develop and equip them with discipline, curiosity, knowledge, skills, and creativity (Ministry of Education, 2016).

In current society, science and technology play a significant role in people's daily lives and working culture. Specifically, they are used to support and integrate creative thinking with others to achieve higher efficiency, such as developing thinking methods, analytical thinking, and critical thinking. Moreover, creative thinking is regarded as the modern learning culture of the new world. Hence, it must enhance understanding of the innovative world's nature. Especially, students who are undeniably regarded as one of the backbones of human resources must practice and learn more about creativity for a substantially modern society (Ministry of Education, 2017). A pressing concern, however, lies in the fact that students have had only a fair level of creative thinking, as pointed out in assessment reports by Office for National Education Standards and Quality Assessment (Public Organization) (2019). Moreover, a lack of creative thinking has been widely observed among Thai students. Specifically, students learn to imitate their teachers and classmates, which in turn results in a lack of novel thinking to form new behavior. In the same way, kindergarten students possess a low level of creative thinking (Sakhon & Insombat, 2013). Hence Thai education is in need of a creative teaching model (Srikoon et al., 2018). These main aspects must be enhanced in order to create an innovative human society.

To date, educational neuroscience, which integrates education with psychology and neuroscience, has been applied to learning management in the classroom (Srikoon, 2023). One of the parts of educational neuroscience is the cognitive function which consists of attention and working memory. On the one hand, the former as in attention is a selective ability of any stimulus and is not focused on any other stimuli. On the other hand, the latter, namely working memory, entails storing data in the short term and simultaneously processing data (Srikoon, 2020). Both variables are related to the other ability, especially achievement and creative thinking (Srikoon et al., 2018). Nevertheless, critical problems have been found; that is, students lack attention in the classroom, do not focus on task responsibility, and lack mindfulness which has been observed at all educational levels across the country (Ubonthum et al., 2019). Moreover, their lack of attention to learning or working affects working memory ability (Bertrand & Camos, 2015). These particular variables have positive effects on creative thinking as well (Zhao et al., 2021). Additionally, in Thai context, Srikoon et al. (2017) point out that attention and working memory are the main cognitive functions needed to be developed in order to increase higher-order thinking, considering that the two functions

affect achievements, creative thinking, research characteristics (Srikoon et al., 2018), analytical thinking (Tippala & Srikoon, 2022), and problem-solving (Srikoon, 2021b). Therefore, if attention and working memory are complex capacities, creative thinking must be given priority to be enhanced.

In recent research, a 4MAT teaching model is a learning approach with four learning styles; each student can learn more comfortably with their learning styles (Feyza & Abdulkadir, 2020). Prior studies have revealed that the 4MAT teaching model has been used as a theory to design learning activities in learning sciences in order to enhance science and mathematics achievements (Enver & Ramazan, 2009; Idris & Ibrahim, 2015; Gamze & Hülya, 2017; Yusuf, 2018). Furthermore, the teaching model can enhance the affective domain of learning outcomes such as physics students' motivation, self-concept and self-efficacy in physics (Serap & Musa, 2016), and motivation (Idris & Ibrahim, 2015). In addition, this teaching approach can also improve creative thinking since it focuses on imaginative learners who use an abstract concept to link new ideas rather than relying on observation alone so as to construct and evaluate their model (Sabry et al., 2021) and can improve learners' creative writing skills and reflective thinking (Alshankyty, 2021). Thus, the 4MAT teaching model which is a well-known model can contribute to enhancing any learning outcome.

Another approach is executive function training, which essentially entails the high-thinking process of the brain. This very function involves cognitive processing which consists of working memory, updating, inhibition, and shifting abilities (Zhao et al., 2021). The roles of executive function also influence thinking, emotion, decision, attention, and working memory (Quan et al., 2020; Dobrin & Shcherbatykh, 2021; Zhao et al., 2021). Additionally, it has been found to enhance creative thinking (Scibinetti & Tocci, 2011; Zhao et al., 2021) and to have a high level of interaction with creative thinking (Beaty et al., 2014; Sharma & Babu, 2017). Consequently, executive function training promotes an improvement in creative thinking, attention, and working memory.

Educators who integrate the 4MAT teaching model with executive function training (4MATE) will be able to construct new learning activities that can improve creative thinking and cognitive function. Therefore, the objective of this research was to examine the effectiveness of the 4MAT teaching model integrated with executive function training (4MATE) in enhancing creative thinking, attention, and working memory.

### **Aims of This Study**

This study explored the effect of the 4MAT teaching model integrated with executive function training (4MATE) on creative thinking, attention, and working memory. This study was carried out after the 4MATE teaching model had been developed. Specifically, the so-called model combined the 4MAT teaching model and executive function training with an in-depth understanding of modern phenomena in teaching model development. The 4MATE teaching model had been appraised by three experts before it was implemented in this study. Therefore, this research was aimed at achieving the following objectives:

1. To investigate the differences in the creative thinking of grade 4 students in terms of scores before and after implementation of the 4MATE teaching model (experimental group) and the 5E teaching model (5E) (control group), respectively.
2. To examine the differences in attention accuracy between the experimental and control groups of learners.
3. To explore the differences in working memory accuracy between the experimental and control groups of learners.

