

*The Development of 4 MAT Lesson Plans on Addition, Subtraction,
Multiplication and Division Combined for Prathomsuksa 3 Students*

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0222

The Asian Conference on the Social Sciences 2013

Official Conference Proceedings 2013

Abstract

The study was aimed at developing the 4 MAT lesson plans with an efficiency criterion of 80/80. Efforts were made to study the effectiveness index of 4 MAT lesson plans, students' learning achievement after learning using 4 MAT lesson plans, and students' satisfaction after learning using 4 MAT lesson plans. The participants comprised of 22 Prathomsuksa 3 (Grade 3) students from Wat Nongsue School, Chachoengsao Province, Thailand. Students had learned about addition, subtraction, multiplication, and division combined for a total of 18 hours. The instruments consisted of 4 MAT lesson plans, a mathematics achievement test, which was including of 30 items with 4 multiple choices, and a questionnaire on students' satisfaction towards 4 MAT learning activities, which was including of 15 items on a Likert scale. The data were statistically analyzed by percentage, mean, and standard deviation. The research hypotheses were tested by using t -test and Chi-square test. Some findings were as follows: the efficiency of 4 MAT lesson plans was 87.19/83.63, which was higher than that of the criterion 80/80. The effectiveness index of 4 MAT lesson plans was found to be 0.77. The students' learning achievement after using 4 MAT lesson plans was statistically significant, which was higher than that before using lesson plans at the level 0.05. The students' satisfactions towards the 4 MAT learning activities were at the highest level. The results indicated that 4 MAT learning activities could be used effectively in order to enhance student's mathematics achievement on several topics.

Keywords: 4 MAT lesson plans, efficiency, effectiveness index, learning achievement.

INTRODUCTION

The development of a learning society is emphasized on a knowledge center for Thailand's vision of becoming a knowledge economy equipped for the 21st Century. Thailand is striving to foster the development of learners and citizens with strong morals and ethics that are able to embrace and understand the world around them and integrate these into a strong sense of their Thai culture and identity to the benefit of their communities (Ministry of Education).

The modern Thai education system stems from the reforms set in place by the 1999 Education Act which put in place administrative structures, decentralization and put a learner centered focus at the heart of the reform process. The modern Thai education system is based around 9 years of compulsory education (enacted in 2003) with 12 years of free basic education guaranteed by the constitution.

The National Education Act B.E. 2542 (revised B.E.2545) and the Compulsory Education Act B.E.2545 state that there shall be three types of education: formal, non-formal and informal. Formal education shall specify the aims, methods, curricula duration assessment, and evaluation conditional to its completion. Non-formal education shall have flexibility in determining the aims, modalities, management procedures, duration, assessment and conditional evaluation to its completion. The contents and curricula for non-formal education shall be appropriate, respond to the requirements, and meet the needs of individual groups of learners. Informal education shall enable learners to learn by themselves according to their interests, potentialities, readiness and opportunities available from individuals, society, environment, media, or other sources of knowledge.

Formal education is divided into two levels: basic education and higher education. Basic Education in Thailand is divided into 6 years of primary schooling (Grade 1–6) from the age of 7 years old followed by 3 years at lower secondary (Grade 4–6). In 2003, compulsory education was extended to 9 years. By 2005, gross enrolment rates for basic education reached 104% for primary education (5.8 million students), 95% for lower secondary education (2.7 million students) and 64% for upper secondary education (1.7 million students divided between 1 million in general education and 700,000 in vocational education). Eight core subjects are used to form the National Curriculum. The flexibility is built into the curriculum to integrate local wisdom and culture as long as it is consistent with the learning standards in each of the subject groups. These include Thai language, mathematics, science, social studies religion and culture, health and physical education, art, career and technology, and foreign languages. At the heart of the teaching and learning inside of the national curriculum, the promotion of thinking skills, self-learning strategies and moral development is the core course. Basic Education is divided into three levels, i.e., pre-elementary level, elementary level, and secondary level. At the pre-elementary level, students are offered a two-year course in public pre-elementary schools and a three-year course in private pre-elementary education aims to nurture and prepare physical, mental, intellectual and emotional skills to students for their further movement to elementary education. Apart from pre-elementary schools and kindergartens, pre-elementary education is also provided in Child Care Centers and Child Development Centers, depending on the target groups and their local areas. At the elementary level, students undergo at least six year of elementary education as a compulsory education. Elementary education puts emphasis on basic literacy and numeracy skills and cultivates desirable behavior in student. Secondary education is divided into two levels; lower and upper secondary levels. Lower secondary education offers a three-year course, which is geared toward developing the students' ethics, knowledge and abilities. It

