DEVELOPMENT OF GEOMETRY MULTIMEDIA TO ENHANCE SEVENTH GRADE STUDENTS' ABILITY IN 2D-3D CONVERSION OF GEOMETRIC PICTURES

ORADEE NOIPUK

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE
(SCIENCE AND TECHNOLOGY EDUCATION)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2009

COPYRIGHT OF MAHIDOL UNIVERSITY

Copyright by Mahidol University

Thesis
Entitled

DEVELOPMENT OF GEOMETRY MULTIMEDIA TO ENHANCE SEVENTH GRADE STUDENTS' ABILITY IN 2D-3D CONVERSION OF GEOMETRIC PICTURES

Oradee Noipuk
.....
Miss Oradee Noipuk
Candidate

.....
Lect. Tussatrin Kruatong, Ph.D.
Major-Advisor

Pintip Ruenwongsa
.....
Assoc. Prof. Pintip Ruenwongsa, Ph.D.
Co-Advisor

.....
Assoc. Prof. Bhinyo Panijpan, Ph.D.
Co-Advisor

B. Mahaisavariya
.....
Prof. Banchong Mahaisavariya, M.D.
Dean
Faculty of Graduate Studies
Mahidol University

Pintip Ruenwongsa
.....
Assoc. Prof. Pintip Ruenwongsa, Ph.D.
Chair
Master of Science Program
in science and Technology Education
Institute for Innovation and
Development of Learning Process
Mahidol University

Copyright by Mahidol University

Thesis
Entitled

DEVELOPMENT OF GEOMETRY MULTIMEDIA TO ENHANCE SEVENTH GRADE STUDENTS' ABILITY IN 2D-3D CONVERSION OF GEOMETRIC PICTURES

was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Science and Technology Education)
on
April 7, 2009

Oradee Noipuk
.....
Miss Oradee Noipuk
Candidate

.....
Mr. Pramuan Siripunkaew, Ph.D.
Chair

.....
Assoc. Prof. Bhinyo Panijpan, Ph.D.
Member

.....
Lect. Tussatrin Kruatong, Ph.D.
Member

Pintip Ruenwongsa
.....
Assoc. Prof. Pintip Ruenwongsa, Ph.D.
Member

.....
Assoc. Prof. Bhinyo Panijpan, Ph.D.
Director
Institute for Innovation and
Development of Learning Process

B. Mahaisavariya
.....
Prof. Banchong Mahaisavariya, M.D.
Dean
Faculty of Graduate Studies
Mahidol University

.....
Prof. Skorn Mongkolsuk, Ph.D.
Dean
Faculty of Science
Mahidol University

Copyright by Mahidol University

ACKNOWLEDGEMENTS

The success of this thesis can be attributed to the extensive support and assistance from my major advisor. I would like to express my gratitude to Dr. Tussatrin Kruatong who fostered my thesis and gave me useful advices for conducting this research.

I am very grateful to Assoc. Prof. Dr. Pintip Ruenwongsa to support facilities, to examine the research instrument, and to suggest value advice in this research.

I would like to thank Assoc. Prof. Dr. Bhinyo Panijpan for kindness in suggesting many challenging ideas, and providing suggestions for improvement.

I would like to thank Dr. Pramuan Siripunkaew for valuable advice and suggestions for improvements and who was the chairman of the thesis defense.

I am grateful to the director of Debsirin Nonthaburi school to give me the permission for conducting the research, and I would like to thank all teachers and students who willingly participated to this study.

Finally, I am very grateful to daddy Uthai and mommy Choonbuey Noipuk for their precious encouragement, entirely care and love. I deeply thank to Onanong and Somtob Noipuk, and Lee Choon Ang who lift me up always. I would like to thank everybody who gave me some valuable suggestion, helped me to supply some necessary instruments. The usefulness of this thesis, I dedicate to my father, my mother and all the teachers who have taught me since my childhood.

Oradee Noipuk

Copyright by Mahidol University

DEVELOPMENT OF GEOMETRY MULTIMEDIA TO ENHANCE SEVENTH GRADE STUDENTS' ABILITY IN 2D-3D CONVERSION OF GEOMETRIC PICTURES

ORADEE NOIPUK 5037070 SCED/M

M.Sc. (SCIENCE AND TECHNOLOGY EDUCATION)

THESIS ADVISORY COMMITTEE : TUSSATRIN KRUATONG, Ph.D.,
PINTIP RUENWONGSA, Ph.D., BHINYO PANIJPAN, Ph.D.

ABSTRACT

The purpose of this quasi-experimental research is to investigate the efficiency of Geometry Multimedia Organization (GMO) in enhancing students' ability in 2D-3D conversion of geometric pictures, the comparison between male and female students' spatial ability, and the students' attitude toward Geometry. The samples were 190 seventh grade students of a high school in Nonthaburi province, Thailand. An experimental group was 98 students and a control group was 92 students. It took 5 weeks to implement GMO in September-October, 2008, and data was collected using parallel-test and questionnaire. T–test and Chi-square test were used to analyze data statistically.

Results revealed that the experimental group had higher spatial ability than that of the control group at $p < 0.01$. Both female and male students have similar abilities in spatial skill at $\alpha = 0.05$. In attitude test, the experimental group had positive results and displayed more powerful effects on students' geometry achievement than those of the control group.

These findings revealed that Geometry Multimedia Organization is an effective mediator to assist teaching 2D-3D conversion of geometric pictures. It can enhance students' spatial skill and encourage male and female students to have a positive attitude toward Geometry.

KEY WORDS: GEOMETRY / MULTIMEDIA / MIDDLE SCHOOL STUDENT / 2D-3D PICTURES

85 pages

Copyright by Mahidol University

การพัฒนาสื่อการสอนทางเรขาคณิตเพื่อส่งเสริมความสามารถในการแปลงภาพสองมิติและสามมิติของนักเรียนชั้นมัธยมศึกษาตอนต้น

DEVELOPMENT OF GEOMETRY MULTIMEDIA TO ENHANCE SEVENTH GRADE STUDENTS' ABILITY IN 2D-3D CONVERSION OF GEOMETRIC PICTURES

อรดี น้อยปุก 5037070 SCED/M

วท.ม. (วิทยาศาสตร์และเทคโนโลยีศึกษา)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์ : ทัศตริน เครือทอง, Ph.D., พินทิพ รื่นวงษา, Ph.D., ภิญโญ พานิชพันธ์ , Ph.D.

บทคัดย่อ

การศึกษาครั้งนี้เป็นการวิจัยเชิงทดลอง เพื่อศึกษาประสิทธิภาพของระบบสื่อมัลติมีเดียที่เกี่ยวกับภาพสองมิติและสามมิติทางเรขาคณิต ที่มีผลต่อความสามารถทางปริภูมิของนักเรียนชั้นมัธยมศึกษาตอนต้น ความสามารถทางปริภูมิของนักเรียนชาย-หญิง และทัศนคติเกี่ยวกับวิชาเรขาคณิต กลุ่มตัวอย่างเป็นนักเรียนชั้นมัธยมศึกษาปีที่ 1 จากโรงเรียนมัธยมในจังหวัดนนทบุรี จำนวน 190 คนโดยแบ่งเป็นกลุ่มทดลองจำนวน 98 คนและกลุ่มควบคุมจำนวน 92 คน เก็บข้อมูลเป็นเวลา 5 สัปดาห์ในระหว่างเดือนกันยายนถึงเดือนตุลาคม พ.ศ. 2551 วิเคราะห์ข้อมูลโดยใช้สถิติ t- test และการทดสอบไคว์แสควร์

ผลการศึกษาพบว่านักเรียนกลุ่มทดลองมีความสามารถทางปริภูมิมากกว่ากลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติที่ $p < 0.01$ ความสามารถทางปริภูมิของนักเรียนชายและหญิงไม่มีความแตกต่างกันที่ระดับนัยสำคัญ 0.05 เมื่อทดสอบถึงทัศนคติเกี่ยวกับวิชาเรขาคณิตของทั้งสองกลุ่ม พบว่า กลุ่มทดลองมีทัศนคติเชิงบวกเกี่ยวกับความสามารถบางประการในวิชาเรขาคณิตมากกว่ากลุ่มควบคุม

จากการวิจัยครั้งนี้พบว่า การนำสื่อการสอนทางเรขาคณิตมีประสิทธิภาพในการช่วยสอนการแปลงภาพเรขาคณิตสองมิติและสามมิติ สื่อการสอนนี้สามารถส่งเสริมทักษะทางปริภูมิของนักเรียนและก่อให้เกิดเจตคติที่ดีต่อวิชาเรขาคณิตได้

85 หน้า

Copyright by Mahidol University

CONTENTS

	Page
ACKNOWLEDGEMENTS……	**iii**
ABSTRACT……	**iv**
LIST OF TABLES……..	**viii**
LIST OF FIGURES……	**x**
CHAPTER I INTRODUCTION……..	**1**
1.1 Background to the Research Study……	1
1.2 Rationale for Investigation……	2
1.3 Outline of the Study……..	4
1.4 Aims of the Research Study……..	4
1.5 Research Questions……...	4
1.6 Summary of the Chapter……...	5
CHAPTER II LITERATURE REVIEW……...	**6**
2.1 Theory of Learning: Cognitive Theory……	6
2.2 Technology Enhanced Learning for Classroom…….	9
2.3 The Cognitive Theory of Multimedia Learning (CTML)	10
2.4 Learning and Teaching Geometry - Spatial Ability…	14
2.5 Student's Difficulty in Learning Geometry and Teachers' Difficulty in Instructional Managements……..	16
2.6 Gender Difference in Mathematics Learning……	17
2.7 Enhancing Spatial Ability via Multimedia…….	17
2.8 Theoretical Framework of This Study……	19
CHAPTER III MATERIALS AND METHODS……	**21**
3.1 Quasi-Experimental Design……	22
3.2 Subjects……..	24
3.3 Research Instruments……...	25
3.4 Data Collection……..	40
3.5 Data Analysis…….	42

Copyright by Mahidol University

CONTENTS (Cont.)

3.6 Summary of the Chapter…… 42

CHAPTER IV RESULTS…… 43

CHAPTER V DISCUSSION…… 57

5.1 GMO versus Other Multimedia……. 57

5.2 The Effective Aspects of GMO…….. 58

5.3 The Outcomes of Research Questions……. 59

5.4 The Students' Attitude toward Learning Geometric Pictures via GMO Instruction 60

5.5 GMO learning contexts…… 61

5.6 The Limitation of This Study…….. 61

5.7 Recommendations……... 62

CHAPTER VI CONCLUSION……. 63

REFERENCES…….. 65

APPENDICES……... 71

BIOGRAPHY…… 85

Copyright by Mahidol University

LIST OF TABLES

Table		Page
4.1	The pretest-mean scores of experimental group and control group	44
4.2	Comparing mean between the pretest scores of experimental group and the pretest scores of control group	44
4.3	The posttest-mean scores between experimental group and control group	45
4.4	Comparing mean between the posttest scores of experimental group and the pretest scores of control group	45
4.5	The pretest scores between male and female students in control group	46
4.6	Comparing pretest scores between male and female students in control group	46
4.7	The posttest scores between male and female students in control group	47
4.8	Posttest-mean score between male and female students in control group	47
4.9	The pretest scores between male and female students in experimental group	48
4.10	Comparing pretest scores between male and female in experiment group	48
4.11	The posttest score between male and female students in experimental group	49
4.12	Comparing posttest scores between male and female in experiment group	49
4.13	The frequency of students' opinion level on Geometry	50

Copyright by Mahidol University

LIST OF TABLES (Cont.)

Table		Page
4.14	The percentage of students' satisfaction levels on Geometry	51
4.15	The outcomes of Chi-square test: the relationship between the instructional approaches and students' attitude toward Geometry	52
4.16	The statements represented students' attitude toward Geometry	53

Copyright by Mahidol University

LIST OF FIGURES

Figures	Page
2.1 Woolfolk s' human cognitive learning module	8
2.2 Human cognitive system	8
2.3 Mayer's cognitive theory of multimedia learning	12
3.1 Diagram of pretest-posttest, nonequivalent control group	23
3.2 Diagram of subjects	24
3.3 The main page of GMO	29
3.4 The main menu of GMO	30
3.5 Simple geometric pictures	31
3.6 Drawing 3D geometric pictures	31
3.7 The cross-section of coffee	32
3.8 The cross-section of the world	33
3.9 The three-dimensional pictures of milk box	34
3.10 The three-dimensional pictures of fancy box	34
3.11 The front-view of building-block task	35
3.12 The side-view of building-block task	36
3.13 The top-view of building-block task	36
3.14 The diagram of lesson-plan in both control groups and treatment groups	39
4.1 Student A's cross-section of durian	54
4.2 Student B's cross-section of durian	55
4.3 Student C's cross-section of durian	55
4.4 Student A's cross-section of strawberry	55
4.5 Student B's cross-section of strawberry	56
4.6 Student C's cross-section of strawberry	56

Copyright by Mahidol University

CHAPTER I
INTRODUCTION

1.1 Background to the Research Study

1.1.1 Context of teaching and learning Geometry in Thailand

Two- and three-dimensional pictures were considered an important part of geometry because they were fundamental concepts of learning mathematics, science and technology. As Einstein mentioned about influencing of spatial ability on scientific thinking that his knowledge was not words, but clear imaginaries and signs were combined. So spatial thinking was considered as the significant factor to support scientific thought for students' learning in all levels. Students should have spatial skill as a tool to manipulate information in learning environments, solving science, and mathematics problems. Hence, helping students to develop their own spatial skills was necessary (Clements & Battista, 1992).

1.1.2 Mathematics curriculum on Geometry

According to Principle and Standard for School Mathematics (NCTM, 2000), grade 6-8 students should be able to analyze characteristics and properties of 2D-3D geometric shapes. The mathematics curriculum of Thailand focused on describing and analyzing the 2D-3D geometric pictures (IPST, 2001): a) Understanding in the characteristics of prism, pyramid, cylinder, cone and sphere b) Drawing simple geometric pictures which are not focused on proof c) Describing the 3D geometric pictures derived from 2D geometric pictures. In summary, Thai students should be able to draw, write and explain the correct shape of the 2D-3D geometric pictures.

1.1.3 Teaching and learning about Geometry

In Thailand, there were few studies on teaching and learning in basic concepts of geometry e.g. Suthtakeit Wanwipa (1999) developed a computer-based geometry lesson composed of the learning activity aimed to encourage students in

Copyright by Mahidol University

geometric imaginary. This computer lesson supported students in the learning achievement of geometry. Jongsuabsook Jesada (1999) affirmed that the lesson on computer program and using guide sheets could aid students to learn geometry and do the geometric tasks correctly. Chamnankit Nuansri (2003) found that most high-school students from Nakhonsawan province hold misconceptions of basic geometry images and they could not identify complex geometric images. The study suggested that spatial ability seemed to be a critical issue, so we needed to develop some instruments for teaching in geometry classes. The scholars found that this showed the effective results in order to support the computer-based geometry instruction, and students were extremely satisfied by learning this lesson and the students' retention on geometry knowledge was efficient in high level (Koijapoa Wanwipa, 2004; Indhison Wajarason, 2004). These studies revealed that multimedia could assist teacher to instruct students efficiently in geometry classes. Furthermore, Adae Kasmas (2005) asserted that the construction of the instructional package learning on the 2D-3D objects could enhance students' spatial ability efficiently and this could motivate students' interest in learning Geometry. As we mentioned so far, the multimedia could effectively enhance Thai students' understanding of geometry (Nueangchompoo Suros, 2006). To solve the current problem in teaching and learning in 2D-3D conversion, multimedia seemed to be a powerful tool that teachers should consider it as learning media to lead students to have higher accomplishment in learning geometry.

1.2 Rationale for Investigation

1.2.1 Problems concerning geometry learning

Imaging the shape of 3D-materials was a crucial problem in learning geometry. Most students had the misconception of geometric images and they could not identify complex geometric images. Especially, students' spatial ability was the critical issue which was necessarily investigated (Chamnankit Nuansri, 2003). Besides, there was the limited number of learning materials and most teachers also held the difficulties in keeping and maintaining these learning materials; for instance, using the real model or objects was applied in teaching 2D - 3D conversion, it was difficult for the teacher to conduct the class, especially when the model or object was in front of the class, and each student saw it at different angles, thus students could not exactly reach the

Copyright by Mahidol University

teachers' purpose. As the results, Students should be enhanced understanding in a 3D object represented on a 2D surface. Furthermore, several research studies found that students' background experiences in interpreting pictures of 3D objects have been insufficient (Gorgorio, 1998; Song & Lee, 2002: Kelly, Ewers & Proctor, 2002: Olkun, 2003). Students often faced the difficulty in imagining 2D-plane images of the three-dimension of block constructions, even the objects in real life (Kelly, Ewers & Proctor, 2002). Sometimes, it was difficult to explain geometric attributes, so we needed some tools to support the instructions (Lieu, 1999). From the pilot study, it showed that most Thai students needed a multimedia to support their learning in geometry chapter and they needed help for improving their understanding in visual and non- visual geometry related to symmetry, cross-section, unfolding and so on. In students' interview data, 2D-3D geometric pictures were difficult to understand because they were abstract and complex contents. Moreover, student's prejudice toward this issue was rather negative. In correspondence with these problems, the pedagogical strategy should be improved and an appropriate instructional design should be done. Besides, the gender difference in previous studies had showed different results in students' spatial skill (Olkun, 2003; Samsudin & Ismail, 2004; Yun, Xi and Li, 2006), thus Thai students should be considered and investigated in this issue so as to provide appropriate instruction in geometry classes for them.