### Conceptual Framework

This research was intended to evaluate the learning outcomes of two teaching models, namely the 4MAT teaching model integrated with executive function training (4MATE teaching model) and the 5E teaching model. The learning outcomes were measured in terms of attention accuracy, working memory accuracy, and creative thinking scores. All teaching models allow teachers and students to learn how their knowledge, cognition, and emotions interact with the learning environment and how both changes occur through the learning process (Joyce et al., 2015). Educational neuroscience is a notable trend in instructional development research, especially executive function training, which has been incorporated into any teaching model that is oriented to enhancing attention, working memory, and creative thinking for developing learners (Meltzer, 2010). Moreover, integrating the traditional teaching model with educational neuroscience can enhance learning outcomes (Srikoon, 2015). To exemplify, Srikoon (2021a) developed research-based learning integrated with cognitive training to improve research characteristics. Srikoon et al. (2017) developed research-based learning in combination with neurocognitive-based learning to enhance attention, working memory, and mood. The 4MATE teaching model is an innovative teaching model which combines the two major approaches, namely the 4MAT teaching model and executive function training (Somsak, 2022). Therefore, the 4MATE teaching model has consolidated these two approaches with a focus on creative thinking, attention, and working. All variables in this research are illustrated in Figure 1.

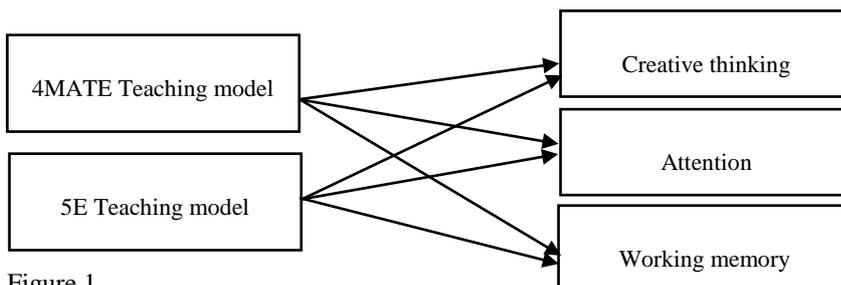


Figure 1

The effects of the 4MATE teaching model and the 5E teaching model on learners' creative thinking, attention, and working memory

#### **4MAT Teaching Model Integrated with Executive Function Training (4MATE)**

McCarthy (1990), introducing the 4MAT teaching model, combines Kolb's learning style approach with two-hemisphere brain research. This can be explained by the fact that the philosophy of the 4MAT teaching model is grounded on fundamental principles of several theories of human development and brain function. According to the 4MAT teaching model, it is assumed that "humans learn and develop through the continuous personal modifications and adaptations as they form meaning in their lives; such an assumption is derived from John Dewey, Karl Gang, and Kolb's theories." (McCarthy et al., 2002)

McCarthy (1990) proposed the syntax of the 4MAT teaching model, which comprises four different learning styles centered on acknowledging and processing received information. Those learning styles include (1) the experience phase, (2) the conceptualization phase, (3) the applying phase, and (4) the creating phase. The learning cycle offered in the 4MAT system comprises eight different activities covering the four different learning styles, using left- and right-brain processing procedures across all quadrants (Alanazi, 2020). Eight syntaxes of the 4MAT teaching model include connecting, attending, imagining, informing, practicing, extending, refining, and reforming (McCarthy, 1990). Previous research has revealed that the 4MAT teaching model can contribute to enhancing creative thinking because it places emphasis on imaginative learners who are independent of mere observation but draw on to an abstract concept to connect new ideas together in order to develop and assess their model. In addition, it features some processes which can enhance cognitive abilities; for instance, the informing step must account for categorization, comparison, planning, and acquiring knowledge (Sabry et al., 2021). Therefore, educators are in favor of applying such a model in the general classroom to enhance learners' learning outcomes.

Executive function is a thinking process in planning and controlling behavior as well as is a higher thinking level for controlling thinking, attention, emotion, decision, and action for building the origin of a thought and accomplishing all goals (Meltzer, 2010). Principal processes of executive function consist are as follows: (1) goal setting, planning, and prioritizing, (2) organizing, (3) retaining and manipulating information in working memory, (4) shifting flexibly, (5) self-monitoring or self-checking (Leanne, 2014). Besides, the neurobehavioral research has uncovered a relationship between executive function and creative thinking (Wang et al., 2021). Specifically, one must incorporate executive function training in learning activities to enhance learning outcomes, especially creative thinking, attention, and working memory.