allows the students to explore their needs, areas of interests and aptitudes, and enables them to meet their appropriate careers. Upper secondary education is a three-year course as a fundamental stage for students who will proceed to higher education. It also aims to prepare student to meet the labor market and to promote their entrepreneurship skills. There are two streams; vocational-oriented stream which is provided in vocational and technical colleges for the students who are good at skills while academic stream is offered in general education schools for the students who are academically inclined.

Mathematics plays an important role in the development of human mind. It inspires creativity; implants logical and systematic thinking and enables one to make sound and precise analyses of various situations, all of which in turn leads to accurate predictions, appropriate planning, optimal problem-solving and decision-making in daily life. Mathematics also serves as a tool for learning science, technology and other disciplines. Therefore, it can be said that mathematics proves useful in everyday life; not only does it help improve the quality of life but it also enables people to live in harmony with others (The Institute for the Promotion of Teaching Science and Technology, 2008).

The Mathematics Learning Area aims to have all Thai students continuously learning mathematics in accordance with their full potential. The following are critical components of a mathematics program:

- **Number and Operations:** number concepts and number sense, real number system, properties of real numbers, number operations, ratio, percentage, problem solving involving number and application of numbers in real life
- **Measurement:** length, distance, weight, area, volume and capacity, money, time, measurement units, estimation in measurement, trigonometric ratio, problem solving in measurement and application of measurement
- **Geometry:** geometric figures and properties of one-dimensional, two-dimensional and three-dimensional geometric figures, visualization, geometric models, theorem of geometry, geometric transformation (translation, reflection and rotation)
- **Algebra:** patterns, relations, functions, sets and operations, reasoning, expression, equation, systems of equations, inequality, graphs, arithmetic sequences, geometric sequences, arithmetic series, and geometric series.
- **Data Analysis and Probability:** selecting issues, questions and method of study, data collection, organizing data, presentation of data, measure of central tendency and data distribution, analyzing and interpreting data, polls, probability, application of statistics and probability in giving an account of events and assisting in decision making
- **Mathematical skills/processes:** solving problems using various methods, reasoning, communication and presentation in mathematics, connecting mathematical ideas to other concepts in mathematics and to other disciplines.

The learning standards and indicators used at the Grade 3 level that are used in this research are as follows:

Strand 1: Numbers and Operations

Students at Grade 3 should be able to understand the effects of operations on numbers and the relationships among the operations, and use the number operations in solving problem (Standard M 1.2). The indicators are as follows: 1) add, subtract, multiply and divide whole numbers up to 100,000; find the answers up to 3-step calculation involving addition, subtraction, multiplication and division; judge the reasonableness of answers and 2) analyze and solve up to 3-step word problems involving addition, subtraction, multiplication and division of whole numbers up to 100,000 and judge the reasonableness of answers.

Strand 6: Mathematical Skills and Processes

Students at Grade 3 should be able to solve problems, use reasoning; use mathematical language in communication and representation, connect mathematical ideas to other mathematical concepts and to other disciplines, think creatively (Standard M 6.1). The indicators are as follows: 1) use various methods in solving problems, 2) appropriately use mathematical concepts and mathematical processes to solve problems in various contexts 3) use reasoning in decision making and make reasonable conclusion, 4) properly use mathematical language and symbols in communication and representation, 5) connect mathematical ideas to other mathematical concepts and to other disciplines, and 6) think creatively.