1.2.2 Computers based on learning Geometry

Multimedia was considered a suitable media to support learning and teaching 2D geometric pictures (Clement, 1999; Olkun, 2003; Samsudin & Ismail, 2004; Song & Lee, 2002). Multimedia could be attractive learning-materials because of its character such as scene, movement, interaction, sound and color (Hsu, Wu & Hwang, 2008). Clements and Sarama (2002) reported that building blocks program could develop compositional imaginary in second-grade students, and it made learners form mental images by modifying their informal knowledge becoming more formal knowledge in mathematical thinking. Multimedia based on virtual reality was effective equipment for the instructional design that presented scenario connecting mathematics content to real-world situations (Hsu, Wu & Hwang, 2008). Additionally, the animation of macromedia flash created for supporting instruction was meaningful to

Copyright by Mahidol University

develop students' geometric perception (Rubio et al, 2007). Many scholars also asserted that multimedia significantly improved students' proficiency in geometric perceptions (Olkun, Altun, & Smith, 2005; Chang, Sung & Lin, 2006). Moreover, Nelson, Kay, Ulrich, and Marcelo (2006) concluded that learning activity could engage students to the real-world problems and student's interest was increasable in learning after using the multimedia as well.

1.3 Outline of the Research Study

According to cognitive theory, various learning focused on the mental process, knowledge structure, and active activities. This study searched for the evidence to support the idea that high-school students could learn best from the concrete to abstract. This was important for students to get their experiences via sensation from a real object (Braungart & Braungart, 2003). This study developed the instructional package called (GMO) based on the Cognitive Theory of Multimedia Learning (CTML) which was used to design multimedia for effective learning by Mayer (2001). The GMO focused on supporting students to build new knowledge in 2D-3D geometric pictures by themselves.

1.4 Aims of the Research Study

The aims of this study are to develop Geometry Multimedia Organization (GMO) - the instructional package represented the virtual reality of 2D-3D pictures in order to help students perceiving the material at the same view, to enhance student's imaginary or perception from 2D-3D pictures, and to motivate students' learning process. Besides, this study would investigate students' understanding, and the impact of GMO toward students' learning Geometry.

1.5 Research Questions

The following research questions guided this study:

3.1 Do experimental groups outperform the tests more than control groups?

3.2 Do female students outperform the tests more than male students?

3.3 Do male students outperform the tests more than female students?

Copyright by Mahidol University

1.6 Summary of the Chapter

Spatial sense was the important skill that can manipulate information in learning environments, solving science, and mathematics problems. This study focused on investigating students' performance in spatial skill. Most students had the misconception of imaging the shape of 3D-materials and they could not identify complex geometric images; therefore, multimedia was considered as a suitable media to support students' effective learning of two-dimensional and three-dimensional geometric pictures. From pilot study, the problem occurred with Thai students lacked the correct imagination of two – dimensional shapes of three – dimensional pictures in some views. Developing Geometry Multimedia Organization (GMO) in this study focused on supporting students to build new knowledge in 2D-3D geometric pictures by themselves. The GMO represented the virtual reality of 2D-3D pictures in order to help students imagine the pictures of models or objects and motivate students' learning process via GMO presentation. This study would investigate students' understanding, and the impact of GMO toward students' learning Geometry.

Copyright by Mahidol University

CHAPTER II
LITERATURE REVIEW

Introduction

This research study is guided by learning theory and instructional design for geometry instruction. In this chapter, the cognitive theory, technology enhanced learning, and literature reviews which are relative to this study will be shown into these topics as following:

2.1 Theory of Learning: Cognitive Theory

2.2 Technology enhanced learning for classroom

2.3 The Cognitive Theory of Multimedia Learning (CTML)

2.4 Learning and teaching geometry - spatial ability

2.5 Student's difficulty in learning geometry and teachers' difficulty in instructional managements.

2.6 Enhancing spatial ability via multimedia

2.7 Theoretical framework of this study

These are the major elements to conduct this study which pertains to the 2D-3D geometric pictures presented via multimedia representation and the investigation of students' performance in spatial skills on challenging tasks in the experimental design.

2.1 Theory of Learning: Cognitive Theory

2.1.1 Importance of Cognitive theory

The cognitive theory is focused on information process which is accessed in learner cognition. This theory mentioned that information starts getting in a limited capacity working memory via verbal/auditory receptors and the information must be extracted in working memory before become schemas which contain in an unlimited long-term memory. This is beneficial for students to use automatically their schemas to solve various problems occurred in daily life efficiently. Therefore, many

Copyright by Mahidol University

instructional designs are defined as the usefully assisted-transferring information from an instructor to learners which refers to the design of instructional equipment to enhance efficient learning in some fields of knowledge such as Science, and Mathematics based on cognitive theory.

2.1.2 Characteristic of Cognitive theory

The components of information accessing process can be explained as following (Sweller, Merrienboer, and Paas,1998):

1) Working memory: the capacity of working memory is able to maximize holding seven elements of data at one time. However, working memory is frequently used to compare, organize or contrast information, thus human can process several information concurrently rather than keep information purely. Thereby, the use of multiple processors may increase working memory capacity more than that of a single processor.

2) Long-term memory: consciousness and function can be filtered in long-term memory through working memory, and long-term memory capacity is developed more slowly than that of working memory. It may be the important component to differentiate levels of ability. In last decade, many studies reported that the predominant factor explaining the differentiation between novice and expert learners was the knowledge of colossal problematic states and associated data, but not the knowledge of complicated problems – solving strategies. Therefore, how to flow knowledge from the limited working memory to the unlimited long-term memory plays an important role to attain educational achievement. This is closely relative to human cognitive system. The function of working memory can not store complex reasoning processes but that of long term memory can do thus appropriately instructional design can facilitate learners to reach complex reasoning processes through human cognitive system.

3) Schemas: schemas are the form of knowledge stored in long-term memory. They can be powerful if learners practice their high level of skill and recognize manifold types of problematic patterns. Consequently, learners can accurately redo the patterns which they are familiar with the problems occurring repeatedly. On the other

Copyright by Mahidol University

hand, learners can act as novice if they are not familiar with the pattern of problems they found. There are two functions of schemas are to organize information in long-term memory and to reduce working memory load. There are three modes involving human learning system viz: sensory memory (pictorial and auditory receptors), working memory, and long-term memory. However, human can receive information in each channel at one time, but they can convert information into other channels. As mentioned so far, we can summarize the process of human cognitive learning that information is delivered through sensory memory and then it is extracted in the working memory before stored as the form of schemas in long term memory as illustrated figure 2.1 below:

Figure 2.1: Woolfolk s' human cognitive learning module

Working memory can be enhanced if information delivery is processed by using auditory and pictorial channel. As we mentioned so far, the cognitive theory significantly influences instructional designs. In cognitive views, it is believed that knowledge is an external source to learners, and learners act as information processors as follows. See figure 2.2.

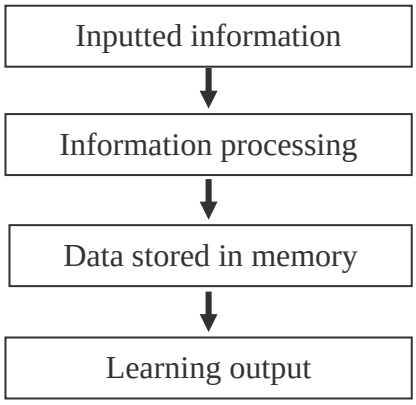


Figure 2.2: Human cognitive system

Copyright by Mahidol University

2.2 Technology enhanced learning for classroom

2.2.1 The attribute of technology enhanced learning

Technology enhanced learning is meaningful learning environment nowadays (Motschnig-Pitrik and Derntl, 2005; Clark, , Stegmann, Weinberger, Menekse, Erkens, 2007; Holzinger, 2008). It can support interactive learning environment for student to receive information, and it is believed that this external condition can effect learner' internal processes for efficient learning (Hannafin, & Land, 1997). This approach is accessible and transferable to manifold learning contexts. It can apply in many fields of studies such as engineering, science as well as mathematics and it is used to design the appropriate instructions to stimulate learners' curiosity and enthusiasm (Wang & Hannafin, 2005), and facilitate learners to achieve targets effectively. Designing instructional programs are mostly based on the constructivist learning model. Zhang (2002) suggested three directions of using instructional programs in Education:

1. The integration to establish instructional strategies, professional developments and productive learning outcomes.

2. The generalization of using computer program can be powerful in the school.

3. All students with individual differences in learning styles and aptitudes can access equally the knowledge which is presented.

Technology enhanced learning can provide students meta-knowledge which initiate solving existing problems and generating new problems by themselves (Hannafin, & Land, 1997). In the attributes of technology being used in the present, there are many forms of information presentation such as features, functions, and goals which will be narrated in the next section.

2.2.2 The multiple types of technology for classroom

Over last decade, there has been a trend of using Information and Communication Technology (ICT) in the educational curriculum (Zhang, 2002). Computers, a type of technology used in classrooms, are increasingly necessary nowadays because they can profitably support learning environment and connect learners to information sources efficiently (Goodyear, 2004); furthermore, they

Copyright by Mahidol University

influences students' learning, and students expect that they will get more accomplishment from them (Guha&Leonard, 2002).

Computer-based instructions are widely used to engage instructors and learners to the interaction of learning activity. Therefore, students are familiar with computers in the classroom. Tjeerd, Brummelhuis, & Pelgrum (1997) asserted that technology enhance learning environment has been widely applied in the education of secondary-school. Various instructional programs were designed to enhance student understanding in many different forms such as Computer Assisted Instruction (CAI), Computer-Aided Design (CAD), Computer Aided Manufacturing (CAM), Geometer's Sketch Pad (GSP); Besides, CD-ROM resources as multimedia made students find out the answers of targeted questions by using them and 3D-visualization learning aimed at supporting students' meta-cognition which refers to handle, monitor and integrate given tasks with their own learning (Korakakis, Pavlatou, Palyvos, Spyrellis, 2008).

These phenomena can confirm the significance of using computers in education nowadays. In case students should receive their knowledge into long-term memory, using computer as a medium to assist teaching evidently increases students' aptitude in learning process, and students can perceive constructive learning through efficiently interactive program. To develop computer based instructional program should be in line with learning process and connect to students' experiences.

2.3 The Cognitive Theory of Multimedia Learning (CTML)

Mayer (2001) developed The Cognitive Theory of Multimedia Learning from cognitive theory and technology application. The theory is aimed at the interaction between a learner and the knowledge presentation which is organized via multimedia in order to foster meaningful learning (Gemino, 2004). CTML is focused on computer-based instruction and the effective process to connect new knowledge and prior knowledge in the long-term memory (Pascal, 2006). In multimedia learning views (Mayer, 2001), there are three types of learning outcomes as follows:

1. No learning – a learner who is poor at knowledge retention and application.
2. Rote learning – a learner who is good at knowledge retention but poor at application.

Copyright by Mahidol University

3. Meaningful learning – a learner who is good at knowledge retention and application.

According to three learning outcomes, the meaningful learning is the required outcome which needs to be happened in students. Therefore, productively instructional design should be the external source integrating between knowledge organization and generalization of solutions for all students in the classroom to participate and find their answer of given activity (Tjeerd, Brummelhuis, & Pelgrum,1997; Guha&Leonard, 2002; Mor and Winters,2006; Sanchez and Rodicio, 2008).

There are three assumptions of a cognitive theory of multimedia learning (Mayer, 2001; Gemino, 2004; Kiili, 2006; Pascal, 2006; Gholson and Craig, 2006; Prangsma, Carla, Boxtel, Kanselaar, 2008; Zhang, Wang, Zhao, Li, Lou, 2008):

1. Dual channels: learners select relevant pictorial information into visual channel and relevant auditory information into verbal channel.
2. Limited capacity: learners can receive a limited quantity of information which is processed in each channel at one time.
3. Active processing: learners are engaged to organize selected information into mental structures, and then integrate it with prior knowledge and necessary information for solving some problems occurred in their daily life. This assumption initiate meaningful learning which can make a learner has better skill-performance on their problem-solving (Zhang Wang, Zhao, Li, Lou, 2008).

The framework of Mayer's cognitive theory of multimedia learning consisting of five processes that transfer information from multimedia presentation to learners can be illustrated in Figure 1. Firstly, learners select relevant words for processing in verbal working-memory. Secondly, learners select relevant images for processing in visual working-memory. Third, learners organize selected words into a verbally mental model. Fourth, learners organize selected images into a visually mental model. Finally, learners integrate verbal and visual representations as well as prior knowledge.

Copyright by Mahidol University

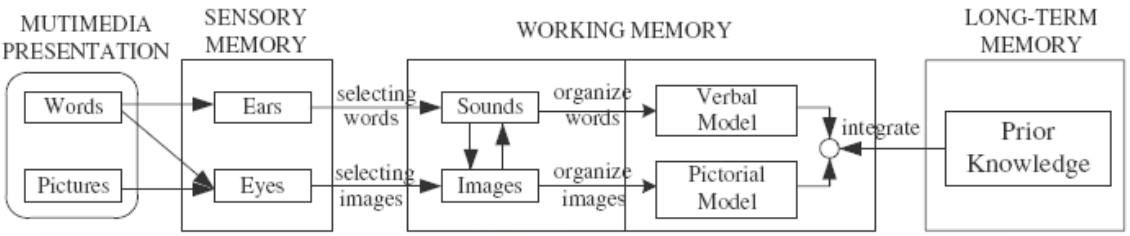


Figure 2.3: Mayer's cognitive theory of multimedia learning

Active learning is considered as the construction of mental model. It consists of three processes (Mayer, 2001):

1. Selection: learners select appropriate images and words from external resources into the working memory in cognitive system.

2. Organization: learners build selected words as internal connections in order to create a coherent verbal and pictorial model.

3. Integration: learners can connect between verbal and pictorial models and the relevant parts of prior knowledge.

An effective multimedia-based instruction should reduce the process of working memory, but increase learners' interest for in-depth learning (Zhang et al, 2008).

2.3.1 The CTML principles of instructional design

There are some principles of multimedia learning for the efficient instruction (Mayer, 2001). These are important for designers should take into account for designing their instructional software. The following principles are explained by Mayer and Moreno (1997).

- **Multimedia principle**: **"**It is better to present an explanation in words and pictures than solely in words". This principle facilitates learners to receive information through verbal and visual modes in order to construct two schemas of understanding rather than only one mode - words alone (Muthukumar, 2005).

- **Contiguity principle**: "When giving a multimedia explanation, present corresponding words and pictures contiguously rather than separately." This principle means that better learning happens if corresponding spoken words and pictures are presented concurrently (Zhang Wang, Zhao, Li, Lou, 2008).

Copyright by Mahidol University

- **Split-attention principle**: “When giving a multimedia explanation, present words as auditory narration rather than as visual on-screen text.” This principle is that words which are used to explain contents should be spoken more than being narrated texts on the screen (Mayer and Moreno, 1997).
- **Individual Differences Principle**: “The foregoing principles are more important for low-knowledge than high-knowledge learners, and for high-spatial rather than low-spatial learners.” This principle said that learners who have more prior knowledge can construct new mental schemas better than learners who have less prior knowledge do (Mayer and Moreno, 1997; Muthukumar, 2005; Zhang Wang, Zhao, Li, Lou, 2008).

2.3.2 CTML implication for instruction in the classroom

CTML is broadly used to be the fundamental of multimedia instructional design for supporting students’ learning process in primary, secondary-school as well as university levels (Gemino, 2004; Gholson and Craig, 2006; Kiili, 2006; Prangsma, Carla, Boxtel, Kanselaar, 2008). Instructional design based on CTML were implemented in the classroom, and showed the effective-learning outcomes in some studies. There are many aspects which scholars explored the effects of using multimedia based on CTML. As mentioned in the previous section, active learning is one of facet to be examined in the classroom. Kiili (2006) designed multimedia learning environment about human immune system in order to support students’ active learning. The result showed that treatment group outperformed the pre-test, post-test, and retention test than control group did. Finally, the researcher suggested that learners should be more participated in learning activity in order to engage them in certain situations. In another case, designing multimedia based on CTML for enhancing students’ mentally pictorial model about history subject (Prangsma, Carla, Boxtel, Kanselaar, 2008) showed the higher short-term results of experimental group. This multimedia presentation disentangled students’ difficulty in abstract verbal information of history lessons. However, there was no difference in retention test. This is an interesting issue to examine which attributes of multimedia presentation can conserve students’ long term learning outcomes.

Copyright by Mahidol University

Gholson and Craig (2006) promoted their constructive activities focusing on vicarious learning by using computer-instruction based on CTML. However, the results were emphasized vicarious-learning explanation, but their equipment was designed following CTML so as to support the instruction which meaningfully construct new knowledge. Besides, three variable of CTML application (recall, retention and transfer) were examined by Gemino (2004). This study aimed at comparing between the method using animation and narration and the method using static diagrams and text. The result showed significantly positive effect in animation and narration. The researcher concluded that CTML might be meaningful theoretical tool in developing multimedia-based instruction. In some cases, researchers investigated the effective characteristics of CTML. For instance, Mayer and Moreno (2002) asserted that multimedia learning environment can support student learning via dual modes of visual and verbal presentation greater than visual presentation without spoken words. In addition, Mayer (2001) and Dunsworth & Atkinson (2007) found that students learned better through computer-based multimedia when they study narrating pictures rather than on-screen texts because visualization and spoken words can foster students' positive attitude and effective learning; moreover they enhance students in deeper understanding. Finally, they concluded that an audio-visual presentation can enhance receiving information and providing effective computer-based multimedia should focus on the visual-aided presentations with representing exact gestures and clear explanations and interactions between instructor and students.

Learning via gesture and communication can lead students to accomplish the educational goal more efficiently than passive learning. Many research asserted that visual presentation of materials influence student learning (Bucciarelli, 2007). However, Mayer (2001) suggested that pictures on the screen might seem as seductive detail and not be as influential as the spoken words in learning process.