Considering this reason, learners should be expected to achieve better creative thinking, attention, and working memory and improve their performance in the subject matter. As a result, the 4MATE teaching model covers all eight phases: experience concentration, experience analysis, experience development, thinking development, performance development, creative innovation, innovative analysis, and battle idea. In the experience concentration stage, teachers stimulate learners' interest with challenging stimuli, and as a result, learners begin posing creative questions about authentic situations and

collaboratively brainstorm their ideas to identify problems. Subsequent to this stage is experience analysis where learners are grouped for collaborative learning and then participate in the discussion about problem situations. The teachers provide them with explanation and coaching to offer additional knowledge. In the experience development stage, learners are encouraged to inquiry about contents so that they are able to summarize the main concepts by themselves. In the thinking development stage, learners take part in the inquiry-based learning activities, along with collaborative discussions on predicting the learning process and the result. In the performance development stage, learners perform their learning through hands-on practices and discussions on all procedures and finally draw conclusions from what they have learned. In the creative innovation stage, they employ their learned concepts to design the innovation that connects all their ideas to their daily lives. In the further stage as in innovative analysis, learners create a list for evaluating their innovation. The teachers usually pinpoint their strengths and weaknesses as well as provide them with such feedback so that the learners can improve the innovation. Finally, in the battle idea stage, each group presents the innovation and has discussions about all learning processes and concepts based on the underlying theoretical framework that can be applicable to their real lives.

Essentially, the teaching model is infinite development. As such, combining teaching approaches is effective and can lead to the evolution of the teaching model in response to a constantly dynamic society (Joyce et al., 2015). Thus, this research was intended to integrate the 4MAT teaching model with executive function to enhance creative thinking, attention, and working memory. Teachers who develop the teaching culture of the school will be able to empower their learners to learn by adjusting the context. Therefore, the development of the teaching models should build on teachers' competency (Joyce et al., 2015).

### **5E Teaching Model**

The 5E teaching model is the teaching structure used to design learning activities in Thailand and is supported by the Institute for the Promotion of Teaching Science and Technology (IPST) (2012) for public schools in Thailand. For this reason, this research implemented it in the control group. The so-called model consists of five phases as follows: engage, explore, explain, elaborate, and evaluate. According to this model, it is proposed that learning should not result from the passive absorption but should be attributed to active learning. Learners should also undergo development through analysis, evaluation, inquiry, and collaborative learning which would promote better understanding and allow for in-depth and long-lasting knowledge. The question, observation, analysis, explanation, conclusion, and new questions will contribute to constructing new knowledge and creating experiences in learning activities (Institute of the Promotion of Teaching Science and Technology, 2012; Sutiani et al., 2021)

To begin with, the engagement phase is concerned with the lesson's introduction, which stimulates learners' motivation and curiosity about the current situations. This step gives a clearer picture of issues to be studied in accordance with the objective of the curriculum. Following this is the explore phase which involves a comprehensive understanding of the issues in question. The teaching techniques to be implemented here

should be practices, experiments, implementation, and research in order to obtain sufficient information for the further step. Afterwards, the explain phase entails the use of the collected data to analyze, interpret and summarize the results, and present them in various forms, such as text, drawings, tables, and charts. The results of this stage can either support or reject formulated hypotheses. What matters most is that the results can create new knowledge and enhance learners' learning. Fourthly, the elaborate phase is the application and connection of created knowledge with existing knowledge or new ideas that have been researched. Moreover, learners should draw on the conclusion to explain the other relevant situations or events in order to broaden their expertise. The final phase, namely evaluation, is concerned with the assessment of both the learning process and the learning outcomes through diverse assessment tools for developing learning which in turn would enable learners to apply their new knowledge to other subjects.

#### **Learning Outcomes: Creative Thinking, Attention, Working Memory**

Creative thinking is a thinking ability that emerges without boundaries. Learners can think creatively in any way and without any limitation (Mumford et al., 2012; Pratomo et al., 2021). Moreover, this form of thinking serves as the principal variable that leads to product innovation (Srikoon et al., 2018). Dietrich's (2004) reveals that the prefrontal cortex is the brain area where three cognitive functions are active: working memory, temporal integration, and attention. It provides a buffer to store information in one's mind and arrange it each time. This process leads to highly complex mental constructs that increase creative thinking. Creative thinking consists of three factors: fluent, original, and flexible thinking. First, fluent thinking is referred to as the ability to find an answer fluently and quickly with an extensive answer in a limited time. Another form of thinking, namely original thinking, is the ability to find a solution many times. Finally, flexible thinking is a new or different idea from other learners (Srikoon et al., 2018). Creative thinking encourages learners to apply appropriate strategies for creating innovative solutions and new products to fit each critical situation in the real world. Therefore, creative thinking is what all learners should be equipped with.