Quality of learners:

After the completion of Grade 3, students should be able to 1) understand numbers (whole numbers up to 100,000) and operations; develop number sense; solve problems involving addition, subtraction, multiplication and division; judge the reasonableness of answers, 2) understand the concepts of length, distance, weight, volume, capacity, time and money; use appropriate measurement methods and apply measurement concepts to solve problems, 3) recognize, identify and draw triangles, quadrilaterals, circles and ellipse; recognize and identify cuboids, spheres, cylinders, points, line segments, rays, lines and angles, 4) complete patterns and describe the relationship in patterns, 5) collect and sort data about oneself and familiar surrounding; read and discuss data from picture graphs, bar charts, and 6) use various methods to solve problems; apply mathematical ideas, skills and processes to solve problems in various situations; give reasons for decisions and make reasonable conclusions; use mathematical language and symbols in communication; connect mathematical ideas to other mathematical concepts and to other disciplines; think creatively.

The organization of mathematical learning–teaching at the primary education level in Thailand has been encountering problems all the time, particularly regarding low achievement (Panasuna, 2005). The Trends in International Mathematics and Science Study 2007 (TIMSS–2007) assessed students in 59 countries, including Thailand. Some 5,412 Grade 8 students from 150 Thai schools were involved in the assessment. The results of TIMSS revealed that Thai students scored just 441 points in mathematics on average, in tests in which, world class scores were 500. These results are not satisfactory. Thai children's performance is lower than the previous assessment. Thai children were ranked in 29th place for mathematics, while students from Chinese Taipei, South Korea, Singapore, Hong Kong, and Japan were among the top 10.

Students at Grade 3 must learn four basic computational skills, i.e., addition, subtraction, multiplication and division. However, these skills are found to be difficult for students. The results from National Test in mathematics of Grade 3 students from Wat Nongsue School, Chachoengsao Province, Thailand in academic year 2009 indicated that the mean score was 57.22%, which was less than 60% (criteria set by Chachoengsao Primary Educational Service Area Office 2). The mathematics topics that were found to be problematic for learning are addition, subtraction, multiplication, and division combined. It was found that most of the students lack the computational skill in these topics.

Recently, there are several teaching models used in the classroom such as TAI, STAD, and 4 MAT models. The 4 MAT is an instructional model that has increasingly spread across educational levels and areas of teaching. In studies conducted in elementary and secondary settings, the use of 4 MAT increased learner motivation and improved academic performance

(Blair & Judah, 1990; McCarthy et al. 2002; Wilkerson & White, 1988). Statistically significant gains in content area learning have been found in the areas of mathematics (Liebermann, 1988; Lieberman, 1989; Panasuna, 2005; Peker, 2003; Szewczyk, 1987; Tatar & Dikici, 2009), medical (Spatz, 1991; Erwin, Spatz, & Turturro, 1992), music (Appell, 1991), environment (Demirkaya, Mutlu, & Usak, 2003), and science (Benezra, 1985; Bowers, 1987; Suvannatouch, 2003; Young, 1986;). In higher education settings, the 4 MAT has been successfully applied in a variety of disciplines, including engineering (Harb, Durrant, & Terry, 1993), law (Kelly, 1990), and tourism (Paraskeva & Sigala, 2003).

THE 4 MAT (4 Mode Application Techniques) is a model that converts learning style concepts into educational strategies. It was developed by Bernice McCarthy in 1980. The model is based on Kolb's (1984) experimental learning theory in the brain hemisphere research findings. The 4 MAT teaching model relies upon the learning loop which includes the four types of students. McCarthy divides this loop into eight steps and designs it as a process that is made up of activities, which are appropriate for the four types of students. In this loop, while teachers revolve around the real, they also teach according to personal differences by using educational strategies suitable for each student's learning styles. The 4 MAT system has two important priorities. The first one is that human beings have got learning styles and preferences to make half hemispheric operations. The second one is that designing and using multiple educational strategies in a systematic environment so as to teach these preferences can develop teaching and learning (Bikmaz, 2002)

McCarthy's 4MAT System is comprised of a series of sequential stages of instruction (an eight step model). 4 MAT's stages of instruction are summarized as follows:

Connect. Connect content knowledge to a concept in a personal way.