2.4 Learning and teaching geometry - spatial ability

2.4.1 The definition of spatial ability

Spatial thinking was considered as the significant factor to support science thought because it could be used to manipulate information in learning environments

Copyright by Mahidol University

and solving problems. There are numerous terms and meanings of spatial ability that researchers proposed; for instance:

Clements and Battista (1992) cited the importance of spatial thinking in geometry that “visualizations are used as a basis for assimilating abstract (geometric) knowledge and individual concepts” and “spatial visualization is comprehension and performance of imaged movements of objects in two- and three-dimensional space”.

In other views, Samsudin & Ismail defined that “Spatial reasoning as skills in representing, transforming, generating and recalling symbolic, nonlinguistic information”. In addition, Moran, Rubio, Gallego, Suarez, Martin (2008) cited that spatial perception comprises:

1. The recognition of 3D materials from different visions.
2. Imagining correctly the internal structure in given spatial configuration.
3. To determine the spatial relationship between environment and individually learning styles.

In summary, spatial ability refers to the ability of generating, sustaining and making use of mental images to apply, manipulate and solve the problems in daily life. It is one of the studies in Geometry.

2.4.2 Spatial instruction in the classroom

Arousing student curiosity in spatial ability is one of the goals in Geometry education, and this goal is still investigated nowadays. As developing meta-cognitive skills can be initially investigated in learners at the age of 11-12, this is of significance to take charge of students’ higher-order thinking behaviors in spatial ability (Korakakis, Pavlatou, Palyvos, Spyrellis, 2008). Two- and three-dimensional pictures are considered as an important part of geometry because they are fundamental concepts for other branches of studies such as Science and Technology. Moreover, scientific thinking also can be influenced by spatial ability as Einstein mentioned that his knowledge was not words, but clear imaginaries and signs were combined. Two- and three-dimensional perceptions relate to student daily life and the way to solve many science problems, so it is of significance to provide students the effectively practical tasks of learning activities in mental model, and providing students with

Copyright by Mahidol University

spatial thinking is significant for student's future science learning (Clements & Battista, 1992).

According to Principle and Standard for School Mathematics, (NCTM, 2000) grade 6-8 students should be able to analyze characteristics and properties of 2D-3D geometric shapes and develop mathematical arguments about geometric relationships-spatial ability. In the mathematics curriculum of Thailand, there are some objectives focused on describing and analyzing the 2D-3D geometric pictures: Students should be able to explain, draw and write the correct shape of the 2D-3D geometric pictures (IPST, 2001). Teaching and learning 2D-3D figures should continue investigating students' understanding in a 3D object represented on a 2D surface (Gorgorio, 1998).

2.5 Student's difficulty in learning geometry and teachers' difficulty in instructional managements.

There are some difficulties happening to students such as the 2D-3D pictures of visualization, imagination, geometric transformation as well as learning motivation (Gorgorio, 1998; Song & Lee, 2002, Kelly, Ewers & Proctor, 2002, Olkun, 2003). Some studies found that students' background experiences in interpreting pictures of 3D objects have been insufficient, and students' perception in the pictures of a block construction on 2D plane was often incorrect. Students can not imagine some 2D-plane views of 3D pictures (Kelly, Ewers & Proctor, 2002). Furthermore, there is a difficulty for teachers to provide their equipment in time due to time consuming and resources.

Although instructors could provide geometric materials for teaching 2D-3D pictures in front of the classroom, some students can not see the materials presented at the same view as other students do. Besides, geometric materials for all students are not sufficient, and it is hard to control students to rotate their own materials following teacher's instruction. After classes, teachers keep and maintain difficultly a lot of objects due to the limitation of place (Olkun, 2003). As has been discussed, implementing the geometric materials in the classroom is not easy as it should be, especially when the teacher have a lot of extra job to be done. However, seventh grade students can learn best from the concrete to abstract.

Copyright by Mahidol University

2.6 Gender Difference in Mathematics Learning

Gender difference was not widely investigated in the mathematics education (Lauzon, 2001). There were some inconsistent results in this issue. In comparing computer and concrete manipulative in learning 2D geometric pictures, primary-school boys gained scores higher than those of primary-school girls (Olkun, 2003). In university level, the results revealed that male students outperformed female students in mental rotation for accuracy and speed (Samsudin & Ismail, 2004). Whereas, some research asserted that there was no significant difference of spatial ability between male and female students in high-school level (Yun, Xi & Li, 2006). Besides, Spelke (2005) explained gender difference in intrinsic aptitude for Mathematics and Science based on individual experiences and times.

2.7 Enhancing spatial ability via multimedia

Multimedia enhanced spatial ability is developed in order to enhance student meta-cognitive ability and it is presumed to be a feasible approach of connecting students' internally mental models and 2D-3D visualization to monitor their active learning to function procedurally in external-modeling ability (Korakakis, Pavlatou, Palyvos, Spyrellis, 2008).

Mayer (2001) explained that there are two indications for multimedia design. First, the presentation should be coherent structure. Second, the message should initiate learner how to construct the knowledge architecture. There are manifold studies which are investigated multimedia development in spatial ability – based spatial concepts. Gorgorio (1998) explored students' performances in solving the problems of rotating-object images. The challenging tasks pertaining to 2D-3D figures would be set as the given situations. The researcher concluded that spatial ability plays an important role to solve rotating-object tasks, and using mental representation mode and individual's attention influence spatial ability significantly.

Besides, this study suggested that the geometric transformation of pictures should be studied continually in cognitive perspective. Saramas & Clement (2002) found that multimedia design in spatial ability motivated students' learning various shapes found in their daily life. It was significant to construct a powerful mediator to

Copyright by Mahidol University

geometry instruction. It was shown that geometry education and technology will be integrated meaningfully in the classroom. Learning two-dimensional geometric pictures via computer-based instruction, using wooden Tangrams - a concrete media appeared that both computer and concrete manipulates showed students' efficient learning rather than conventional manipulate. Thus, computer and concrete manipulates could not be differentiated in the term of efficiency (Olkun, 2003).

Besides, Samsudin & Ismail, (2004) reported that three-dimensional objects presented by using Virtual Reality Modeling Language (VRML) for geometry classes in secondary school showed that VRML-based instruction is very productive in the geometry classroom and visual encouragements in 3D pictures influenced drawing skills in geometry class. VRML-based geometry can provide virtual reality environment, and it yields effective outcomes for teaching and learning geometry (Song & Lee, 2002). This showed the same results as using Computer-Based Multimedia Tutor (CBMT) focused on the mental-rotation concept. Students who had high prior spatial experience had better performance than those who had less prior spatial experience. Using CBMT trained students' accurate performance on mental rotation test to explore the geometric concept of reflection and rotation.

The instruction should be refined strategies to enhance students' spatial perception (Samsudin & Ismail, 2004). Tangram puzzles was considered to represent two dimensional pictures and visual judgments show pleasant results on students' geometric performances (Olkun, Altun & Smith, 2005). Mental folding, unfolding, as well as rotation ability were investigated by Yun, Xi, & Li (2006). They created Virtual Geometry Learning System (VGLS) to teach those tasks. VGLS instruction can improve significantly students' spatial skill. As we mentioned above, Spatial skills were presented via multimedia yielded positive effect in learning environment and supports students' spatial thinking (Samsudin & Ismail, 2004; Olkun, Altun & Smith, 2005; Yun, Xi, & Li 2006) and multimedia learning environments can induce better learning efficiently through visual and verbal presentations in deep understandings. Besides, gestures seem to be a messenger which children show their knowledge, and improve learners' memory in the messages which were produced in the past. It was described that "working in groups is more effective than working individually in

Copyright by Mahidol University

producing real cognitive progressions." We try to search for strategies which can produce meta-cognitive ability (refers to ability which can organize our way to systematic procedure). Students' individual abilities are manifold levels of skills which correlate with IQ measures (Bucciarelli, 2007).

Considering geometry education in university, Garcia, Quiros, Santos, Gonzalez, Fernanz (2007) concerned that animated multimedia can accelerate 50 students in geometry-learning process. This tool was designed from Macromedia Flash to enhance students' spatial perception in "Descriptive Geometry Concept" the results were explained as the field of both advantages and disadvantages. Most students did not accept that this software can replace classes of theory and the notes they take in the theory class, but they accepted that they prefer this multimedia environment to the conventional instruction and this equipment can capture their attention more than theory. The researcher inferred the same conclusion as Olkun, Altun & Smith (2005).

Using a geometric multimedia program based on van Hiele's geometric thinking level theory in order to apply in geometry classroom in the fundamental concepts of 2D-geometric pictures, Chang, Sung, Lin (2007) showed four benefits from using this program: 1. it supported visual association ability in geometric shapes, 2. it enhanced interactive operation, 3. it induced inference and induction abilities in student thinking, 4. it showed efficient learning results. In addition, they asserted that most designed multimedia is based on specific field of study rather than on the theory of geometry, and they expected that this study may inspire future research pertaining to cognitive theory and educational technology. Flash applications in geometric images were used widely to increase students' spatial perception by doing exercises. Moran, Rubio, Gallego, Suarez, Martin (2008) asserted that multimedia can support spatial thinking as previous researches were conducted.

2.8 Theoretical framework of this study

My pilot study showed that most students needed a multimedia to support their learning in geometry chapter and they need a help for improving their understanding in visual and non- visual geometry related to symmetry, cross-section, unfolding and so on. In students' interview data, some students' comments such as "spatial ability is

Copyright by Mahidol University

difficult, complex, and boring.", "I can not be good in spatial ability" or "I do not like spatial ability" and so on. "Mathematics is difficult"- it is hard to understand because it consists of some abstract and complex contents, and student's prejudice toward mathematics. In correspondence with these problems, the pedagogical strategy should be improved and an appropriate instructional design should be done. These can be shown that how to improve students' learning environments in spatial ability should be aware so as to change some bias and motivate students' learning process to this ability.

Technology enhanced learning approach is considered as a means to support the learning process in geometry education. Students can learn spatial concepts via multimedia which is considered as a powerful technology to increase meaningful environment in the classroom, and scattered widely in educational society because pictures can superiorly represent some main ideas more than the explanation with numerous words, enable the retention of information that students do not encode in their working memory as well as bring about the effective learning in any fields of subject. Multimedia-aided instruction is an appropriate learning environment to engage students to the real world problem because the instruction with the manipulation of artificial equipments in the classroom is sometimes difficult for teachers to protect damaging valuable tools from students' usage and control timing for teaching some concepts while using these apparatus.

According to CTML, multimedia learning focused on the mentally cognitive process pertaining to the relationship between short-term and long-term memory, knowledge structure, and activities affecting to stimulus and response in human learning (Zhang, Wang, Zhao, Li, Lou, 2008). Internal structure affects learners to select stimuli from environment. The main stage pertains to the response and action (Braungart & Braungart, 2003), so learning is defined as internal events which derive from person's experience. In cognitive learning models, students use information-processing strategies to interpret and understand the knowledge they received (Billings, & Halstead, in press). Hence, it is very important for students to get their experiences via sensation. Then multimedia seems to be a powerful tool that teacher consider it as the assistance of the instruction in order to lead students to get accomplishment in learning spatial ability. Furthermore, multimedia used worldwide

Copyright by Mahidol University

is quite well source of motivation to aid teaching and learning (Gorgorio, 1998; Song & Lee, 2002, Kelly, Ewers & Proctor, 2002, Olkun, 2003).

Teachers are considered as prudently educational conductors who regulate instructional design to generate the good quality of information resources to provide students' learning process through using computer-based instruction, and they can utilize computer to facilitate their instructions by selecting the content which can be appropriately presented through computers in order to support students' learning skills (Zhang, 2002). Furthermore, Guha & Leonard (2002) asserted that teachers can provide the instructional multimedia of Mathematics to motivate students' interests in classroom, and increase students' positive attitude toward Mathematics with computer and spatial education and technology development will be integrated meaningfully in order to improve teaching and learning in the classroom (Saramas & Clements, 2002).

In summary, cognitive theory, technology enhanced learning, the Cognitive Theory of Multimedia Learning, and spatial education are integrated to developing the research instrument for the spatial instruction of secondary school. Our reviews can reflect the importance of spatial ability and technology based on CTML and instructional design. In the next chapter, we will explain the instructional software design based on CTML which is used to support the concept of 2D-3D geometric configuration.

Copyright by Mahidol University

CHAPTER III
MATERIALS AND METHODS

This chapter sets out the research methodology used to answer the research questions. The Quasi-experimental research design is described in terms of sampling and treatments. All research instruments used in this study are described in details of construction of Geometry Multimedia Organization (GMO), lesson plans, 2D-3D spatial skill-attitude test and observations. The trustworthiness of the research results is discussed in terms of the validity and reliability of the research instruments. Processes of data collection and data analysis of this research are described as quantitative and qualitative parts. The end of the chapter follows the summary of the chapter. These are amplified as following.

3.1 Quasi-experimental design

In general, an experimental design can be formed by using randomly assigning classrooms to treatments. Educational researches are sometimes inconvenience to get random assignment of subjects. Thus a case might be selected from setting classrooms (intact groups) can be a random basis. This is called a quasi-experimental research. In brief, a quasi-experimental research is conducted by using the intact groups of subjects in the experiment (Wiersma and Jurs, 2005).

- Pretest-posttest, nonequivalent control group

Pretest-posttest, nonequivalent control group which is one type of quasi-experimental design involves the use of pretest-posttest in the experiment. It is widely used in the experimental design. Only two groups (a control group and a treatment group which are not randomly selected) are provided in the different contexts so that the researcher compares them in order to investigate some variables affecting both groups. The general form can be shown in figure 3.1 as follows:

Copyright by Mahidol University

O_1	X	O_2	experimental group
O_3	(X)	O_4	control group

Given, X_n = the experiment n, for instance, X_1 means the experiment 1, X_2 means the experiment 2, and so on.

(X) = not authentic experiment, but it seems to be experimental.

O_n = observation or measurement.

O_{odd} = pre-test measurement

O_{even} = post-test measurement

Figure 3.1: Diagram of pretest-posttest, nonequivalent control group (Boontum, 2008)

The advantages of Pretest-posttest, nonequivalent control group design are checking the similarity of both groups and pretest scores are used to generate gain scores after the experiment (Wiersma and G. Jurs, 2005). The pretest is provided for both groups since it influences the dependent variable. Pretest scores is considered as statistical control, and gain scores will be generated afterward. The advantage of pretest scores is investigating the similarity of the groups. In short, pretest-posttest, nonequivalent control group support investigating some similar groups by using pretest-posttest scores in order to compare the results after completing experiment.

This study is a quasi-experimental research, and subjects are designed as pretest-posttest, nonequivalent control group. The purposes of the study are the effectiveness of GMO in enhancing student learning 2D - 3D conversion of geometric pictures and the comparison between female abilities and male abilities in the 2D-3D geometric pictures and attitude in learning geometry. There are five steps in pretest-posttest, nonequivalent control group as follows:

1. Subjects: All selected groups are the same characters for this investigation, and considered as similarity.

2. Pretest measurement: before we begin the experiment, pretests is administered in both control classrooms and experimental classrooms (O_1 and O_3)

Copyright by Mahidol University

3. Experiment: the experimental classrooms are taught via Geometry Multimedia Organization (GMO) instruction and block creativity, but the control classrooms are taught via traditional instructions and block creativity. This experiment is implemented for a four-week period.

4. Posttest measurement: posttests are administered in both control classrooms and experimental classrooms (O_2 and O_4) after four weeks. Besides, geometric attitude tests are given to investigate students' comment in their aptitude of geometric 2D-3D pictures.

5. Discussion: the gain results are analyzed by using statistical formulas and SPSS for windows version 12.

3.2 Subjects

There are 190 seventh-grade students from a secondary school in Nonthaburi province participating in this study. They are average abilities in mathematics, and have studied the basis of geometric knowledge in primary school. McMillan & Schumacher (2001, p. 336) suggested that the appropriate size of a sample should be 20-30 persons for further reliability. There are four classrooms selected in this study: 2 control classes (class A consists of 29 boys and 16 girls, class B consists of 26 boys and 27 girls), and 2 treatment classes (class C consists of 24 boys and 29 girls, class D consists of 17 boys and 22 girls). These can be shown as a figure 4 below:

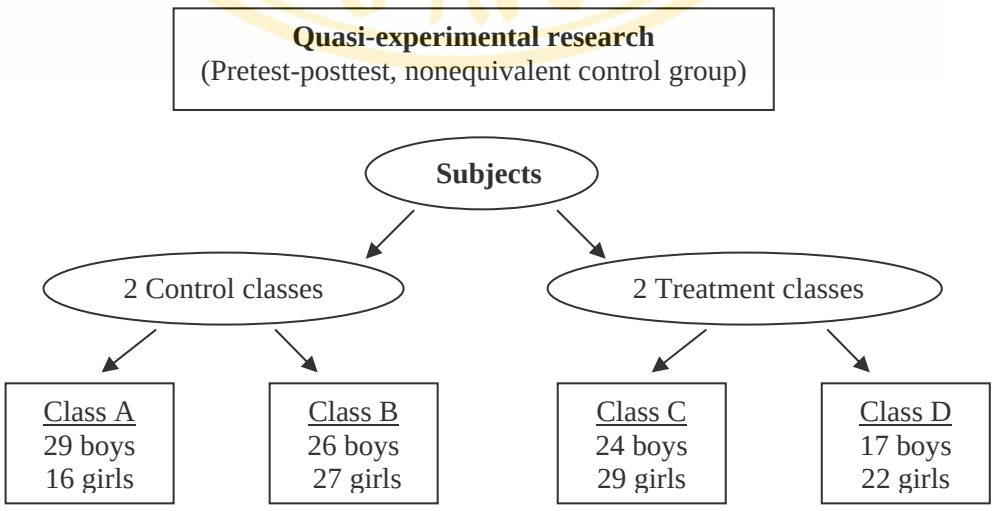


Figure 3.2: Diagram of subjects

Copyright by Mahidol University

3.3 Research instruments

There are five types of research instruments in this study as follows:

3.3.1) **Geometric test (Geo-test)**: pretest and posttest are designed to investigate students' ability in 2D-3D geometric pictures before and after experiment.