Attention is the essence of information processing. In fact, it is the concentration ability or involves choosing the stimulus (interesting stimuli) and discarding others that can potentially interfere or hinder the selected stimulus. This process is the brain's ability to select and receive one stimulus without paying attention to different stimuli (Srikoon, 2019). The attention process begins with alertness, selected attention, and executive control (Sternberg, 2012). Based on Lindsay's review (2020), it can be concluded that the attention mechanism begins with control of the flow of information into the thalamus and then into the neocortex. Clearly, neuromodulation systems play a significant role in controlling attention. Norepinephrine, acetylcholine, and dopamine are also believed to influence alertness, oriented to important information, and executive control of attention, respectively. Attention is comprised of simple reaction attention, focus attention, selected attention, and sustained attention (Srikoon, 2019). It influences working memory, experience construction, and learning outcomes (Marchetti, 2014).

Working memory is a type of memory system that stores information quickly for manipulation and processing in the subsequent processes (Sweatt, 2010). A review by Sausa (2006) reveals that the prefrontal cortex is the main part where working memory is active. It consists of two areas of the brain. Ventrolateral PFC plays a role in non-spatial short-term memory such as color and shapes, while dorsolateral PFC is responsible for spatial short-term memory. Working memory consists of four elements: the phonological loop, visuospatial sketchpad, episodic buffer, and central executive system (Baddeley, 2003). In Thai context, Srikoon (2019) confirms their construct validity. This research has revealed that working memory consists of four factors, namely primary processing, shifting, updating, and inhibiting. Moreover, previous research found that working memory influences achievement, problem-solving, and creative thinking (Srikoon et al., 2018; Srikoon, 2021b)

## **METHOD**

### **Research Design**

In terms of the research design, a true experimental pre-test and post-test control group design was adopted in the present study. This research design is primarily used for evaluating the teaching models when there is more than one sample group, and learning outcomes are assessed and random assignment is conducted. It was also suitable for evaluating questions about the effect of teaching models because it focused on the outcomes of the comparative data based on as criteria for analyzing and interpreting the results. Therefore, this research design can increase the accuracy of the analysis of the dependent variables (creative thinking, attention, and working memory) which were the results of the teaching model (4MATE and 5E teaching model) and can eliminate the complications potentially attributed to any extraneous variable.

In addition to that, the pre-test and post-test design can help eliminate the significant constraints of the non-equivalent group that typically adopts the post-test only design; the experimental and control groups may not have been equivalent before any teaching model is developed and implemented, so this may have different effects on dependent variables according to different concepts and approaches. Simply put, it is the observed impacts on the learning outcomes. Therefore, if the mean post-test score of one group is higher than that of the other group, the researchers can focus on the different points (if the same pre-test is employed with groups) and placebo development (e.g., result scores from the 5E teaching model) which could account for such differences.

### **Participant and Sampling Procedure**

The present study was conducted through a true experimental design in which learners were randomly assigned to an experimental group and a control group. The first step, namely random selection, was started in the sampling process, followed by random assignment. Eighty samples were randomly selected from 104 grade 4 learners in a primary school in Chiang Mai, Thailand, during the second semester of the 2020 academic year. Both an experimental group and a control group learned about physical properties of materials in the science and technology subject in accordance with the

Basic Education Core Curriculum B.E.2551 (A.D.2008) (Ministry of Education, 2008) for 10 hours. The selected samples were later randomly classified into two groups: an experimental group (4MATE teaching model: n=40) and a control group (5E teaching model: n=40). The flip of a coin was used for random assignment.

The two most important processes were random selection and random assignment. The former contributes to the external validity, in which researchers generalized the results of this study to the other population. The latter as in random assignment is the important process since it contributes to internal validity and allows the researchers to reach the decisions on the effect of the intervention. Therefore, random selection and random assignments were very different phenomena. They still should be performed to ensure the internal and external validity of the research method.

### **Intervention Process**

The study was carried out to elaborate on the intervention, employ the essential evidence of the intervention, and assess its validity. The research consisted of two phases. Initially, the researchers developed the 4MATE teaching model, and this teaching model was validated by the experts. This initial study aimed to assess the face validity of the intervention before the actual research was conducted.

The 4MATE model was developed based on two major approaches, the 4MAT teaching model and executive function training. A review of literature was carried out, focusing on two topics, namely the 4MAT teaching model (McCarthy, 1990; McCarthy et al., 2002; Alanazi, 2020; Sabry et al., 2021) and executive function training (Meltzer, 2010; Leanne, 2014; Wang et al., 2021). Afterwards, the prototype of the 4MATE teaching model was constructed. The 4MATE teaching model was employed to assess the content validity through professional meetings with three educational experts from the University of Phayao. Following that, the developed teaching model was revised based on the guideline and feedback provided by three educational experts. These processes determined each teaching process when the 4MATE teaching model was to be implemented.