Attend. Guide students to reflection and analysis of their experience.

Image. Employ a nonverbal medium to assess students' understanding of the concept.

Inform. Provide students with content knowledge pertaining to the subject.

Practice. Provide students with hands-on activities for practice and mastery.

Extend. Require students to organize and synthesize their learning in some personal and meaningful way.

Refine. Analyze relevant applications of learning (ongoing throughout model)

Perform. Provide opportunities for students to synthesize learning through sharing with others.

The addition, subtraction, multiplication, and division combined is one of the important topics of mathematics and takes place among the first topics encountered by a student at the primary education. In order to increase learner motivation and improved academic performance on addition, subtraction, multiplication, and division combined, the 4 MAT teaching model was used to design learning activities on that topic. Therefore, the purposes of this study were to develop 4 MAT lesson plans on addition, subtraction, multiplication and division combined for Prathomsuksa 3 (Grade 3) students with an efficiency criterion of 80/80, study the effectiveness index of 4 MAT lesson plans, study the students' learning achievement after learning using 4 MAT lesson plans, study the students' satisfaction after learning using 4 MAT lesson plans and study the number of students who obtained 70 percent of total scores.

METHODOLOGY

Participants

The participants in this study were 22 Grade 3 students, 10 boys and 12 girls, studying in the second semester of 2010 academic year at Wat Nongsue School under the Office of Chachoengsao Educational Service Area 2, Thailand. They were purposively selected.

Instrumentation

Three types of research instruments were used, i.e., 4 MAT lesson plans on the addition, subtraction, multiplication, and division combined; the mathematics achievement test; and the Mathematics Satisfaction Scale. The data were statistically analyzed by percentage, mean, standard deviation. The research hypotheses were tested by using *t*-test (Dependent Samples) and Chi-square test.

The mathematics achievement test developed by the researchers was administered to all students in this study both as the pretest at the beginning of the study and as the posttest at the end of the study. It included 30 items with 4 multiple choices. The degree of difficulty was between 0.43–0.78. The discrimination index was between 0.40–0.85. This shows that each item had a satisfactory level of discrimination. It could be said that the test items developed are suitable to measure students' knowledge on the topic of addition, subtraction, multiplication and division combined. The reliability of the test was 0.93, indicating that the reliability of the test items was at an excellent level.

To measure students' satisfaction towards 4 MAT learning activities, the researchers administered the Mathematics Satisfaction Scale after treatment. This instrument was developed by the researchers. It consisted of 15 items made up of all positively worded items to which the students were expected to respond by expressing their level of satisfaction or otherwise on a five-point Likert scale of at least satisfied rated 1, somewhat satisfied rated 2, fairly satisfied rated 3, very satisfied rated 4, and most satisfied rated 5. The scale was validated for its content by reviewers ($n = 5$) with expertise in the field. The instrument was pilot tested by administering to 30 students who were not part of the target population. The discriminations were between 2.21–5.66 and the Cronbach alpha value obtained was 0.90, which showed that this scale was reliable, and can be used for the study.

Research Design

In this study, research design was one group pretest–posttest design as shown in Table 1 below:

Table 1

Research Design for this study

Group	Pretest	Treatment	Posttest
Experimental	T ₁	X	T ₂

As shown in Table 1 above, T₁ was pretest, X was the learning mathematics via 4 MAT lesson plans or treatment, and T₂ was posttest, respectively.

A pretest was administered to all of students at the beginning of a class. They then were taught mathematics on addition, subtraction, multiplication and division combined using 4 MAT learning activities. Next, a posttest was administered to all students after finishing all of the lessons. Finally, all students were asked to complete the questionnaire focusing on their satisfaction about learning via 4 MAT lesson plans.

Data Analysis

The data were analyzed as follows: finding the efficiency of 4 MAT lesson plans; secondly, finding the effectiveness index of the learning process, following a method of Goodman, Fletcher and Schneider (1980), comparing the students' learning achievement before and after using the 4 MAT learning activities, finding students' satisfactions towards the 4 MAT learning activities and finally, finding the number of students who obtained 70 percent of total scores.