3.3.2) **Geo-worksheet**: the exercise of each lesson plan is given to students after teacher complete instruction in each period (50 minutes a period).

3.3.3) **Geometry Multimedia Organization package (GMO package)**: the multimedia presentations which comprise of four sections for teaching 2D-3D geometric pictures. They are provided for seven lesson plans.

3.3.4) **GMO lesson plan**: there are seven lesson plans are designed following the contents of GMO, and each lesson plan is set for 50 minutes per a period.

3.3.5) **The questionnaire for geometric attitude test**: the questionnaire used for investigating students' attitude toward Geometry.

3.3.1) Geometric test (Geo-test)

Geo-tests are drawing and written tests. There are five sections in the geo-test: 1) the pictures of geometrical basis, 2) the 3D pictures in daily life, 3) the cross-section of materials, 4) the front-view, side-view, and top-view of 3D pictures, and 5) counting the number of block in block-constructed pictures following each given direction. The pictures of geometrical basis and the 3D pictures in daily life consist of four different challenging items. The cross-section of materials consists of two challenging items, and the front-view, side-view, and top-view of 3D pictures consist of six challenging tasks, and counting the number of block in block-constructed pictures following each given direction consist of four challenging tasks. The total items of the geo-test are 20 items. Geo-test is examined by two experts in education and two mathematics teachers. Pre-test (Appendix A) and post-test (Appendix B) were designed as a parallel test. The geometric tests were trialed with 100 students who had learned geometric in the current taught.

The criterion of Geo-test evaluation is based on rubrics. It consisting of 5 parts as follows:

Part 1: Simple geometric pictures

Part 2: Three-dimensional pictures

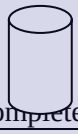
Copyright by Mahidol University

Part 3: Cross-sections of materials

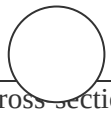
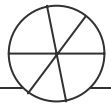
Part 4: Three-dimensional pictures of building-blocks

Part 5: Counting the number of building-blocks

The criterion of part 1 and part 2:

score level	The required performance	Example
0	Students do not draw any pictures or draw wrong pictures.	Draw a rectangle
1	Students draw the correct picture which is not complete in 3D shape.	Draw a cylinder  not complete
2	Students draw the correct and complete picture in 3D shape.	Draw a cylinder complete

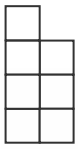
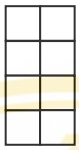
The criterion of part 3:

score level	The required performance	Example
0	Students do not draw any pictures or draw wrong pictures.	Draw the cross-section of orange
1	Students draw the correct cross-section shape of an object but do not draw completed details within the shape.	Draw the cross-section of orange 
2	Students draw the correct cross-section shape of an object and draw completed details within the shape.	Draw the cross-section of orange 

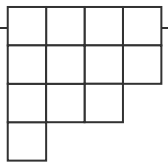
Copyright by Mahidol University

The criterion of part 4:
For example, the correct 2D figures of the 3D block-building are shown below:

Front view Side view Top view

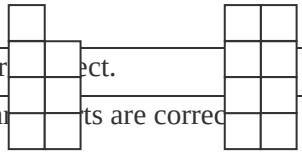



Direction: there are three parts of the question (front view, side view, and top view). There are three levels of the scores (0, 1, 2) for each part as following:

score level	The required performance	Example
0	Students do not draw any pictures of three parts or each picture is wrong.	
1	Two cases: 1.there are two third of correct pictures drawn	The example above
	2. at least two correct pictures are drawn in the right parts	side view front view
2	All pictures of three parts are correct.	The example above 

The criterion of part 5:

score level	The required performance
0	-nothing is filled in the table. -there are some correct numbers in the table of three parts.
1	-at least two third of the table ar ect.
2	-the numbers in each table of thr ts are correc



Copyright by Mahidol University

The data from this test was used to develop the quality of Geo-test in term of its reliability. The result is reported below:

- Geo pre-test: According to the pretest from 100 students, Geo-pretest developed for four sections consists of 20 items. The Cronbach's alpha reliability of Geo-pretest is 0.75, for 88 students.

- Geo post-test: According to the posttest from 100 students, Geo-posttest developed for four sections consists of 20 items. The Cronbach's alpha reliability of Geo post-test is 0.79, for 86 students.

3.3.2) Geo-worksheets

Geo-worksheets in each lesson plan are provided for students so as to support their skills in spatial thinking of geometric pictures after class. They were given to students when the teacher finishes the instruction in each period. There are six geo-worksheets as follows.

Exercise 1: it relates to the recognition of the 2D-3D superficial pictures of geometry such as polygon, rhombus, trapezoid, and so forth. This worksheet is purposed on the review of basic knowledge in geometric pictures.

Exercise 2: it relates to the drawing skills in the complex geometric constructions such as the construction of box and pyramid. This worksheet is focused on how to draw the structure of three-dimensional pictures.

Exercise 3: it relates to the drawing skills in the cross-section of materials in everyday life such as the cross-section of fruits. This worksheet is aimed at how to imagine the possible cross-section of fruits.

Exercise 4: it relates to the drawing the two-dimensional pictures from the three-dimensional pictures in the designate direction. This worksheet is purposed on the relationship between 2D-3D geometric configurations.

Exercise 5: it relates to the drawing two-dimensional pictures and counting the number of blocks in the given directed surface of the three-dimensional pictures of block-constructions. This worksheet is centered on the spatial perception in 2D-3D conversion of geometric pictures.

Exercise 6: it relates to the drawing skills in three-dimensional block building from the given 3 two-dimensional block pictures (the front view of block building, the

Copyright by Mahidol University

side view of block building, and the top view of block building). This worksheet is focused on applying the generalization of spatial skills to draw the correct three-dimensional pictures.

3.3.3) Geometry Multimedia Organization package (GMO)

Multimedia design is focused on supporting students to build new knowledge by themselves. GMO package based on CTML takes six months to create contents and exercises about the visualization in two-dimensional and three-dimensional pictures based on Thai mathematics curriculum of the Institute for the Promotion of Teaching Science and Technology (IPST, 2001) in order to enhance students' ability in the 2D - 3D conversion of geometric pictures. Macromedia Flash 8 and Maple 11 will be used to construct GMO package. See the main page of GMO in figure 3.3 and the main menu of GMO in figure 3.4:

Figure 3.3: the main page of GMO

Copyright by Mahidol University

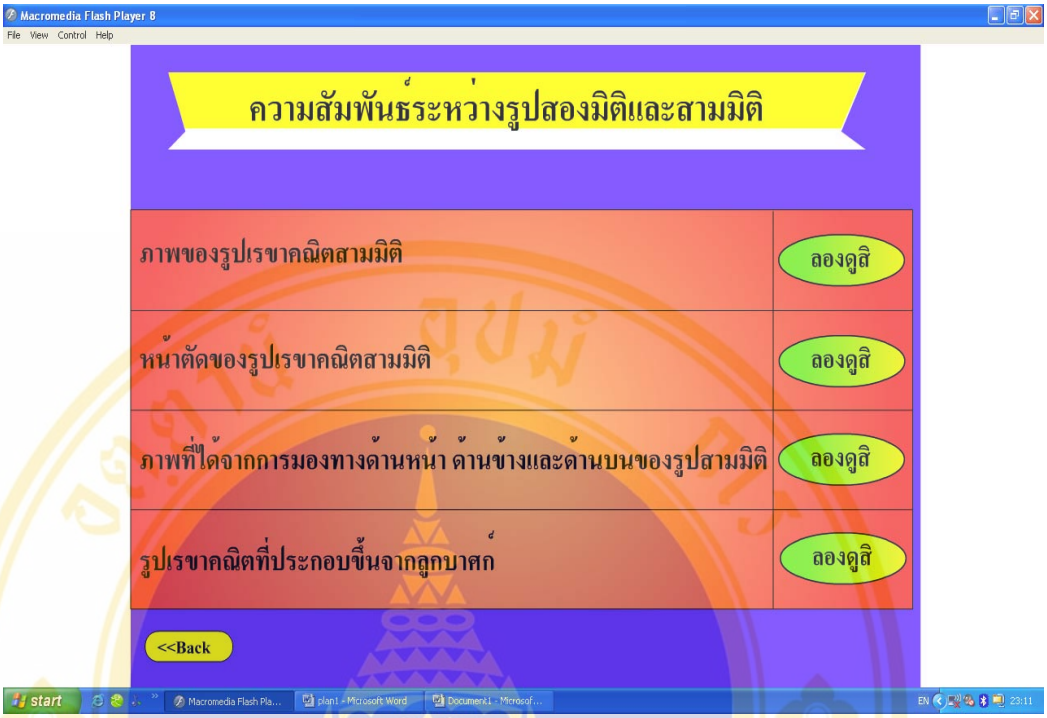


Figure 3.4: The main menu of GMO

GMO represented the virtual reality of 2D-3D pictures in order to help students perceiving the material at the same view, to enhance student's imaginary or perception from 2D-3D picture, to motivate students' learning process. The skill-training exercises are contained in each part. The contents in GMO package were examined by the experts in technological education and mathematics teachers. There were four units and each unit includes the narrations and sounds based on Multimedia principle, Contiguity principle, Split-attention principle and Individual Differences Principle as following:

Part 1: the simple geometric pictures

There were various examples of geometric figures in order to review students' prior knowledge in geometry concepts such as simple two-three dimensional pictures, cylinder, pyramid, trapezoid, and so forth. The simulated drawing of geometric configurations provided for students are purposed on improving students' drawing skills in geometric pictures because this could influence students' spatial thinking via their gestures (Bucciarelli, 2007). There were various challenging tasks with the simple to complex levels sequentially. Furthermore, the researcher added supplementary knowledge so that this could stimulate students to learn more types of

Copyright by Mahidol University

geometric concepts (Rubio et al., 2007). See simple geometric pictures in figure 3.5 and drawing 3D geometric pictures in figure 3.6:

Figure 3.5: Simple geometric pictures

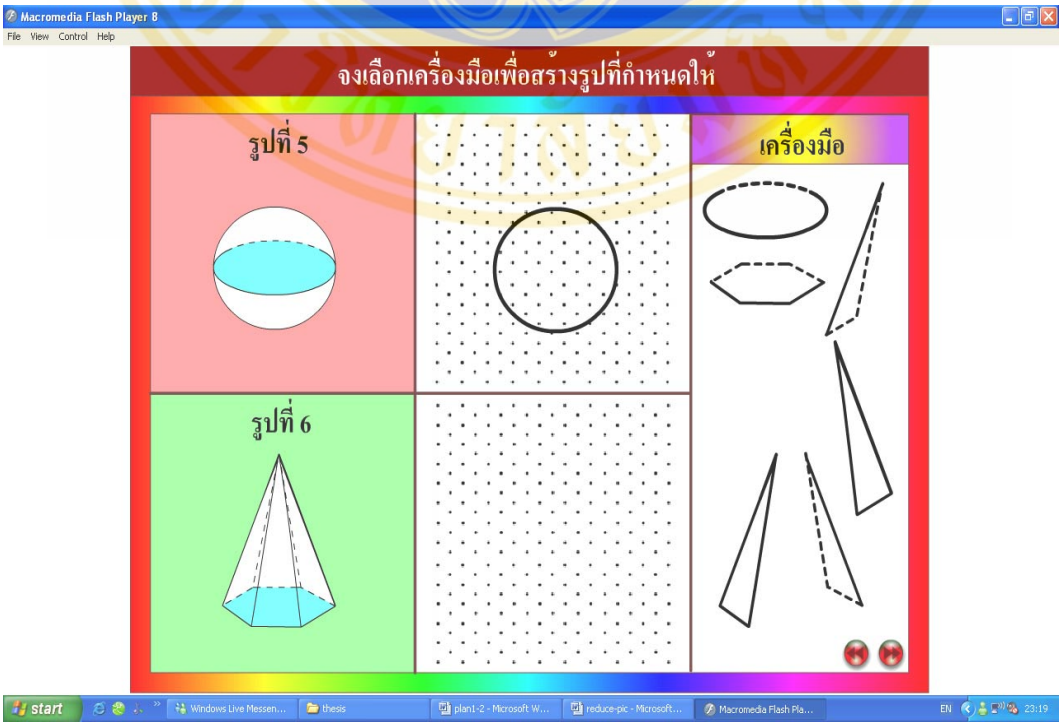


Figure 3.6: Drawing 3D geometric pictures

Copyright by Mahidol University

Part 2: the cross-section of materials

This part was concerned about students' imaginary which could support spatial skills. Sometimes, imaginary was important for human to learn the body structure of organism or the new knowledge which they found ,and they needed the prediction of molecule structure, so this issue was raised in this part. There were eight challenging tasks for students to analyze and form the cross-section model in their minds when they saw the materials in daily life. The materials were presented in this unit, for instance, vegetable, fruits such as coffee, tree, tomato, etc. See the cross-section of coffee in the figure 3.7 and the cross-section of the world in the figure 3.8:

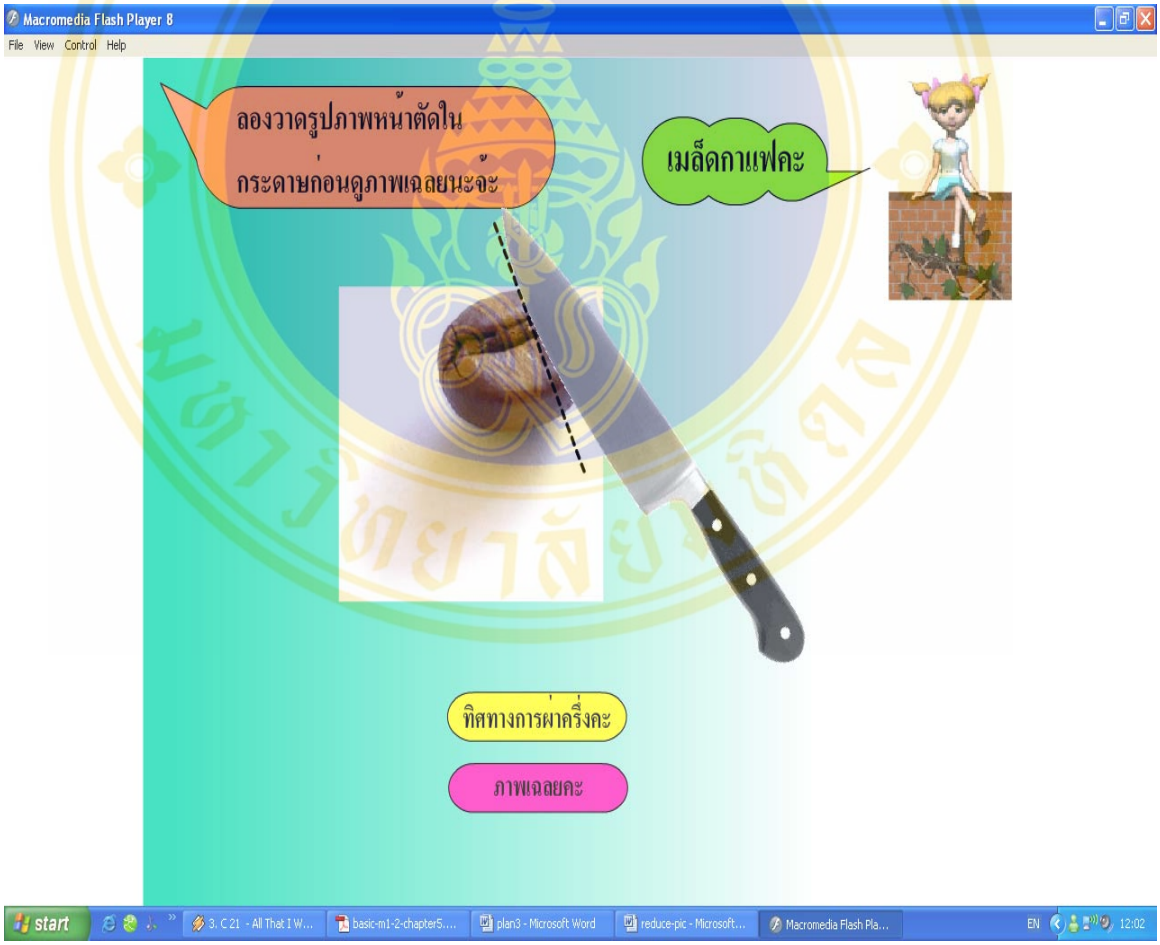


Figure 3.7: The cross-section of coffee

Copyright by Mahidol University

Figure 3.8: The cross-section of the world

Part 3: the three-dimensional pictures in daily life

This part was provided the challenging three-dimensional pictures of material which were found in daily life for students to examine and draw the two-dimensional pictures of those materials following the given direction (front view, side view, and top view). This point might initiate students' observation in the connection between two-dimensional and three-dimensional pictures. There were eight challenging tasks in the objects from daily life such as a bottle, a vase, a box, and so on. See the three-dimensional pictures of milk box in the figure 3.9 and the three-dimensional pictures of fancy box in the figure 3.10:

Copyright by Mahidol University

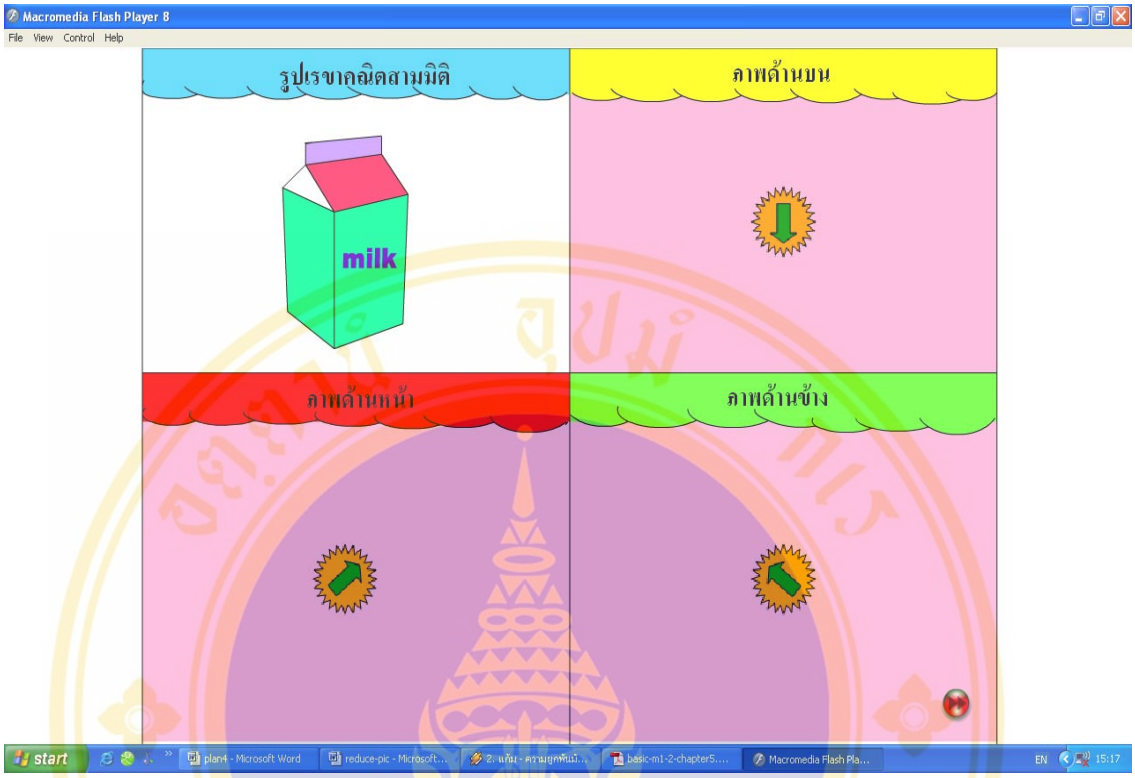


Figure 3.9: The three-dimensional pictures of milk box

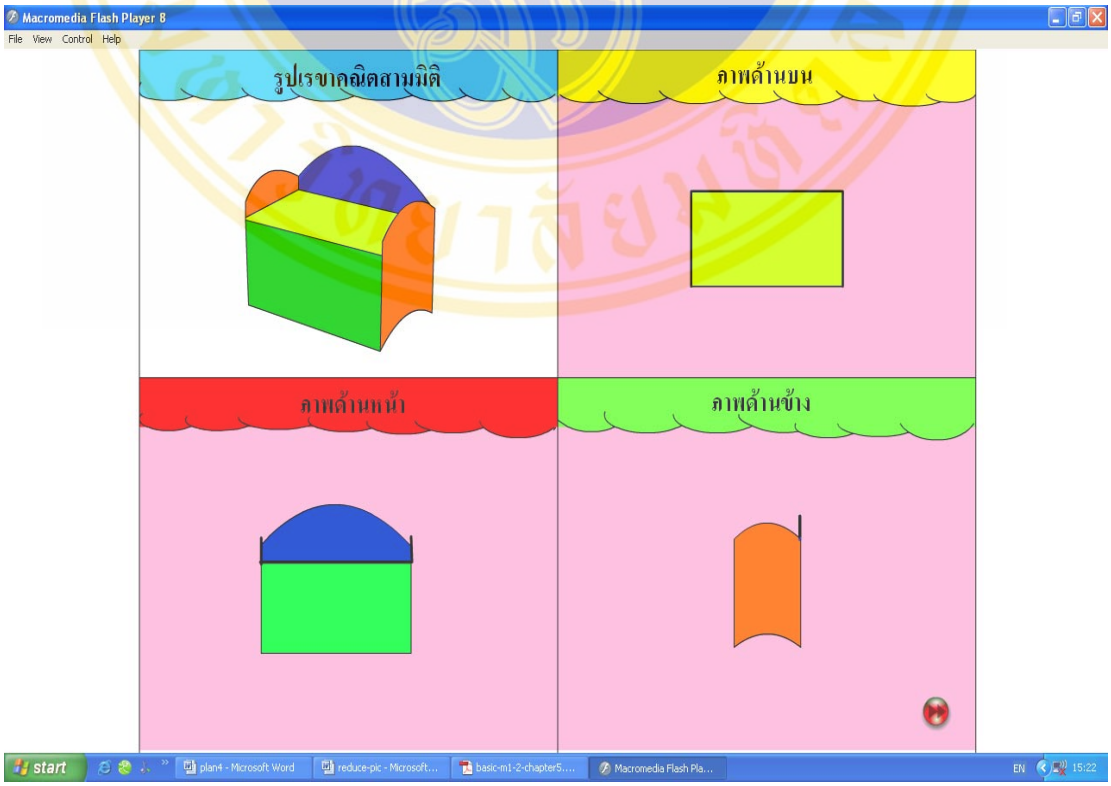


Figure 3.10: The three-dimensional pictures of fancy box

Copyright by Mahidol University

Part 4: The front-view, side-view, and top-view of three-dimensional pictures of building-blocks pictures

They seemed to be the challenging games. There were three sub-tasks: front-view case, side-view case, and top-view case in the task. In all tasks, learners performed each case sequentially by selecting the correct choice from four multiple choices, then clicked “next” button to go forward to other cases until completing whole task. After that, learners clicked other tasks which they wanted to learn more. This part contained eight challenging tasks. The package of contents and skill-training exercises were contained in each part. This multimedia was designed to assist instructors in teaching geometrically two-dimensional and three-dimensional pictures. See the front-view of building-block task in the figure 3.11, the side-view of building-block task in the figure 3.12, and the top-view of building-block task in the figure 3.13:

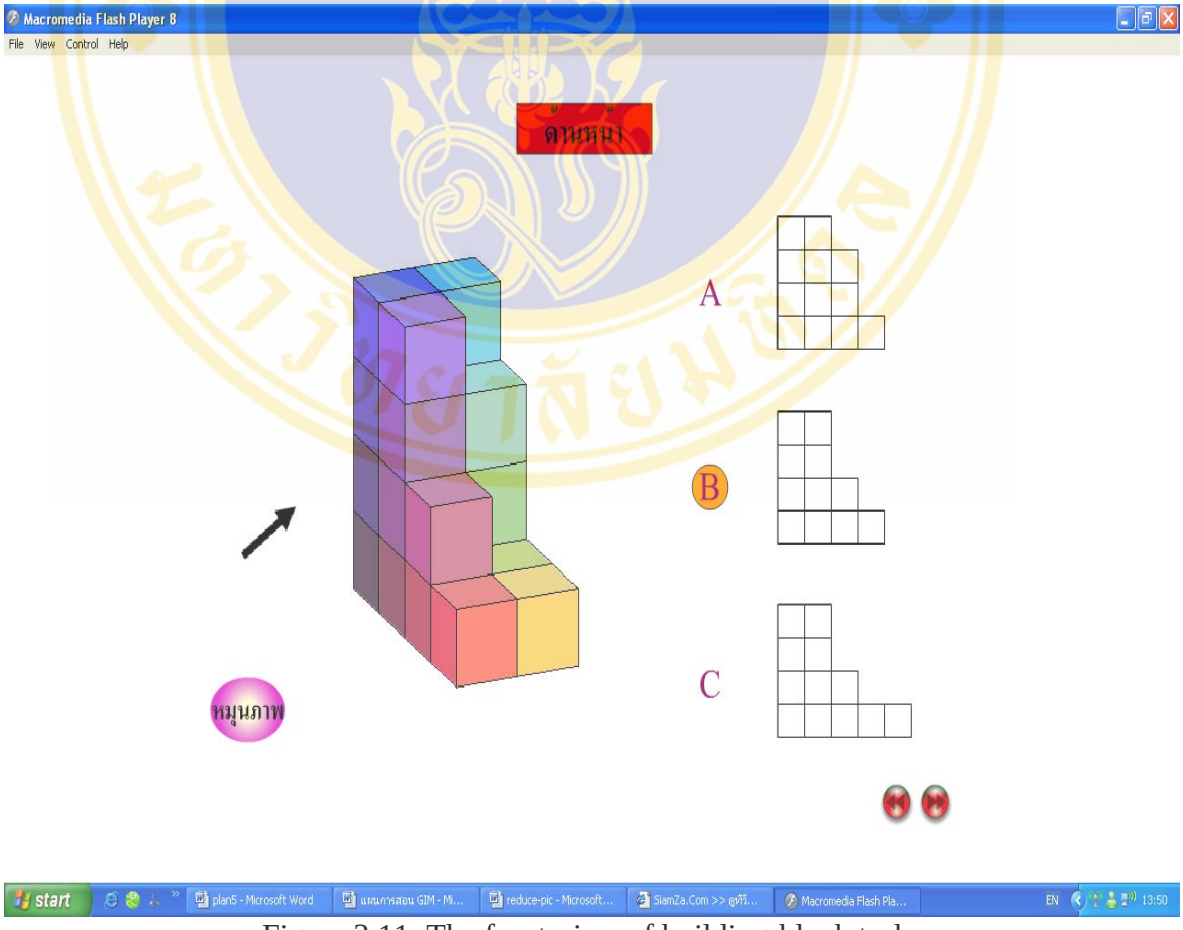


Figure 3.11: The front-view of building-block task

Copyright by Mahidol University

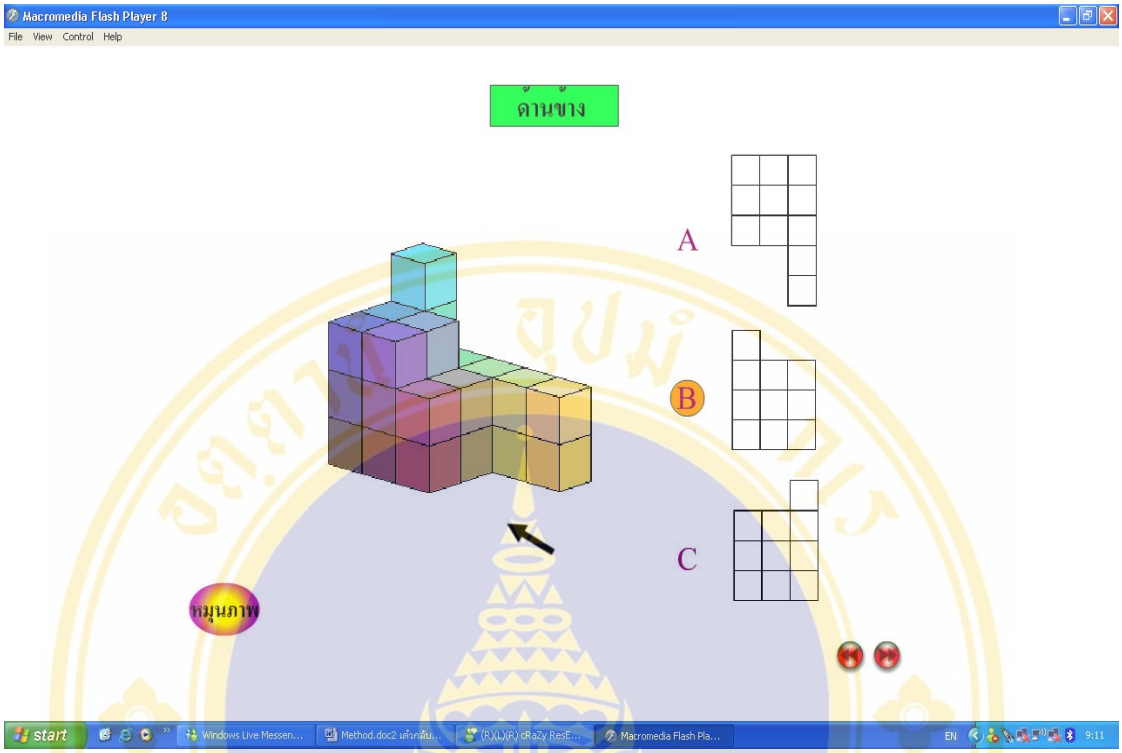


Figure 3.12: The side-view of building-block task

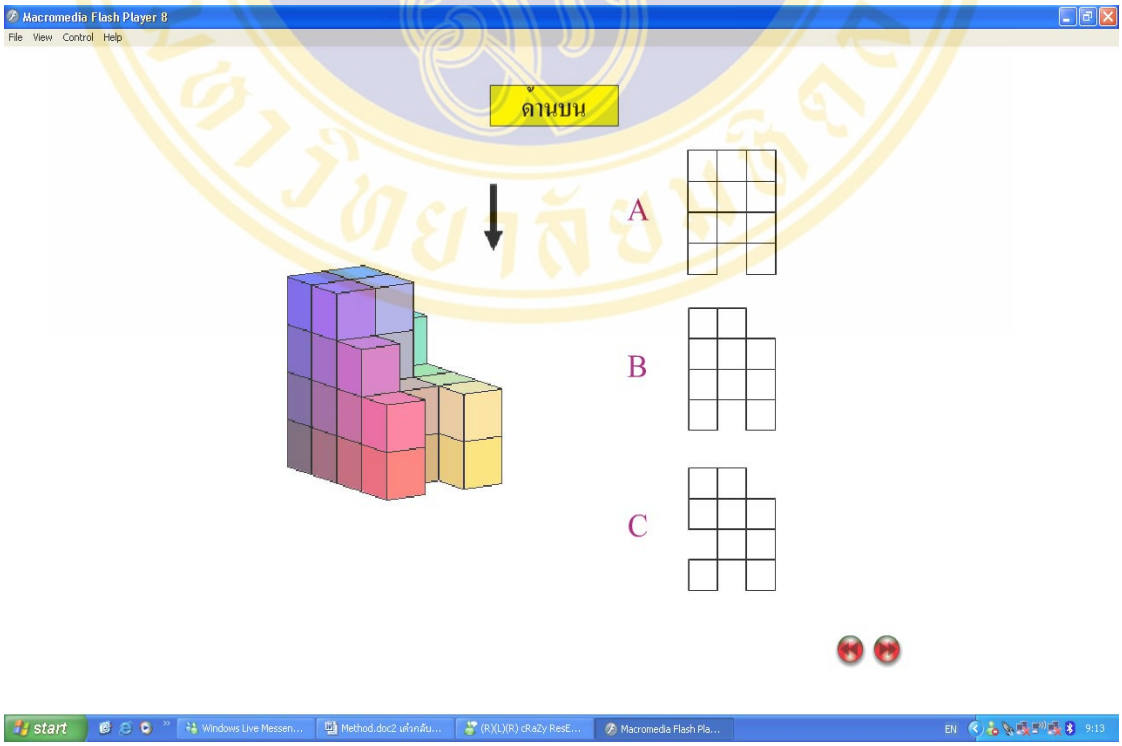


Figure 3.13: The top-view of building-block task

Copyright by Mahidol University

3.3.4) GMO lesson plans

According to traditionally lesson plans for control groups based on Thai mathematics curriculum, we did not describe their details. However, each lesson-plan in both traditional instruction and experimental instruction was focused on the same purposes and contents, but they were presented in different teaching-strategy. There were seven lesson plans of GMO designed in this study. Their contents were based on mathematics book of Thai educational curriculum, and each lesson plan took 50 minutes a period as following:

a) Lesson plan 1: this lesson plan was designed to aid teaching the pictures of simply geometrical pictures such as simply two-three dimensional pictures (cylinder, pyramid, trapezoid, and so forth), and supplementary knowledge. In the purposes of this section in the mathematics curriculum (IPST, 2001), it was determined that "students could explain the characters and components of the given three-dimensional geometric pictures." In this regard, this activity focused on this aim. After completing the instruction, the teacher assigned the exercises 1 to students as their homework.

b) Lesson plan 2: this lesson plan was designed to aid geometric-drawing instruction by using the simulated drawing of geometric configurations to present how to draw the symmetrical picture of material. In the purposes of this section in the mathematics curriculum (IPST, 2001), it was determined that "students could draw the character and component of the given three-dimensional geometric pictures". In this regard, the teacher gave students isometric papers before beginning instruction. After that, students learned the symmetry of three-dimensional material pictures through self-drawing that material in step-by-step following teacher instruction. Every case was sequentially completed. Finally, the teacher assigned the exercises 2 to students as their homework.

c) Lesson plan 3: this lesson plan wass designed to support students' imaginary and possibility in the cross-section shape of material. There were eight challenging situations provided in this section. In the purposes of this section in the mathematics curriculum (IPST, 2001), it was determined that "students could explain the cross-section of material configuration." In this regard, this part was provided the challenging situations which was found in students' daily life and set the direction of cross-section, and let students predict what cross-section shape should be in the given

Copyright by Mahidol University

pictures of material then, students drew the cross-section of their imaginary on the specific worksheets provided for this part. Finally, students could see the correct answer after they finished drawing in each case. After completing the instruction, the teacher assigned the exercises 3 to students as their homework.

d) Lesson plan 4: this lesson plan was designed to enhance students' spatial perception in the relationship between two-dimensional and three-dimensional pictures. In the purposes of this section in the mathematics curriculum (IPST, 2001), it was determined that "students could draw two-dimensional pictures derived from looking the three-dimensional pictures following the given directions." In this regard, the section presented the learning environment pertaining to daily objects which could see everywhere. There were eight challenging tasks in this part. The teacher gave students to lesson 4-worksheet in the classroom, and motivated students to figure in the situation which has three views (front view, side view, and top view). After that, students had to draw the two-dimensional picture of the object in each view. Then, the teacher showed the correct answer after students finished drawing.