Next, the following three documents were brought into discussions to improve the prototype of the 4MATE teaching model: (1) the perfect accuracy of the knowledge about the 4MAT teaching model and executive function training and the methodology of integrating both teaching models; (2) the applicability of 4MATE teaching model and the lesson plans; (3) the teaching guide to the model. Three documents were discussed by three educational experts in the curriculum and instruction. Finally, a meeting with all three experts was organized to assess the face validity of three areas in question. They reached a conclusion that the 4MATE teaching model was excellent and feasible. Therefore, the model could be utilized in classrooms.

The true experimental design employed in this research could compare the differences in learning outcomes in respect of creative thinking, attention, and working memory. The research hypothesis was tested under the condition of two different teaching models, particularly 4MATE teaching and 5E teaching model.

The 4MATE teaching model was employed in the experiment group. The syntax of the 4MATE teaching model consisted of the following eight steps. (1) Experience concentration phase: the teacher encouraged learners to ask questions and interpret them, coached learners, and observed the context around them. (2) Experience analysis: learners were classified into groups to analyze the observation results by sharing reasons and additional details on various issues and then participating in-class discussions. (3) Experience development: the teacher guided learners to brainstorm their ideas, prioritize ideas of different issues, and create a concept map as well as to inquire about different issues to create more quality concept maps, analyze them, and revise the main points of the concept. (4) Thinking development phase: the teacher as a facilitator prompted and encouraged learners to search for information from various resources and materials. These processes developed a body of knowledge, deep thinking, and the ability to predict and hypothesize the results based on their understanding. (5) Performance development: this step required learners to apply their learned concepts in practice. Specifically, the teacher provided guidelines on practices, trained learners to use the tool correctly, and encouraged them to participate in learning activities actively and take notes by themselves. (6) Creative innovation phase: the teacher instructed learners to design the innovation according to their abilities, and the learners applied the knowledge they had acquired in the prior steps. (7) Innovative analysis phases: the teacher instructed learners to create self-assessment checklists, advised them to attempt to understand the advantages and drawbacks of their innovation and to improve it. (8) Battle ideas: learners present the innovation, expand their knowledge, and identify the innovation from all processes. In particular, they were engaged in sharing, discussing, and exchanging ideas in order to link them a real-life situation.

The pre-test and post-test measured learning outcomes regarding creative thinking, attention, and working memory. The 4MATE teaching model and 5E teaching model were employed to teaching about the physical properties of materials in science class for two hours per week, a total of five weeks. The former was used in the experiment group, while the latter was utilized in the control group. This research aimed to compare the learning outcomes between the 4MATE and 5E teaching models, namely creative thinking, attention, and working memory.

What should be given particular attention in experimental research was to ensure that the experimental procedures did not interfere with regular in-class teaching. A detailed action plan for in-class implementation of the intervention procedures was provided to a school principal to request his approval of all steps before the research and the experiment were conducted. The researchers' main role involved informing the learners of all processes of both teaching models. Therefore, it was necessary to communicate the action plan to teachers involved in the intervention process. Also, the principal, assistant principal, and head of the school should be informed of the action plan to allow for the flow of the experiment in all classrooms.

### **Research Instruments**

The three research instruments were employed to measure creative thinking, attention, and working memory learning outcomes. First, the creative thinking test was used to

assess creative thinking. It was a five-item essay test which lasted 50 minutes, and three factors were focused on in the test: fluent (UT), flexible (ET), and original thinking (OT). The so-called test developed by Srikoon et al. (2018) had excellent quality content validity, and Hoys' reliability of the overall test was measured. It had a reliability of 0.792 (Srikoon, 2015).

Two sets of computerized battery tests were also utilized in this research: attention and working memory computerized battery tests implemented to measure attention and working memory accuracy, respectively. The former, namely attention computerized battery test, consisted of 4 sub-tests: (1) simple reaction accuracy (SA); (2) focus attention accuracy (FA); (3) selected attention accuracy (EA); and (4) sustained attention accuracy (UA). Test-retest reliability of these sub-tests was 0.842, 0.884, 0.933, and 0.952 respectively. Srikoon (2019) evaluated the construct validity, revealing that the goodness of fit was achieved in all indicators. The learners were administered with 30-item tests written in Thai. The total length of the attention computerized battery test was 30 minutes.

Finally, the working memory computerized battery test comprised four sub-tests. The 30-item tests written in Thai were distributed to the learners. This test included 4 sub-tests: (1) basic processing accuracy (BM); (2) shifting working memory accuracy (SM); (3) updating working memory accuracy (UM); (4) inhibiting working memory accuracy (IM). Test-retest reliability of these sub-tests was 0.875, 0.904, 0.894, and 0.882 respectively. The construct validity of these sub-tests was evaluated by Srikoon (2019), and it was uncovered that the goodness of fit was found in all indicators. Similar to the prior test, the working memory computerized battery test lasted 30 minutes.