The data were statistically analyzed by percentage, mean, standard deviation. The significance level was set to .05 since it is the most used value in educational studies. The research hypotheses were tested by using *t*-test (Dependent Samples) and Chi-square test.

FINDINGS AND INTERPRETATIONS

The findings of the current research revealed five aspects that are worth discussing: efficiency of 4 MAT lesson plans, effectiveness index of 4 MAT learning activities, learning achievement of students participating in 4 MAT lessons, students' satisfactions towards the 4 MAT learning activities and the number of students who obtained 70 percent of total scores.

The result illustrated that the Efficiency of the process (E_1) was 87.19 and the performance result (E_2) was 83.63. 4 MAT lessons on addition, subtraction, multiplication and division combined showed efficiency (E_1/E_2) of 87.19/83.63. This was higher than the given criterion of 80/80 (Table 2).

Table 2

The efficiency of 4 MAT lesson plans

Academic performance	Score	N	\bar{X}	SD	Percentage
Process effectiveness (E_1)	10,358	22	470.82	36.30	87.19
Performance effectiveness (E_2)	552	22	25.09	4.32	83.63

The effectiveness index (E.I.) of 4 MAT lesson plans was at 0.77, representing 77%. This was higher than the given criterion of 70% and indicated that with the experience of tackling 4 MAT lessons, the students sample had gained more knowledge (Table 3).

Table 3

The effectiveness index (E.I.) of 4 MAT lesson plans

N	Score	Score		Percentage		E.I.
		Pre	Post	Pre	Post	
22	660	193	552	29.24	83.63	0.77

As it is seen in Table 4, the mean score achieved by the sample before and after the experiment was 8.77, 25.09, respectively with standard deviations of 3.22, 4.32, respectively. The result from testing revealed that the posttest scores of students were significantly higher than their pretest with .05 significant differences. This means that the designed lessons effectively improved learning outcomes of the students. The learning improvement rate of the students was 54.4%. According to the results obtained, there is a 16.32 point difference in favor of the posttest between the means of the scores that the students got in the pre and post achievement tests. This difference can be named as the average achievement score that the students obtained. The “*t*” value has proved to be significant according to the results of a paired *t*-test that has been conducted to learn the significance of the difference between these average scores that the students obtained in the pre and post tests [$t = 18.36; p < .05$].

Depending upon the findings, it can be said that the experimental program that has been constructed according to the 4 MAT learning activities has been effective for the success of the students on Addition, Subtraction, Multiplication and Division Combined. It also found that after learning through 4 MAT teaching methods, the average percentage score of students’ mathematics learning achievement was 83.63%, which was higher than the set criteria of 70.00%. The comparison of the students’ pretest and posttest scores can be illustrated in Table 4.

Table 4
 Comparing of Pretest and Posttest Scores of Students

Test	Score					
	No. of Students (N)	\bar{X}	<i>SD</i>	$\sum D$	$\sum D^2$	<i>t</i>
Pretest	22	8.77	3.22	359	6223	18.36*
Posttest	22	25.09	4.32			

Note. * $p < .05$ ($df = 21, t .05 = 1.721$)

The Mathematics Satisfaction Scale, conducted after 22 Grade 3 students had completed the lessons, revealed that the sample students were most satisfied with the 4 MAT learning activities ($\bar{X} = 4.81, SD = 0.52$). The criterion for interpreting students’ satisfactions towards the 4 MAT learning activities was shown as follows: Rank 1.00–1.50 means “Least satisfied”; 1.51–2.50 means “Somewhat satisfied”; 2.51–3.50 means “Fairly satisfied”; 3.51–4.50 means “Very satisfied”; and 4.51–5.00 means “Most satisfied”.

The result also indicated that the number of students who obtained 70 percent of total scores was 90.91 percent upward at .05 level of significance [$\chi^2 = 5.24$].