f) Lesson plan 5: this lesson focused on the two-dimensional pictures drawing in the given directed surface of the three-dimensional pictures of block-constructions. This section was aimed at the spatial perception in 2D-3D conversion of geometric pictures. There were eight challenging tasks in this part. The teacher provided students to analyze the cube-construction and used the collaborative learning which all students joined this activity and they were allowed to show their opinions in the present task. After receiving the students' conclusion of the given task, the teacher showed the correct answer. This activity might motivate students' curiosity in learning Geometry. After completing the instruction, the teacher assigned the exercises 4 to students as their homework.

g) Lesson plan 6: this lesson plan was emphasized on counting the number of blocks in the given directed surface of the three-dimensional pictures of block-constructions. This lesson plan continued investigating the spatial perception of 2D-3D conversion of geometric pictures. The teacher let students count the number of blocks in the given cube-construction, and allowed all students to participate in oral-answering to the given tasks. There were eight challenging tasks for students. After

Copyright by Mahidol University

completing the instruction, the teacher assigned the exercises 5 to students as their homework.

h) Lesson plan 7: this lesson plan was purposed on hands-on activity about the two-dimensional and three-dimensional pictures. The teacher provided the set of wooden cubes which consisted of 27 blocks in this activity to student groups (3-4 students per a group).There were eleven different types of challenging tasks, each group got the unique task. The students had to find the correctly absolute cube-construction derived from the front-view, side-view, and top-view of the given task. Then, the teacher checked up students' absolute cube-construction in each group, observed, and recorded students' behavior when they answered teacher how to get their results in the score-checking paper. After completing the activity, the teacher assigned the exercises 6 to students as their homework. See Figure 3.14:

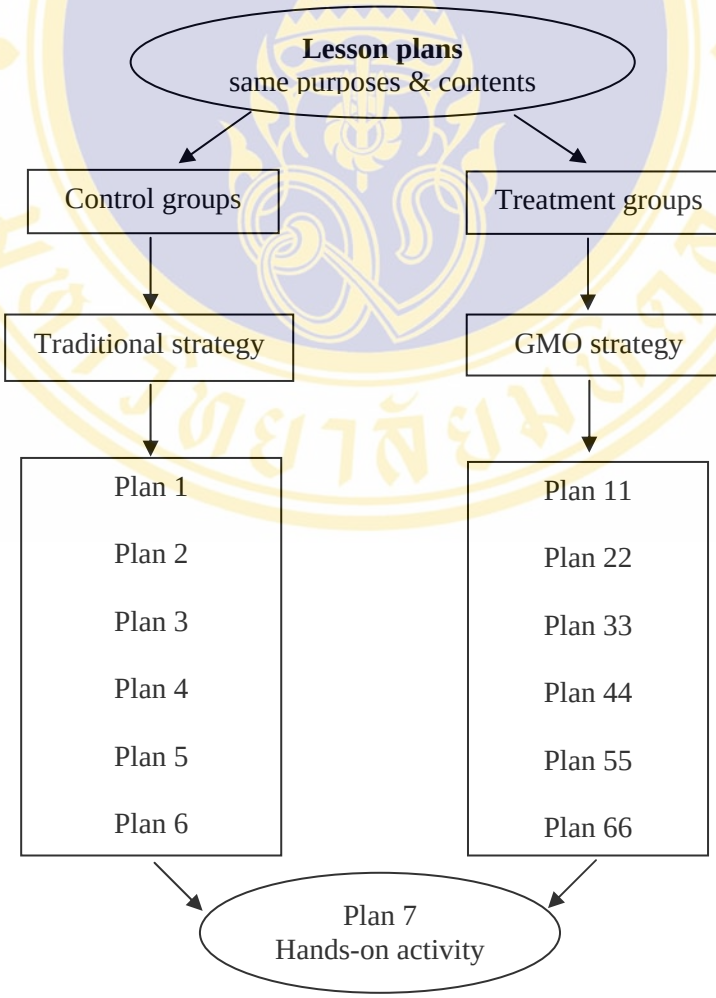


Figure 3.14: The diagram of lesson-plan in both control groups and treatment groups

Copyright by Mahidol University

3.3.5) The questionnaire for geometric attitude test

From previous research, geometry attitude scales were developed by Juliana Utley (2007). It consisted of 32 statements that focused on 1) usefulness of Geometry 2) confidence in learning Geometry 3) enjoyment of Geometry. Another survey constructed by Lee A. Schmidt (2004), called the "Write To Learn Attitude Survey (WTLAS)" composed of 21 statements that focused on 1) apprehensions about writing abilities and 2) perceived benefits of writing to learning activities. In this study, to find out students response to GMO, the questionnaire for evaluating the learning behavior in geometry was developed by modifying from both research focusing on students' attitude toward learning Geometry and drawing 2D-3D pictures. The questionnaire related to students' thought, emotion, and capacity toward Geometry. It consisted of 15 items, nine positive statements which were item 2, 3, 6, 7, 8, 9, 12, 13, 14 and six negative statements which were item 1, 4, 5, 10, 11, and 15. This questionnaire (Appendix C) based on using 5-point Likert scales as follows:

5 refers to strongly agree
4 refers to agree
3 refers to undecided
2 refers to disagree
1 refers to strongly disagree

The criterions as mentioned above were used in positive statements, but negative statements were considered by using the criterions as follows

1 refers to strongly agree
2 refers to agree
3 refers to undecided
4 refers to disagree
5 refers to strongly disagree

3.4 Data collection

Data collections were conducted by the researcher and two research assistants (the teachers in the school). This study was divided in two procedures: 4.1) Preparations for Implementation of GMO, 4.2) implementation and collecting data. These could be described as following:

Copyright by Mahidol University

3.4.1) Preparations for Implementation of GMO

1) Making a pilot study to survey what difficulty student face when they learn the 2D-3D pictures in Geometry.

2) Designing the appropriate multimedia which was based on Thai mathematics curriculum to support teaching the 2D-3D pictures in Geometry, then investigating the quality of multimedia by triangulation, technology professional officers and mathematics teachers.

3) Selecting a secondary school, and send the requirement of the permission to conduct the research for education.

4) Meeting mathematics teachers (two persons) who were responsible for the sample clusters in order to prepare the instructional design in this topic and collaborate with the teachers for the period of time in this study.

5) To explain the detail of this experiment and discuss the conclusion of preparation.

3.4.2) Procedure and collecting data

Data collection was executed in the second semester of academic year 2008 (December), and the period of this experiment was three weeks.

a) The implementation of the study: the seven lesson-plans of GMO were provided for three weeks. Each lesson-plan took 50 minutes and was taught in sequence as mentioned in GMO lesson plans. There were skill-training exercises in each lesson-plan. The instructor used GMO to support teaching 2D-3D Geometric pictures via computer screen on the major board in front of the classroom. Besides, the seventh lesson-plan provided the hands-on activity to support students' spatial skills in 2D-3D conversion of geometric pictures.

b) Geo-test: students performed pre-test before the experiment began. Next, we implemented GMO instruction for five weeks. After that, students performed post-test. Both pretest and posttest took 50 minutes for students to complete the test.

c) The questionnaire for geometric attitude test: After the implementation of GMO, the questionnaire for geometric attitude test was administered to all students. They could take 15 minutes to complete the questionnaire.

d) Observation: Classroom observations aimed at studying how the students learn, classroom learning environment and classroom interaction, students-teacher and

Copyright by Mahidol University

student-student interactions, and to study the strength and weakness points of using GMO in classroom. The classroom was observed every period for 5 weeks.

3.5 Data analysis

The data of this study are analyzed by using SPSS program. The determination of data analysis is shown as following:

1. The means ($\bar{x}$) and standard deviation (S.D.) for pretest and posttest of students' spatial ability between the control group and the experimental group

2. Chi-square test for evaluating students' attitude toward Geometry between the control group and the experimental group

3. The comparison between control groups and experimental groups in spatial ability by using the independent sample-t-test at the significance 0.01

4. The comparison between males and females in spatial ability by using the independent sample-t-test at the significance 0.05

3.6 Summary of the chapter

This study is a quasi-experimental research design in the field of the constructivism paradigm in order to enhance students to develop their spatial ability in 2D-3D geometric pictures. The subjects are 190 seventh-grade students from a secondary school in Nonthaburi province participating in this study. They are average abilities in mathematics. There are four types of research instruments in this study as follows: 1) Geometric test (Geo-test), 3.2) Geo-worksheet, 3.3) Geometry Multimedia Organization package (GMO package), 3.4) GMO lesson plan and 3.5) The questionnaire for geometric attitude test. The independent sample-t-test was used to compare between the control group and the experimental group and Chi-square test was used to evaluate students' attitude toward Geometry in data analysis. Furthermore, observations could support the data for the validation and generalization of this study in Thai geometry classes.

Copyright by Mahidol University

CHAPTER IV
RESULTS

In this chapter, the data of this study are analyzed by using SPSS program. They have been determined to present the results of data analysis as following:

4.1 The results of data consisted of:

- The means ($\bar{x}$) and standard deviation (S.D.) for pretest and posttest of students' spatial ability between the control group and the experimental group
- The pre- posttest comparison between control groups and experimental groups in spatial ability by using the independent sample-t-test at the significance 0.01
- The pre- posttest comparison between males and females in spatial ability by using the independent sample-t-test at the significance 0.05
- Chi-square test for investigating the relationship between students' attitude toward Geometry and instructional strategies
- Data of the observation showed students' learning reaction in GMO classroom

4.2 Students' spatial skills in 2D-3D geometric pictures

The pretest and posttest which were derived from 4.2.1 and 4.2.2 were implemented to the experiment group (n = 91 students) who learn 2D-3D geometric pictures via using GMO presentation and control group (n = 98 students) who learn 2D-3D geometric pictures by using conventional instruction with additional equipment so as to compare between the learning outcomes of GMO instruction and the learning outcomes of traditional instruction. The pretest and posttest were calculated by using SPSS program and they can be shown as following:

Copyright by Mahidol University

4.2.1 The comparison of pretest between the learning outcomes of experimental group and the learning outcomes of control group

	Method	**N**	$\overline{X}$	**S.D.**
Pretest	Control	98	14.29	4.941
	Experiment	91	15.82	4.979

Table 4.1: The pretest-mean scores of experimental group and control group

In Table 4.1, the mean of experimental group is 15.82 and the Standard Deviation (S.D.) of treatment group is 4.979 for 91 students. The mean of control group is 14.29 and the Standard Deviation (S.D.) of control group is 4.941 for 98 students. According to Table 4.1, the independent-sample T test was conducted to compare pretest-mean scores between control group and experimental group (one-tailed test of hypothesis at the level of significance (α) = 0.01). The independent-sample T test results and descriptive statistics which are related are shown in Table 4.2 as follows

Given, $H_0 : \mu_{exp} = \mu_{con}$

$H_1 : \mu_{exp} > \mu_{con}$

Pre-control		Pre-experiment		t	p	Sig. (1-tailed)
$\overline{X}$	SD	$\overline{X}$	SD			
14.29	4.941	15.82	4.979	-2.131	0.017	0.01

Table 4.2: Comparing mean between the pretest scores of experimental group and the pretest scores of control group

In table 4.2, $t_{0.01,187}$ = - 2.131, p = 0.017 since this is one-tailed test of hypothesis, it concludes that H_o is accepted. It means that there is no difference in pretest scores between control group and experimental group at level of significance 0.01.

Copyright by Mahidol University

4.2.2 The comparison of posttest between the learning outcomes of experimental group and the learning outcomes of control group

	Method	**N**	$\overline{X}$	**S.D.**
Posttest	Control	98	24.99	8.194
	Experiment	91	29.40	6.917

Table 4.3: The posttest-mean scores between experimental group and control group

In Table 4.3, the mean of experimental group is 29.40 and the Standard Deviation (S.D.) of experimental group is 6.917 for 91 students. The mean of control group is 24.99 and the Standard Deviation (S.D.) of control group is 8.194 for 98 students. According to Table 4.3, the independent-sample T test was conducted to compare posttest-mean scores between control group and experimental group (one-tailed test of hypothesis at the level of significance (α) = 0.01). The independent-sample T test results and descriptive statistics which are related are shown in Table 4.4 as follows

Given, $H_0: \mu_{exp} = \mu_{con}$

$H_1: \mu_{exp} > \mu_{con}$

Post-control		Post-experiment		t	p	Sig. (1-tailed)
$\overline{X}$	SD	$\overline{X}$	SD			
24.99	8.194	29.40	6.914	-4.004	0.000	0.01

Table 4.4: Comparing mean between the posttest scores of experimental group and the pretest scores of control group

In Table 4.4, t = - 4.004, p = 0.000 since this is one-tailed test of hypothesis; it concludes that H_o is rejected, but H_1 is accepted. It means that the posttest scores of experimental group are higher than those of control group at level of significance 0.01.

Copyright by Mahidol University

4.2.3 The comparison of pretest scores between female performances and male performances in control group.

	sex	**N**	$\overline{X}$	**S.D.**
Pretest	male	55	14.49	4.864
	female	43	14.02	5.083

Table 4.5: The pretest scores between male and female students in control group

In Table 4.5, the mean of male group is 14.49 and the Standard Deviation (S.D.) of male is 4.864 for 55 students. The mean of female group is 14.02 and the Standard Deviation (S.D.) of male group is 5.083 for 43 students. According to Table 4.5, an independent-sample T test was conducted to compare mean between male group and female group (two-tailed test of hypothesis at the level of significance (α) = 0.05). The independent-sample T test results and descriptive statistics which are related are shown in Table 4.6 as follows

Given, $H_0: \mu_{girl} = \mu_{boy}$

$H_1: \mu_{girl} \neq \mu_{boy}$

Pre-male		pre-female		t	p	Sig. (2-tailed)
$\overline{X}$	SD	$\overline{X}$	SD			
14.49	4.864	14.02	5.083	- 0.4630.	0.644	0.05

Table 4.6: Comparing pretest scores between male and female students in control group

In Table 4.6, $t_{0.05,96}$ = - 0.463, p = 0.644 since this is two-tailed test of hypothesis; it concludes that H_o is accepted. It means that there is no difference of pretest scores between male students and female students in control group at level of significance 0.05.

Copyright by Mahidol University

4.2.4 The comparison of posttest between female performances and male performances in control group

	sex	**N**	$\overline{X}$	**S.D.**
Posttest	male	55	25.09	8.061
	female	43	24.86	8.456

Table 4.7: The posttest scores between male and female students in control group

In Table 4.7, the mean of male group is 25.09 and the Standard Deviation (S.D.) of male group is 8.061 for 55 students. The mean of female group is 24.86 and the Standard Deviation (S.D.) of female group is 8.456 for 43 students. According to Table 4.7, an independent-sample T test was conducted to compare mean between male group and female group (two-tailed test of hypothesis at the level of significance (α) = 0.05). The independent-sample T test results and descriptive statistics which are related are shown in Table 4.8 as follows

Given, $H_0: \mu_{girl} = \mu_{boy}$

$H_1: \mu_{girl} \neq \mu_{boy}$

Post-male		post-female		t	p	Sig. (2-tailed)
$\overline{X}$	SD	$\overline{X}$	SD			
25.09	8.061	24.86	8.456	-0.137	0.891	0.05

Table 4.8: Posttest-mean score between male and female students in control group

In Table 4.8, $t_{0.05,96}$ = - 0.137, p = 0.891 since this is two-tailed test of hypothesis; it concludes that H_o is accepted. It means that there is no difference of posttest scores between male students and female students in control group at level of significance 0.05.

Copyright by Mahidol University

4.2.5 The comparison of pretest between female performances and male performances in experimental group

	sex	**N**	$\overline{X}$	**S.D.**
Pretest	male	41	17.49	6.245
	female	50	17.32	4.779

Table 4.9: The pretest scores between male and female students in experimental group

In Table 4.9, the mean of male group is 17.49 and the Standard Deviation (S.D.) of male is 6.245 for 41 students. The mean of female group is 17.32 and the Standard Deviation (S.D.) of male group is 4.779 for 50 students. According to Table 4.9, the independent-sample T test was conducted to compare mean between male group and female group (two-tailed test of hypothesis at the level of significance (α) = 0.05). The independent-sample T test results and descriptive statistics which are related are shown in Table 4.10 as follows

Given, $H_0: \mu_{girl} = \mu_{boy}$

$H_1: \mu_{girl} \neq \mu_{boy}$

Pre-male		pre-female		t	p	Sig. (2-tailed)
$\overline{X}$	SD	$\overline{X}$	SD			
17.49	6.245	17.32	4.779	-0.145	0.885	0.05

Table 4.10: Comparing pretest scores between male and female in experiment group

In Table 4.10, $t_{0.05,89}$ = - 0.145, p = 0.885 since this is two-tailed test of hypothesis; it concludes that H_o is accepted. It means that there is no difference of pretest scores between male students and female students in experimental group at level of significance 0.05.

Copyright by Mahidol University

4.2.6 The comparison of posttest between female performances and male performances in experimental group

	sex	N	$\overline{X}$	S.D.
Posttest	male	41	29.95	6.656
	female	50	28.94	7.158

Table 4.11: The posttest score between male and female students in experimental group

In Table 4.11, the mean of male group is 29.95 and the Standard Deviation (S.D.) of male is 6.656 for 41 students. The mean of female group is 28.94 and the Standard Deviation (S.D.) of male group is 7.158 for 50 students. According to Table 4.11, an independent-sample T test was conducted to compare mean between male group and female group (two-tailed test of hypothesis at the level of significance (α) = 0.05). The independent-sample T test results and descriptive statistics which are related are shown in Table 4.12 as follows

Given, $H_0: \mu_{girl} = \mu_{boy}$

$H_1: \mu_{girl} \neq \mu_{boy}$

Post-male		post-female		t	p	Sig. (2-tailed)
$\overline{X}$	SD	$\overline{X}$	SD			
29.95	6.656	28.94	7.158	-0.692	0.491	0.05

Table 4.12: Comparing posttest scores between male and female in experiment group

In Table 4.12, $t_{0.05,89}$ = - 0.692, p = 0.491 since this is two-tailed test of hypothesis; it concludes that H_o is accepted. It means that there is no difference of pretest scores between male students and female students in experimental group at level of significance 0.05.