This research focused on three significant learning outcomes: creative thinking, attention, and working memory. Therefore, the data were analyzed according to these factors. The first factor, particularly creative thinking, can be defined as a set of cognitive activities, mental activities, and behavior of learners that can help construct new ideas, solutions, and innovations (Munir & Awan, 2021), and it comprises of fluent, original, and flexible thinking (Srikoon et al., 2018). Apart from that, attention is described as the ability of the brain to concentrate on and choose the information (Sternberg, 2012; Srikoon, 2019). It is comprised of simple reaction attention, focus attention, selected attention, and sustained attention (Srikoon, 2019). The other crucial cognitive ability, namely working memory, is the brain's ability to store information in a brief period of time for manipulation and information processing in mental activity (Sweatt, 2010). It features primary processing, shifting, updating, and inhibiting (Srikoon, 2019). Attention influences working memory (Greene & Neveh-Benjamin, 2022) and has a constructive relationship with working memory (Srikoon, 2019). On the contrary, working memory affects attention, and its training can enhance attention management (Al-Saad et al., 2021). Moreover, this particular factor is the initial process which perceives information before sending this information to be organized in working memory (Sweatt, 2010). Therefore, attention and working memory closely interrelates with the cognitive mechanism. Simply speaking, these two are working in concert to enhance creative thinking (Sternberg, 2012; Redifer et al., 2019). It can be concluded

that attention and working memory are entirely interrelated, and creative thinking requires attention and working memory for all mechanisms.

### Data Analysis

In this research, it was necessary for the researchers to assess the mean scores of the two groups across the three factors simultaneously in the same fashion. Thus, all independent variables were analyzed, and the mean of the total linear combination between the two groups was compared. One-way multivariate analysis of variance (one-way MANOVA) was performed to test the research hypothesis. Especially, Pillai's Trace is the statistical test in the multivariate analysis of variance; that is, it was to identify the difference between the mean of the identified group subjects on a linear combination of dependent variables. What is of great concern is that Pillai's Trace should be used in nonequal sample cases in both groups. Besides, the research data were grounded on some basic assumptions of multivariate analysis of variance statistics (Tabachnick & Fidell, 2013).

### FINDINGS

The results of this research are reported based on the research objectives mentioned above. The finding reveals the differences in creative thinking, attention, and working memory of grade 4 students before and after implementing the 4MATE and 5E teaching models. This is followed by an evaluation of the impact of the two models on grade 4 learners' creative thinking, attention, and working memory.

#### Finding on Creative Thinking

Creative thinking was measured by scores. The pre-test and post-test mean scores (M) and standard deviation (SD) of the experimental and control groups measured by each subtest are shown in Table 1.

Table 1

Mean scores (M) and standard deviation (SD) of creative thinking in both the experimental group and control group

creative thinking	4MATE teaching model				5E teaching model			
	Pre-test		Post-test		Pre-test		Post-test	
	M	SD	M	SD	M	SD	M	SD
UT	30.775	12.234	71.200	2.947	28.375	11.540	39.550	16.242
ET	15.675	0.557	25.825	3.343	14.725	3.707	16.850	3.807
OT	46.125	22.887	169.200	62.771	40.975	22.500	59.425	24.489

#### Multivariate Test

All the multivariate tests (Pillai's Trace) were significant in terms of creative thinking. This finding pointed out that the teaching models influenced creative thinking at a 0.05 significance level ( $F(3,76) = 52.025, p = 0.000$ ) and could account for the variance of

67.3 percent of creative thinking ( $\eta_p^2 = 0.673$ ).

The multivariate test revealed the significance of at least one pair of mean scores. Thus, the individual comparison of the observed mean difference was conducted using the univariate ANOVAs. The univariate tests showed a significant relationship of effects between all forms of creative thinking, namely fluent (UT) ( $F(1,78) = 65.554, p=0.000, \eta_p^2 = 0.457$ ), flexible (ET) ( $F(1,78) = 125.549, p=0.000, \eta_p^2 = 0.617$ ), and original thinking (OT) ( $F(1,78) = 106.172, p=0.000, \eta_p^2 = 0.576$ ).

### Finding on Attention

Attention was also measured by accuracy scores. The pre-test and post-test mean scores (M) and standard deviation (SD) of both the experimental and control groups measured by each subtest are depicted in Table 2.