CONCLUSIONS AND DISCUSSION

The efficiency of 4 MAT lesson plans was 87.19/83.63, which was higher than that of the criterion 80/80. The results illustrated that the first efficiency of the process (E_1) were higher than the second efficiency of the outcome (E_2). This means that the students got activity scores greater than their posttest scores. This is because they had done repeated activities; they can revise, do the activities and check the answers by themselves before doing the posttest. Consequently, they can encourage themselves to learn through the 4 MAT activities. Moreover, the efficiency of the outcomes was lower than the efficiency of the process since

the posttest was more difficult than the activities. This finding partially is consistent with the finding in Tadnamthong's (2005) study. She studied the effective of achievement in learning mathematics "Fraction" of 36 Grade 5 students by using 80/80 standard. The result indicated that the subject mean score from the achievement in learning mathematics by using 4 MAT lesson plan of Grade 5 students has an efficiency 89/81.91 which met the standard. It is also consistent with the Sane'e's (2008) findings. She studied Grade 4 students' achievement on fractions in mathematics learning substance group by using the 4 MAT teaching model. The samples in this study were selected by purposive sampling technique. There were 27 students in Grade 4 in the first semester of academic year 2008 at Banpakphreag School, Amphoe Bangkhan, Nakhon Si Thammarat Province. The research result also indicated that the effectiveness of the 4 MAT lesson plans on Fractions in Mathematics learning Substance group for Grade 4 students were 86.81/84.44 which also met the standard.

The result of this study also revealed that the effectiveness index of 4 MAT lesson plans on addition, subtraction, multiplication and division combined was at 0.77 which is indicated that learners progressed in learning at 77%. This could be explained that the 4 MAT lesson plans support individual learning. Students can learn in accordance with their interests, skills and their appropriate time. Students were interested in and enthusiastic in learning, responsible for their assignment, happy and joyful, show unity in group. They showed their attempt in challenging capability. They were proud of successful work performance and able to apply their knowledge to be useful. This finding is consistent with the finding by Keaw-on (2009) that the plans for organization of learning activities using 4 MAT learning cycle approach entitled Graphic and Longitudinal Measurement for Grade 3 students had efficiencies of 79.40/77.78, which met the required criterion of 75/75. The effectiveness indices of learning plans by using 4 MAT learning cycle approach were 0.5754; showing that the students had learning progress at 57.54 percent.

Moreover, the students' learning achievement after using 4 MAT lesson plans was statistically significant, which was higher than that before using lesson plans at the level .05. The result revealed that students who learned addition, subtraction, multiplication and division combined through 4 MAT lesson plans had higher mathematics learning achievements on posttest mean scores than in pretest mean scores with statistically significant difference at a .05 level. Thus we could conclude that 4 MAT lesson plans had efficiency because it could lead the students achieve higher learning. This finding is in line with the finding by Chanclai (2002) who studied the research in order to compare creative thinking and mathematics achievement on quadrilateral of Grade 6 students taught by the 4 MAT system and the conventional method. The result revealed that the posttest mathematics achievement of the students taught by the 4 MAT system was significantly higher than that of the pretest. ($p < .01$). This result is also consistent with research finding of Songseeda (2008) who studied mathematics achievement and mathematical communication skills of Grade 7 students before and after being taught through the 4 MAT system and compare to the criterion. The result of the study indicated that the mathematical achievement of the experimental group after being taught through the 4 MAT system was statistically higher than before being taught at the .01 level of significance.

The result of this study also illustrated that students' satisfactions in learning addition, subtraction, multiplication and division combined through 4 MAT learning activities were at the highest level (most satisfied). It is consistent with the finding by Konmun (2009) that the students' opinions on learning mathematics through 4 MAT teaching method was at very agreeable level.

The investigation also revealed that the number of students who obtained 70 percent of total scores was 90.91 percent upward at .05 level of significance. The finding is in line with the finding of Songseeda (2008) who found that the mathematical achievement of the experimental group after being taught through the 4 MAT system was statistically higher than the 70 percentage criterion at the .01 level of significance. It is also consistent with another study that found that the 6 learning plans constructed through 4 MAT teaching method consumed 12 teaching hours could develop mathematics learning of Grade 4 students. After learning through 4 MAT teaching method, the average percentage score of students' mathematics learning achievement was 68.22%, which was higher than the set criteria of 60.00% (Konmun, 2009).