Copyright by Mahidol University

4.2.7 The students' attitude toward learning geometric pictures via GMO instruction and conventional instruction

Statements	agree		undecided		disagree	
	con	exp	con	exp	con	exp
1. Geometry has no relevance in my life.	25	20	19	12	54	59
2. I can see ways of using geometry concepts to solve everyday problems.	57	56	39	33	2	2
3. I will need a firm understanding of geometry in my future work.	81	84	16	7	1	0
4. Geometry problems are boring.	8	6	33	16	57	69
5. I often have trouble solving geometry problems.	37	25	44	32	17	34
6. I am confident I can get good grades in geometry.	34	49	57	36	7	6
7. I am confident that if I work long enough on a geometry problem, I will be able to solve it.	80	83	15	7	3	1
8. I am sure that I can learn geometry concepts.	80	86	15	5	3	0
9. Geometry is an interesting subject to study.	80	84	14	5	4	2
10. Working out geometry problems does not appeal to me.	13	6	49	32	36	53
11. Expressing ideas through drawing seems to be a waste of time.	15	8	27	9	56	74
12. I get nervous when I am asked to draw.	38	40	41	34	19	17
13. I like to draw my ideas down.	64	73	28	14	6	4
14. I enjoy drawing.	73	84	14	5	11	2
15. I don't think I draw as well as other people do.	28	14	40	28	30	49

$N_{control} = 98$, $N_{experiment} = 91$ / con = control group, exp = experiment group

Table 4.13: The frequency of students' opinion level on Geometry

Copyright by Mahidol University

Statements	agree		undecided		disagree	
	con	exp	con	exp	con	exp
1. Geometry has no relevance in my life.	18.9	15.2	14.4	9.1	40.9	44.7
2. I can see ways of using geometry concepts to solve everyday problems.	43.2	42.4	29.5	25.0	1.5	1.5
3. I will need a firm understanding of geometry in my future work.	61.4	63.6	12.1	5.3	0.8	0
4. Geometry problems are boring.	6.1	4.5	25.0	12.1	43.2	52.3
5. I often have trouble solving geometry problems.	28.0	18.9	33.3	24.2	12.9	25.8
6. I am confident I can get good grades in geometry.	25.8	37.1	43.2	27.3	5.3	4.5
7. I am confident that if I work long enough on a geometry problem, I will be able to solve it.	60.6	62.9	11.4	5.3	2.3	0.8
8. I am sure that I can learn geometry concepts.	60.6	65.2	11.4	3.8	2.3	0
9. Geometry is an interesting subject to study.	60.6	63.6	10.6	3.8	3.0	1.5
10. Working out geometry problems does not appeal to me.	9.8	4.5	37.1	24.2	27.3	40.2
11. Expressing ideas through drawing seems to be a waste of time.	11.4	6.1	20.5	6.8	42.4	56.1
12. I get nervous when I am asked to draw.	28.8	30.3	31.1	25.8	14.4	12.9
13. I like to draw my ideas down.	48.5	55.3	21.2	10.6	4.5	3.0
14. I enjoy drawing.	55.3	63.6	10.6	3.8	8.3	1.5
15. I don't think I draw as well as other people.	21.2	10.6	30.3	21.2	22.7	37.1

Table 4.14: The percentage of students' satisfaction levels on Geometry

In geometry attitude test, there are 15 items. It is developed by modifying from Juliana Utley's and Lee A. Schmidt's studies. In this experiment, to find out students response to two teaching approaches, the questionnaire for evaluating Geometry attitude will be developed research focusing on students' attitude toward learning Geometry and drawing 2D-3D pictures. In Table 4.14, it is presented that the frequency of students' opinion level on Geometry. The researcher classify the results of the 5-Likert scale questionnaire into three classes: agree, undecided, and disagree.

Copyright by Mahidol University

Chi-square test is used to analyze these data via using SPSS program, and the hypothesis of this analysis can be shown as following:

Given, H_0: The instructional method is not related to students' attitude toward geometry

H_1: The instructional method is related to students' attitude toward geometry

Each item was analyzed to compare students' attitude to geometry learning derived from GMO-presentation using and traditional instructions at level of significance 0.05. The results showed in Table 4.15 as follow:

Statements	Pearson Chi-Square value	p-value
1. Geometry has no relevance in my life.	2.101	.350
2. I can see ways of using geometry concepts to solve everyday problems.	.250	.883
3. I will need a firm understanding of geometry in my future work.	4.323	.115
4. Geometry problems are boring.	7.077*	**.029**
5. I often have trouble solving geometry problems.	9.638*	**.008**
6. I am confident I can get good grades in geometry.	7.280*	**.026**
7. I am confident that if I work long enough on a geometry problem, I will be able to solve it.	3.710	.156
8. I am sure that I can learn geometry concepts	7.969*	**.019**
9. Geometry is an interesting subject to study.	4.775	.092
10. Working out geometry problems does not appeal to me.	9.147*	**.010**
11. Expressing ideas through drawing seems to be a waste of time.	13.382*	**.001**
12. I get nervous when I am asked to draw.	.557	.757
13. I like to draw my ideas down.	5.406	.067
14. I enjoy drawing.	11.020*	**.004**
15. I don't think I draw as well as other people do.	11.110*	**.004**

* $p < 0.05$

Table 4.15: The outcomes of Chi-square test: the relationship between the instructional approaches and students' attitude toward Geometry

In Table 4.15, the p-values of eight statements were less than the level of significance ($\alpha = 0.05$): item 4 (0.29), item 5 (0.08), item 6 (0.026), item 8 (0.019), item 10 (0.010), item 11 (0.001), item 14 (0.04), item 15 (0.04), thus the eight statements showed the relationship between instructional approaches and students' attitude in table 4.16 as following:

Copyright by Mahidol University

Statements	Agree		undecided		disagree	
	con	exp	con	exp	con	exp
4. Geometry problems are boring.	6.1	4.5	25.0	12.1	***43.2***	***52.3***
5. I often have trouble solving geometry problems.	28.0	18.9	33.3	24.2	***12.9***	***25.8***
6. I am confident I can get good grades in geometry.	***25.8***	***37.1***	43.2	27.3	5.3	4.5
8. I am sure that I can learn geometry concepts.	***60.6***	***65.2***	11.4	3.8	2.3	0
10. Working out geometry problems does not appeal to me.	9.8	4.5	37.1	24.2	***27.3***	***40.2***
11. Expressing ideas through drawing seems to be a waste of time.	11.4	6.1	20.5	6.8	***42.4***	***56.1***
14. I enjoy drawing.	***55.3***	***63.6***	10.6	3.8	8.3	1.5
15. I don't think I draw as well as other people.	21.2	10.6	30.3	21.2	***22.7***	***37.1***

Table 4.16: The statements represented students' attitude toward Geometry

In experimental group, students' opinions are shown as the following summary:

1. Geometry is not boring subject.
2. Students do not have trouble in solving Geometry problems.
3. Students are confident to get a good grade in Geometry.
4. Students are sure to be able to learn Geometry concepts.
5. Students can work out geometry problems always.
6. Expressing ideas through drawing does not seem to be a waste of time.
7. Students enjoy drawing.
8. Students can draw geometric pictures as well as other people do.

4.3 GMO learning contexts

There are some video-files recorded to show the environment of GMO classes in order to confirm the effectiveness of GMO. These data can be explained in each unit as follows:

4.3.1) Learning Environment

In GMO classroom, the students enjoyed in learning this multimedia such as the interesting contents, the various drawing activities, and the imaginary

Copyright by Mahidol University

of geometric pictures. This environment encouraged students to show their opinions and ideas about geometric pictures without embarrassment. Besides, students intended to draw the pictures and posed many questions to ask teacher about the 2D-3D pictures. They were enthusiastic and attended upon GMO presentation.

4.3.2) Teacher and Student Interaction

The teacher motivated students' creative thinking via posing the questions, then Students showed reactions toward teacher's questions. The teacher asked students to give an example of square shaped objects in the classroom and students replied various answers such as speaker, table, door and TV screen. Students interested in the activities that teacher presented and students volunteered to join the activity in the front of the classroom and they did the activity with pleasant feeling.

4.3.3) Student and Student Interaction

When the teacher asked the questions, the teacher provided students' opportunity to discuss their own ideas in groups before sharing the groups' answer to the whole class. For example, when students were asked to predict the number of the blocks from 2D pictures, see chapter 3, p. 38. All students shared their own ideas in groups and we found that each group could be able to find the way to count the number of blocks.

4.3.4) Student Differences

Most students have their own answers when the teacher asked the questions. The students' various answers motivate other students to analyze their own thinking which kept in their mind again, and many students talked more about the interesting question that teacher posed. Furthermore, we found that students' drawing represented their own imaginary about the 2D geometric pictures clearly as following examples:

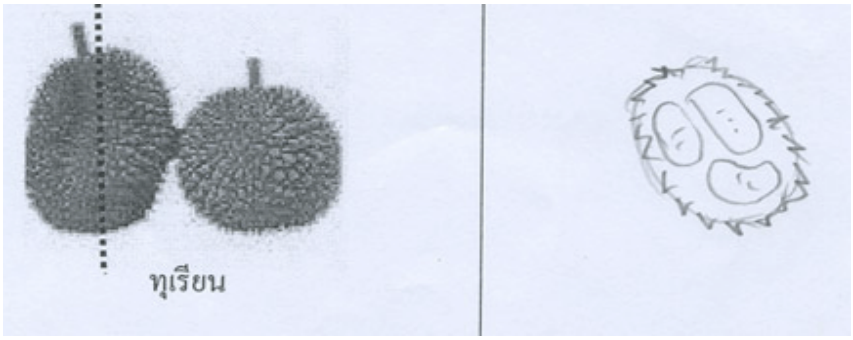


Figure 4.1: Student A's cross-section of durian

Copyright by Mahidol University

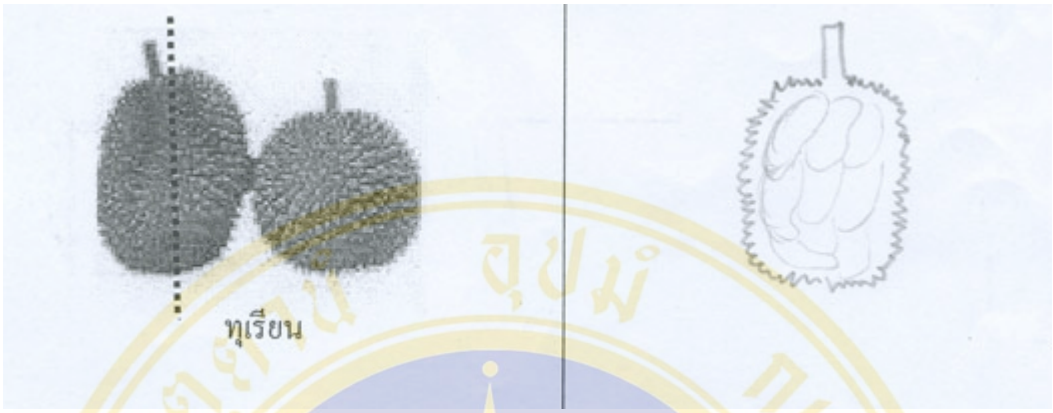


Figure 4.2: Student B’s cross-section of durian

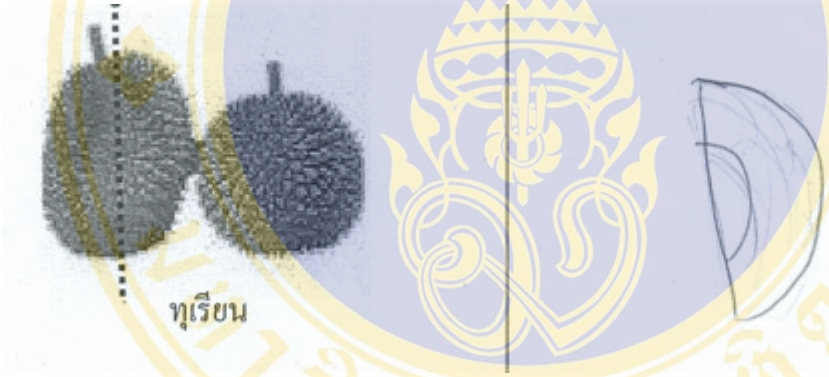


Figure 4.3: Student C’s cross-section of durian

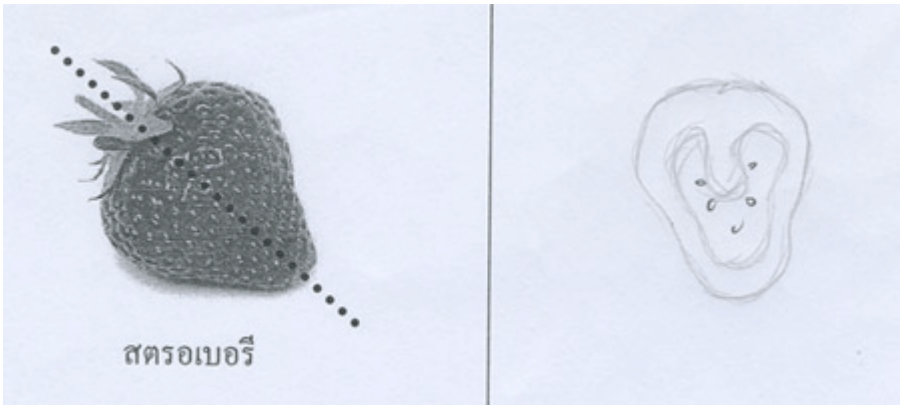


Figure 4.4: Student A’s cross-section of strawberry

Copyright by Mahidol University

Figure 4.5: Student B's cross-section of strawberry

Figure 4.6: Student C's cross-section of strawberry

In these figures above, each student showed individual's imaginary about the cross-section of fruits. They drew the pictures based on their prior knowledge at that time.

Copyright by Mahidol University

CHAPTER V
DISCUSSION

5.1 GMO versus other multimedia

According to Olkun (2003), his geometry program based Tangrams was focused on mental rotation of blocks, measuring the area of the geometric shape and how to construct the larger geometric shape from the smaller geometric elements. This effective program was developed for basic geometric pictures in two dimensions, but GMO was developed for 2D-3D geometric pictures, so students could learn both 2D and 3D figures in order to get more spatial skill in the context of this framework.

Samsudin & Ismail (2004) developed Computer Based Multimedia Tutor (CBMT) focused on the mental rotation in terms of accuracy and speed. Their efficacy geometry program aimed at students' accuracy and speed performance on mental rotation for undergraduate degree; however, GMO program aimed at preparing high school students for 2D-3D geometric perspectives and consisted of four different types of situation to establish some necessary and useful knowledge about 2D-3D geometric pictures for higher study in the future.

Besides, Yun, Xi & Li (2006) created Virtual Geometry Learning System (VGLS). It consisted of six units: the basic geometry object, the section-shape of basic geometry object, the motion change of basic geometry object, the three views maps of basic geometry object, the folding and unfolding of basic geometry object. VGLS program was mainly effective in mental rotation and folding and unfolding abilities. Nevertheless, GMO package was developed similarly with VGLS in some aspects but the GMO was added the section of block-buildings analysis corresponding to Thai mathematic curriculum. Students learned the 2D-3D conversion of block-buildings and learnt how to count the invisible blocks. These provided students to use their spatial skill derived from GMO presentation to obtain out-performance better than that of students in the non-treatment group.

Copyright by Mahidol University

Finally, Chang, Sung & Lin (2007) developed GeoCAL- a multimedia learning software program- to assist primary school students in learning basic geometric shapes. Their program focused on 2D geometric pictures and it was attractive design for young children but GMO was neatly designed and based on CTML, thus it was an effective instructional package for seventh-grade students to enhance students in 2D-3D geometric pictures.

5.2 The effective aspects of GMO

As the data have been analyzed in the previous chapter, the results of this study showed the efficiency of GMO affected students' spatial skills in four aspects:

5.2.1) Simple geometric pictures: these could review students' knowledge background about basic shape of geometric pictures; therefore this could enhance students' prior knowledge and provide their preparation for learning some new 2D-3D geometry knowledge.

5.2.2) The cross-section of materials: these could motivate students' imaginary in the cross-section shape of the given material, thus students could realistically imagine about the cross-section of the given new situations.

5.2.3) The three-dimensional pictures in daily life: these could revise students' thinking about shapes of the material in some views (front-, top- , and side- view), so this point aroused students to imagine the 2D shape of the material in three directional views and they could apply their skills well in a new situation.

5.2.4) The front-view, side-view, and top-view of three-dimensional pictures of building-blocks pictures: these provided students to construct 2D shape of 3D building-blocks in three directional views. Not only students could imagine the correct 2D shape of the 3D shape in each view, but they could transform a 3D shape into a 2D shape also. Hence, students' spatial ability is appropriately converted in 2D-3D geometric pictures via GMO presentation.

According to four aspects, GMO could enhance students to learn geometry effectively and support their learning process, and GMO could improve students' spatial ability. GMO-presented instruction showed that the multimedia affected students' learning better than traditional instruction did. This was an effective instrument to support 2D-3D visualization to monitor procedurally students' active

Copyright by Mahidol University

learning through their performance in physical appearance as has been reported by Song & Lee (2002), Olkun (2003), Samsudin & Ismail (2004), Olkun, Altun & Smith (2005), Yun, Xi & Li (2006), Chang, Sung & Lin (2007). Besides, teachers can provide learning and teaching processes by using GMO presentation to support their instruction so as to engage students in the real-world problems (Saramas & Clement, 2002).