Table 2

Mean scores (M) and standard deviation (SD) of attention accuracy in both the experimental group and control group

attention accuracy	4MATE teaching model				5E teaching model			
	Pre-test		Post-test		Pre-test		Post-test	
	M	SD	M	SD	M	SD	M	SD
SA	24.875	0.966	29.175	1.083	24.600	0.871	26.825	2.881
FA	28.675	1.591	28.925	1.366	28.150	2.833	27.475	1.840
EA	28.550	1.518	28.850	1.231	28.600	1.499	27.075	2.235
UA	28.900	1.150	29.250	1.006	28.925	2.721	26.250	3.513

### Multivariate Test

For attention accuracy, all the multivariate tests (Pillai's Trace) were significant. This indicated that the teaching models had an influence on attention accuracy at a 0.05 significance level ( $F(4,75) = 10.964, p = 0.000$ ) and could account for the variance of 36.9 percent of attention accuracy ( $\eta_p^2 = 0.369$ ).

The multivariate test revealed the significance of at least one pair of mean scores. Thus, the individual comparison of the observed mean difference was carried out through the univariate ANOVAs. The univariate tests found the significant relationship of effects between all types of attention accuracy: simple reaction (SA) ( $F(1,78) = 23.312, p=0.000, \eta_p^2 = 0.230$ ), focus attention (FA) ( $F(1,78) = 16.019, p=0.000, \eta_p^2 = 0.170$ ), selected attention (EA) ( $F(1,78) = 19.360, p=0.000, \eta_p^2 = 0.199$ ), and sustained attention accuracy (UA) ( $F(1,78) = 26.948, p=0.000, \eta_p^2 = 0.257$ ).

### Finding on Working Memory

Similar to attention, working memory was also measured in terms of the accuracy scores. The pre-test and post-test mean scores (M) and standard deviation (SD) of both the experimental and control groups measured by each subtest, are illustrated in Table 2.

Table 3

Mean scores (M) and standard deviation (SD) of working memory accuracy in both the experimental group and control group

working memory accuracy	4MATE teaching model				5E teaching model			
	Pre-test		Post-test		Pre-test		Post-test	
	M	SD	M	SD	M	SD	M	SD
BM	24.875	0.966	29.175	1.083	24.600	0.871	26.825	2.881
SM	28.675	1.591	28.925	1.366	28.150	2.833	27.475	1.839
UM	28.550	1.518	28.850	1.231	28.600	1.499	27.075	2.235
IM	28.900	1.150	29.250	1.006	28.925	2.721	26.250	3.514

#### Multivariate Test

For working memory accuracy, all the multivariate tests (Pillai's Trace) were significant in working memory. This finding showed that the teaching models affected working memory accuracy at a 0.05 significance level ( $F(4,75)=12.343$ ,  $p=0.000$ ) and could

account for the variance of 39.7 percent of working memory accuracy ( $\eta_p^2 = 0.397$ ).

The multivariate test revealed the significance of at least one pair of mean scores. Thus, the individual comparison of the observed mean difference was conducted through the univariate ANOVAs. The univariate tests showed the significant relationship of effects between all kinds of attention accuracy, namely basic processing accuracy (BM) ( $F$

(1,78) = 13.931,  $p=0.000$ ,  $\eta_p^2 = 0.152$ ), shifting working memory accuracy (SM) ( $F$

(1,78) = 12.597,  $p=0.000$ ,  $\eta_p^2 = 0.139$ ), updating working memory accuracy (UM) ( $F$

(1,78) = 45.858,  $p=0.000$ ,  $\eta_p^2 = 0.370$ ), and inhibiting working memory accuracy (IM)

( $F(1,78) = 13.891$ ,  $p=0.000$ ,  $\eta_p^2 = 0.151$ ).

### DISCUSSION

The findings of this research revealed a greater understanding of the instructional procedures of the 4MATE teaching model, derived from integration of the 4MAT teaching model with executive function training to enhance learners' creative thinking, attention, and working memory, and it was found that this model could improve learning outcomes. The researchers successfully investigated the methodology about new learning mechanism in order to develop the teaching model integrated with these new

theories to fit with an educational context. Thus, innovative teaching models could be developed and become more effective.

The results of this research showed the effectiveness of the 4MATE teaching model in enhancing learners' creative thinking, and attention. Based on the empirical evidence in this research, it is hoped that the 4MATE teaching model will be utilized to improve learners' learning outcomes in general classroom contexts.