In conclusion, the researchers' developed 4 MAT lesson plans on addition, subtraction, multiplication and division combined for Grade 3 students had a high efficiency and effectiveness. Therefore, these lesson plans could be used as a guideline for teachers and students in developing and improving their mathematics learning achievement and satisfaction of learning on addition, subtraction, multiplication and division combined. Accordingly, administrators, teachers, and related persons in learning management should apply the 4 MAT lesson plans on addition, subtraction, multiplication and division combined for Grade 3 students to develop instruction in other contents.

Acknowledgements

The authors would like to express their gratitude to Professor Dr. Somsak Pantuwatana for his guidance. Special thanks are also extended to Mr. Ross Walker for his valuable advice. Appreciation is extended to the students who were involved in this study, and without whom this study would never have been possible. Finally, acknowledgement is made of Rajabhat Rajanagarindra University for funding.

REFERENCES

- Appell, C. (1991). **The effects of the 4MAT system on instruction, academic achievement and attitude in the elementary music classroom**. Unpublished doctoral dissertation. University of Oregon.
- Benerzra, S. (1985). **Bernice McCarthy's 4MAT learning style adaptations in middle school life science**. Unpublished manuscript.
- Bikmaz, H. (2002). Translation: Bernice McCarthy. **Educational Leadership**, 105–111.
- Blair, D. & Judah, S. (1990). Need a strong foundation for an interdisciplinary program? Try 4MAT. **Educational Leadership**, 48(2), 37–38.
- Bowers, P. (1987). **The effect of the 4MAT system on achievement and attitudes in science**. Unpublished doctoral dissertation. The University of North Carolina at Chapel Hill.
- Chanclai, S. (2002). **A comparison of creative thinking and mathematics achievement on quadrilateral of Prathom Suksa Six students taught by the 4 MAT system and the conventional method**. Master of Education in Elementary Education. Burapha University.
- Ministry of Education. (1999). **The Educational System in Thailand** [online].
- Demirkaya, H., Mutlu, M. & Usak, M. (2003). 4MAT Öğretim Sistemi Modelinin Çevre. Eğitimine Uygulanması. **Pamukkale Üniversitesi Eğitim Fakültesi Dergisi**, 14(2003), 68–82.