Specifically, the researcher combined activities of the executive function training with the 4MAT teaching model. First, in the experience concentration phase, learners must pose questions with regards to different authentic issues and take part in reasoning discussions in the classroom. These activities can improve attention and working memory (Meltzer, 2010; Sternberg, 2012). Second, in the experience analysis phase, they have to analyze the observation results, which allows for the improvement in attention and working memory (Sausa, 2006; Bertrand & Camos, 2015), and discussions, which enables the enhanced working memory (Meltzer, 2010). Following this phase is the experience development phase where the learners engage in brainstorming and organizing ideas; that aids in enhancing working memory (Meltzer, 2010). At this stage, they must create concept maps and more quality concept maps, which can lead to improved creative thinking (Hardiman, 2012; Meltzer, 2010; Srikoon, 2015). Subsequently, in the thinking development phase, they need to search for a variety of learning environments to expand knowledge, which is the basis of creative thinking (Hardiman, 2012; Mumford et al., 2012). Fifth, in performance development, they are required to learn through inquiry practices; this activity contributes to an advancement in creative thinking (Hardiman, 2012; Srikoon, 2015). Later, in the creative innovation phase, the learners learn to design innovations; particularly, they need to apply their knowledge to developing a prototype of the innovation (Hardiman, 2012; Sternberg, 2012). What follows the creative innovation phase is innovation analysis in which the learners learn to develop self-assessment methods for a self-direct learning cycle to improve their innovation, which is a learning activity for practicing creative thinking (Hardiman, 2012; Sternberg, 2012). Finally, in the battle ideas phase, learners recall their new knowledge to battle ideas. These activities entail sharing, discussing, and collaborating on ideas so as to develop new creative ideas in a real-life situation (Sweatt, 2010; Sausa, 2006). In all of these phases, teachers primarily act as a guiding teacher and facilitator in coaching learners to be an innovator (Hardiman, 2012; Sternberg, 2012).

The findings of this research suggest that the executive function training should be given more attention in order to develop the teaching model to enhance learners' learning outcomes. To achieve that, the teachers should be encouraged to apply the 4MATE teaching model to their classrooms since it has been proven to effectively improve learners' creative thinking, attention, and working memory. It implies that teaching centered on executive function training can allow for enhanced attention (Meltzer, 2010; Sternberg, 2012; Quan et al., 2020). As a result, this may enable the improvement in the working memory and storage of a larger body of knowledge in the long-term memory (Baddeley, 2003; Sausa, 2006; Sweatt, 2010). Simply put, when attention and working

memory function more effectively, creative thinking will be improved (Sternberg, 2012; Marchetti, 2014; Beaty et al., 2014; Sharma & Babu, 2017). Moreover, it is assumed that teaching focusing on executive function training will help develop creative thinking, potentially enabling learners to construct innovative products and other essential skills in the 21st century (Srikoon et al., 2018; Marchetti, 2014; Srikoon, 2021b; Wang et al., 2021; Elfiky, 2022).

Essentially, integration of the 4MAT teaching model with executive function training is an interdisciplinary science for the design of teaching models. These processes are performed to develop the innovation, using either a new concept or a new theory, and in-depth explanations to develop science of teaching pedagogy professionally. Moreover, application of educational neuroscience in learning can contribute to improvement of teaching and students' learning outcomes (Sweatt, 2010; Hardiman, 2012; Al-Balushi & Al-Balushi, 2018). Simply put, it can be employed to enhance effectiveness of teaching.

In conclusion, the revolutionary phenomenon in education has emerged. This finding has widened a body of knowledge in educational neuroscience that incorporated executive function into teaching model development, eventually contributing to teaching innovation for classroom practices and guidelines on in-class implementation. Teachers should be urged to improve their understanding of the brain, which could help develop and reform learning and instructional activities. Hence, they should work in concert and use collaborative practices to seek new approaches for classroom development; that is, they should apply theories of educational neuroscience to design learning activities in the future.

### **CONCLUSION AND SUGGESTIONS**

In conclusion, the multivariate and univariate tests showed the significant relationship of effects among all forms of learning outcomes including creative thinking attention and working memory, and it was uncovered that the learners in the experimental group achieved higher learning outcomes than those in the control group did as briefly described below.

1. The grade 4 students taught with the 4MATE teaching model had higher creative thinking scores were than those with the 5E teaching model (5E).
2. The attention accuracy scores of those learning through the 4MATE teaching model were higher than those through the 5E teaching model (5E).
3. Those taught with the 4MATE teaching model achieved higher working memory accuracy scores than did those with the 5E teaching model (5E).

Additionally, this research found that the 4MATE teaching model can enhance creative thinking, attention, and working memory. Considering this finding, teachers should implement the 4MATE teaching model in general classroom contexts and attempt to learn about the 4MATE teaching model in detail to equip themselves with comprehensive understanding, which will allow them to make the most use of its potential to design classroom activities. Moreover, they are urged to design 4MATE

instructional activities based on the conceptual framework, and such activities should be carried out according to the steps laid out in the framework and be suitable with the instructional time to ensure the maximum benefit from this teaching model.

#### **FUTURE RESEARCH**

The present study implemented the 4MATE teaching model in the science and technology subject. As a result, the model should be applied to other subjects to improve the learners' creative thinking, attention, and working memory. In addition, it was implemented with Grade 4 students, so it should be utilized with those at other grades to allow for generalization of this teaching model. This very model should be also used to develop other dependent variables, especially thinking and the 21<sup>st</sup> century skills because it was derived from a combination of 4MAT and the executive function concept which is the modern learning approach. Lastly, future research should examine other theories related to educational neuroscience such as emotion, connectivity, and neuroconstructivism to develop a new teaching model.

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