- Erwin, D., Spatz, T. & Turturro, C. (1992). Development of an African-American role model intervention to increase breast self-examination and mammography. **Journal of Cancer Education**, 7(1992), 311–319.
- Goodman, R.; Fletcher, K.; & Schneider, E. (1980). The effectiveness index as comparative measure in media product evaluation. **Educational Technology**, 20(9), 30–34.
- Harb, J.; Durrant, S. & Terry, R. (1993). Use of the Kolb learning cycle and the 4MAT system in engineering education. **Journal of Engineering Education**, 82(2), 70–77.
- Jackson, P. (2001). **The effects of teaching methods and 4MAT learning styles on community college students' achievement, attitudes, and retention in introductory microbiology**. Unpublished doctoral dissertation. Lynn University.
- Keaw-on, Thidarat (2009). **Mathematical reasoning abilities, and learning achievement entitled graphic and longitudinal measurement of Prathomsuksa 3 students learned using 4 MAT learning cycle model and the conventional learning approach**. Master of Education in Curriculum and Instruction, Mahasarakham University.
- Kelly, C. (1990). Using 4MAT in law school. **Educational Leadership**, 48(2), 40–41.
- Konmun, S. (2009). **Development of mathematics learning titled fraction of Prathom Suksa 4 students through 4 MAT teaching method**. Master of Education in Elementary Education. Chaing Mai University.
- Kolb, D. (1984). **Experiential learning: Experiences as the source of learning and development**. Englewood Cliffs, NJ: Prentice Hall, Inc.
- Liebermann, M. (1988). **Report on the Fairfax County area III 4MAT geometry project**. Fairfax, VA.
- Lieberman, M. (1989). **Report on the Fairfax County area III 4MAT pre-algebra project**. Fairfax, VA.
- McCarthy, B. (1987). **The 4MAT system**. Barrington, IL: Excel, Inc.
- McCarthy, B. (1990). Using the 4MAT system to bring learning styles to schools. **Educational Leadership**, 48(2), 31–37.
- McCarthy, B., Germain, C. & Lippitt, I. (2002). **The 4MAT research guide**. Wanconda, IL: About Learning Inc.
- Mullis, I., Martin, M., Foy, P. et al. (2008). **TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades**. Chestnut Hill, MA: Boston College.
- Panasuna, R. (2005). **Development plans for learning activities by using the learning cycle model to compare with IPST model, entitled "Addition and subtraction of the numbers with each sum or remainder and the standing number not exceeding 100" in the mathematics learning strand for Prathomsuksa 1**. Master of Education in Curriculum and Instruction. Mahasarakham University.
- Paraskeva, A. & Sigala, M. (2003). Teaching hospitality and tourism management: A matter of style. **Journal of Teaching in Travel and Tourism**, 3(4), 1–18.
- Peker, M. (2003). **The effects of learning styles and 4MAT education model on the students' achievements and attitudes**. Unpublished doctoral dissertation.
- Ratanaprasob, S. (2007). **The construction of instructional package for mathematics on division for prathomsuksa three**. Master of Education in Curriculum and Instruction. Burapha University.
- Sanee, P. (2008). **A study of Grade 4 students' achievement on fractions in mathematics learning substance group using 4 mat teaching model**. Master of Education in Curriculum and Instruction Development, Nakhon Si Thammarat Rajabhat University.
- Songsakkaesorn, S. (2006). **A comparison of academic achievement and learning interest in mathematics in addition of Prathomsuksa 1 students taught through 4 MAT**

- teaching activities and by standard teaching method.** Master of Education in Curriculum and Instruction, Rajabhat Rajanagarindra University.
- Songseeda, P. (2008). The effects of the 4 MAT teaching and learning “Decimals and fractions” on academic achievement and mathematical communication skills of mathayomsuksa I students. **Journal of Educational Research.** Faculty of Education. Srinakharinwirot University, 2(2), 81–85.
- Spatz, T. (1991). Improving breast self-examination training by using the 4MAT instructional model. **Journal of Cancer Education**, 6(1991), 179–183.
- Suvannatouch, R. (2003). **Science learning achievement and scientific creative thinking of mathayom Suksa 1 students taught through 4 MAT system.** Master of Education in Science Education. Chaing Mai University.
- Szewczyk, I. (1987). **Effects of 4MAT, an experimentally-based teaching method upon achievement and selected attitudinal factors of high school geometry students.** Unpublished doctoral dissertation.
- Tadnamthong, R. (2005). **Learning achievement in mathematics of Grade V students by using 4 MAT lesson plan.** Master of Education in Curriculum and Instruction, Pranakhon Rajabhat University.
- Tatar, E. & Dikici, R. (2009). The effect of the 4MAT method (Learning styles and brain hemispheres) of instruction on achievement in mathematics. **International Journal of Mathematical Education in Science and Technology**, 40(8), 1027–1036.
- The Institute for the Promotion of Teaching Science and Technology. (2008). **The basic education core curriculum. B.E. 2551.**
- Ursin, V. (1995). **Effects of the 4MAT system of instruction on achievement, products, and attitudes toward science of ninth-grade students.** Unpublished doctoral dissertation. University of Connecticut.
- Wilkerson, R. & White, K. (1988). Effects of the 4MAT system of instruction on students’ achievement, retention, and attitudes. **The Elementary School Journal**, 357–368.
- Young, D. (1986). **Administrative implications of instructional strategies and student learning style preferences on science achievement of seventh grade students.** Unpublished doctoral dissertation. The University of Hawaii.