5.3 The outcomes of research questions

According to chapter 4, the answers of research questions of this study are described as following:

5.3.1 Research question 1

The result showed that the spatial ability between the control group and the experimental group was no difference at the level of significance 0.01 before the experiment began. This meant that the students in the control group and experimental group have similar abilities in spatial skill. After the experiment was completed, it showed that the spatial ability between the control group and the experimental group was difference at the level of significance 0.01. This meant that the students in the experimental group had higher spatial ability than that of the students in the control group. In summary, these results concluded that the experimental group outperformed spatial ability than that of the control group.

5.3.2 Research question 2 and 3

The results were considered on the spatial ability between female students and male students. These were classified in two cases:

a) Before the experiment: In the control group, the results revealed that there was no difference at the level of significance 0.05. This meant that both female students and male students in the control group have similar abilities in spatial skill. In the experimental group, it revealed that there was no difference at the level of significance 0.05. This meant that both female students and male students in the experimental group have similar abilities in spatial skill.

b) After the experiment: In the control group, the results revealed that there was no difference at the level of significance 0.05. This meant that both female students and male students in the control group have similar abilities in spatial skill. In

Copyright by Mahidol University

the experimental group, it revealed that there was no difference at the level of significance 0.05. This meant that both female students and male students in the experimental group have similar abilities in spatial skill.

According to both cases, these results concluded that female students did not outperform the tests than that of male students and male students did not outperform the tests than that of female students. Both male and female students in the experimental group and the control group could perform their spatial ability similarly on the geometric tasks as has been reported by Yun, Xi & Li (2006); however, these results were not consistent with those of Olkun (2003) and Samsudin & Ismail (2004) because there might be different in the context of each study and this issue might depend on some factors such as individual's ability, instructor, and so on (Lauzon, 2001; Spelke, 2005; Fisher, 2008). According to the results of this study, it indicated that the gender difference on spatial ability is not the critical issue for Thai seventh-grade students in geometry classes. This is a beneficial point for teachers to manipulate geometry classes favorably.

5.4 The students' attitude toward learning geometric pictures via GMO instruction and the conventional instruction

This was analyzed by using Chi-square test to investigate the relationship between the instructional strategy and students' attitude toward learning geometric pictures. The results showed that there are some statements from the experimental group showed better results than those of the control group as follows:

1) Geometry is not boring subject.
2) Students do not have trouble in solving Geometry problems.
3) Students are confident to get a good grade in Geometry.
4) Students are sure to be able to learn Geometry concepts.
5) Students can work out geometry problems always.
6) Expressing ideas through drawing does not seem to be a waste of time.
7) Students enjoy drawing.
8) Students can draw geometric pictures as well as other people do.

These results asserted that learning through GMO instruction had a positive result and powerful effect on students' geometry achievement as has been reported by

Copyright by Mahidol University

Suthtakeit Wanwipa (1999), Jongsuabsook Jesada (1999), Olkun, (2003), Koijapoa Wanwipa (2004) , Olkun, Altun, and Smith (2005), Chang, Sung and Lin (2006), Nueangchompoo Suros (2006). Considering students' attitude toward learning geometric pictures between the experimental group and the control group, the results showed more outstanding satisfaction in experimental group than that of the control group. These results can confirm the effectiveness of GMO for enhancing students' understanding in 2D-3D geometric pictures.

5.5 GMO learning contexts

According to chapter 4, the results showed the effectiveness of GMO in enhancing students' learning in 2D-3D geometric pictures. In the context of GMO, this could make students showed their own authentic imaginary obviously via their drawing pictures and encouraged students' participation in the activities. The interaction between teacher and students showed positive results because students responded to teacher' questions and had more discussion in the topic that teacher gave. In peer discussion, students interacted with each other about the tasks they faced and they presented their ideas efficiently. In general, there are different abilities in students to learn external environment. All students had their own unique abilities because students' spatial abilities depended on their prior knowledge. Therefore, the students' spatial skill still continued developing through times and life experiences.

5.6 The limitation of this study

GMO was developed to enhance 2D-3D spatial skill and used practically in the geometry classrooms in Thailand. Then, it showed significantly pleasant outcomes. However, the limitations of GMO were found in this study such as: the amount of sample was small because of the characteristic of quasi-experimental design, so next experiments should be conducted in different schools for confirmation and generalization of the effective technology in geometry classrooms. Besides, the attributes of software used in this study was not sufficient to create the complex design, thus some modern software being suitable for designing 3D-motion shapes is still necessary for future research.

Copyright by Mahidol University

5.7 Recommendations

1. Thai students should be investigated the spatial skills by using the other programs such as 3D animation programs.

2. There should be examined the other parts of spatial skill such as calculating the volume of 3D- geometric shapes or the consideration of proving the character of geometric pictures by using instructional package based on computer.

3. The students' mental-model construction of 2D-3D pictures should be investigated in-depth detail so that we will understand how students learn in this aspect and it will be benefit for effectively geometry instruction in the future.

4. A new Thai curriculum involving Design and Technology Curriculum also aims to provide students' spatial skill, thus a part of this study could be useful in enhancing students' background for further study in design and technology subject.

Copyright by Mahidol University

CHAPTER VI
CONCLUSION

5.1 Developing Geometry Multimedia Organization (GMO)

The learning package consisted of four challenging parts:

5.1.1 The simply geometric pictures: this part focused on reviewing students' prior knowledge in geometry concepts such as simple two-three dimensional pictures, cylinder, pyramid, trapezoid, and so forth. The simulated drawing of geometric configurations provided for students are purposed on improving students' drawing skills in geometric pictures.

5.1.2 The cross-section of materials: this part focused on analyzing and forming the cross-section model in their minds when they saw the materials in daily life. The materials were presented, for instance, vegetable, fruit, coffee, tree, etc.

5.1.3 Three-dimensional pictures of materials: this part focused on examining and drawing the two-dimensional pictures of those materials following the given direction (front view, side view, and top view).

5.1.4 Three-dimensional pictures of building-blocks: this part seemed to be the challenging games. There were three sub-tasks: front-view case, side-view case, and top-view case in the task.

5.2 GMO based on the Cognitive Theory of Multimedia Learning (CTML)

This multimedia was designed based on the Cognitive Theory of Multimedia Learning (CTML): Multimedia principle, Contiguity principle, Split-attention principle, and Individual Differences Principle in order to support the active learning in 2D-3D geometric pictures. According to CTML, GMO could support students to learn 2D-3D objects by selecting relevant words and images, organizing them into coherent verbal and pictorial representations and integrating the verbal and pictorial representations.

Copyright by Mahidol University

5.3 The quasi - experiment

A five-week training package was used to instruct the high-school students in the geometric concepts. The quasi-experiment was conducted with 190 students. The efficiency of GMO was measured and compared with traditional instruction. These data were collected by pre-posttest, and the questionnaire for geometric attitude test. The results revealed that the experimental groups had higher spatial skills toward learning 2D-3D geometric pictures than those of the control groups. Furthermore, the students' attitude in experimental groups had higher satisfaction toward learning geometry subject than those of the control groups. The results showed that GMO could assist instructors in teaching 2D-3D geometric pictures.

5.4 The outcomes of the experiment

The results of this study are described as following:

5.4.1) Geometry Multimedia Organization can be used to enhance student's ability in 2D - 3D conversion of geometric figures.

5.4.2)Geometry Multimedia Organization can be an efficiently instructional package for teaching 2D - 3D geometric figures.

5.4.3) There is no difference between male and female students to the spatial skill in 2D - 3D conversion of geometric figures.

5.4.4) Geometry Multimedia Organization can be an appropriate mediator to support students' understanding in Geometry and foster efficiently students to link between their prior knowledge and some new ideas in 2D - 3D geometric figures.

Copyright by Mahidol University

REFERENCES

1. Ardac, D. and Unal, S. (2008). Does the amount of on-screen text influence student learning from a multimedia-based instructional unit?. *Instructional Science: An International Journal of the Learning Sciences*, 36, 75-88.
2. Balioan, N. Hoeksema, K., Hoppe, U. Milrad, M. (2006). Technologies and Educational Activities for Supporting and Implementing Challenge-Based Learning. *International Federation for Information Processing, Education for the 21th Century-Impact of ICT and Digital Resources, eds. 210*, 7-16.
3. Barak, M., Waks, S. and Doppelt, Y. (2000). Majoring in Technology Studies at High School and Fostering Learning. *Learning Environment Research*, 3, 135-157.
4. Braungart, M.M., Braungart, R.G. (2003). *Applying learning theory to health care Pratice*. *In Bastable SB, ed. Nurse as Educator*. (2nded) Boston: Jone and Bartlett Publisher.
5. Bucciarelli, M. (2007). How the construction of mental models improves learning. *Mind & Society*, 6, 67-89.
6. Chang, K.-E., Sung, Y.-T., Lin, S.-Y. (2007), Developing geometry thinking through multimedia learning activities. *Computers in Human Behavior*. 23, 2212–2229.
7. Clark, D.B., Stegmann, K., Weinberger, A., Menekse, M. Erkens, G. (2007). Chapter 11: Technology-Enhanced Learning Environments to Support Students' Argumentation. *Science & Technology Education Library, Argumentation in Science Education (Eds)*, 217-243.
8. Clements, D. H., & Battista, M. T. (1992). Geometry and spatial reasoning. In D.A.Grouws (Ed.), *Handbook of research on mathematics teaching and learning*. New York: Macmillan, 426-454.
9. Dunsworth, Q., Atkinson, R.K. (2007). Fostering multimedia learning of science: Exploring the role of an animated agent's image. *Computers &*

Copyright by Mahidol University

Education, 49, 677-690.

10. Fisher M. (2008), Study: No gender differences in math performance. Retrieved July 24, 2008 from http://www.news.wisc.edu/15412
11. Garcia, R.R., Quiros, J.S., Santos, R.G., Gonzalez, S.M., Fernanz, S.M. (2007). Interactive multimedia animation with Macromedia Flash in Descriptive Geometry teaching. *Computer & education*, *49*, 615-639.
12. Gemino, A. (2004). Empirical comparisons of animation and narration in requirements validation. *Requirements Engineering*, 9, 153-168.
13. Gholson, B. and Craig, S.D. (2006). Promotion Constructive Activities that Support Vicarious Learning during Computer-Based Instruction. *Educational Psychology Review*, 18, 119-139.
14. Goodyear, P. (2004). *Patterns, pattern languages and educational design*. Retrieved April 8, 2008, from http://ascilite.org.au/conferences/perth04/procs/pdf/goodyear.pdf
15. Gorgorio, N. (1998), Exploring the functionality of visual and non-visual strategies in solving rotation problems. *Educational studies in mathematics*, *35*, 207-231.
16. Guha, S., Leonard, J. (2002). Motivation in Elementary Mathematics: How Students and Teachers Benefit from Computers. *TechTrends*, 46, 40-43.
17. Hannafin, M.J. and Land, S.M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional Science*, 25, 167-202.
18. Holzinger, A. (2008). Universal access to technology-enhanced learning. *Universal Access in the Information Society*, 7, 195-197.
19. Hsu, Y.-S., Wu, H.-K. and Hwang, F.-K. (2008), Fostering High School Students' Conceptual Understandings About Seasons: The Design of a Technology-Enhanced Learning Environment. *Research in Science Education*, *38*, 127–147.
20. IPST. (2001). Thai mathematics curriculum. Retrieved April 16, 2008, from http://www.ipst.ac.th/math_curriculum/Math/math_3.doc
21. Kablan, Z., Erden, M. (2008). Instructional effiency of integrated and separated text with animated presentations in computer-based science

Copyright by Mahidol University

instruction. *Computers & Education*, 51, 660-668.

22. Kelly, G., Ewers, T. & Proctor, L. (2002), Developing Spatial Sense: Comparing Appearance with Reality. *Mathematics Teacher*, *95*, 702-704.
23. Kiili, K. (2006). Towards a participatory multimedia learning model. *Education and Information Technologies*, 11, 21-32.
24. Korakakis, G., Pavlatou, E.A., Palyvos, J.A., Spyrellis, N. (2008). 3D visualization types in multimedia applications for science learning: A case study for 8th grade students in Greece. *Computer & Education*. doi:10.1016/j.compedu.2008.09.011
25. Lauzon, D. (2001). Gender Difference in Large Scale, Quantitative Assessments of Mathematics and Science Achievement. Retrieved October 25, 2008, http://qed.econ.queensu.ca/pub/jdi/deutsch/edu_conf/Lauzon2_paper.pdf
26. Lieu D. K. (1999), Using Interactive Multimedia Computer Tutorials for Engineering Graphics Education. *Journal for Geometry and Graphics*, *3*, 85-91.
27. Mayer, R., & Moreno, R. (2002). Animation as an aid to multimedia learning. *Educational Psychology Review*, 14, 87–99.
28. Mayer, T. (2001). Multimedia learning. New York: Cambridge University Press.
29. Mor, Y. and Winters, N. (2006). Design approaches in technology enhanced learning. a preprint of an article submitted for consideration in the 'Interactive Learning Environments', 2006 Copyright Taylor & Francis http://journalsonline.tandf.co.uk/
30. Moran, S., Rubio, R., Gallego, R., Suarez, J., Martin, S. (2008). Proposal of interactive applications to enhance student's spatial perception. *Computers & Education*, 50, 772-786.
31. Motschnig-Pitrik, R. and Derntl, M. (2005). Learning Process Models as Mediators Between Didactical Practice and Web Support. *Lecture Notes in Computer Science, Conceptual Modeling (Eds)*, 112-127.
32. Muthukumar, S.L.(2005). Creating interactive multimedia-based educational courseware: cognition in learning. *Cognition, Technology & Work*, 7, 46-50.
33. NCTM. (2000). "Principle and Standard for School Mathematics. National Council of Teachers of Mathematics". Retrieved March 5, 2008 from

Copyright by Mahidol University

http://standards.nctm.org/document/chapter6/geom.htm

34. Olkun, S., Altun, A. and Smith, G.(2005). Computers and 2D geometric learning of Turkish fourth and fifth graders. *British Journal of Educational Technology*, *36*, 317–326.
35. Olkun, S. (2003). Comparing computer versus concrete manipulatives in learning 2D geometry. *Journal of Computers in Mathematics and Science Teaching*, *22*, 43–56.
36. Paas, F. G. W. C., Renkl, A., & Sweller, J. (2004). Cognitive Load Theory: Instructional Implications of the Interaction between Information Structure and Cognitive Architecture. *Instructional Science*, 32, 1–8.
37. Pascal, W.M. (2006). Cognitive Aging and Computer-Based Instructional Design: Where Do We Go From Here? *Educational Psychology Review*, 18, 141-157.
38. Plomp, T., Brummelhuis, A.C.A. ten. and Pelgrum, W.J. (1997). New Approaches for Teaching, Learning and Using Information and Communication Technologies in Education. *Prospects*, 27, 427-443.
39. Prangsma, M.E., Carla, A.M., Boxtel, V., Kanselaar, G. (2008). Developing a "big picture": Effects of collaborative construction of multimodal representations in history. *Instructional Science*, 36, 117-136.
40. Rebelo, F. and Filgueiras, E. (2007), Effectiveness of Multimedia Systems in Children's Education**.** *Journal of Science Education and Technology*, *4566*, 274–283.
41. Samsudin K. A. & Ismail A.(2004), The Improvement of Mental Rotation through Computer Based Multimedia Tutor. *Malaysian Online Journal of Instructional Technology (MOJIT), 1*, 24-34.
42. Sanchez, E., Garcia-Rodicio, H. (2008). The use of modality in the design of verbal aids in computer-based learning environments. *Interacting with Computers*, 20, 545-561.
43. Song, K.S. & Lee, W.Y. (2002), A virtual reality application for geometry classes**.** *Journal of Computer Assisted Learning* , *18*, 149-156.
44. Spelke, E.S. (2005). Sex Differences in Intrinsic Aptitude for Mathematics and Science? Retrieved November 14, 2008, from

Copyright by Mahidol University

http://www.wjh.harvard.edu/~lds/pdfs/spelke2005.pdf

45. Sweller, J., van Merrienboer, J.J., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, 10, 251–296.

46. Sarama, J., & Clements, D. H., (2002). Building blocks for young childeren's mathematical development. *Educational Computing Research. 27*, 93-110.

47. William Wiersma and Stephen G. Jurs, (2005), RESEARCH METHODS IN EDUCATION: AN INTRODUCTION. Pearson Education Inc., Eighth Edition.

48. Woolfolk. (2007). Dr. Dornisch's Professional Growth Scholarship Module. Retrieved March 5, 2008 from http://myweb.liu.edu/~mdornisc/modules/cognitivism.html

49. Yun, R., Xi, H. and Li, Y.(2006), The Experiment of Improving Students' Spatial Ability by Using VGLS. *Advances in Computational Mathematics*, *4282*, 467-473.

50. Zhang, J. (2002). Incorporating ICT into K-12 Schools: China's Perspective in the Global Backgrounds. *TechTrends*, 46, 49-57.

51. Zhang, H., Wang, Y., Zhao, B., Li, G. Lou, Y. (2008). Multimedia Instructional Design Corresponded to Cognitive Psychology. *Lecture Notes in Computer Science, Advances in Blended learning*, 155-164.

52. Jongsuabsook J. (1999). A Comparison of Mathematics Learning Achievement of Mathayomsuksa Four Students on "Fundamental of Analytical Geometry" among Group Learning by Using Programmed Lesson, Guide Sheet, and from the Teacher, Saravithaya School, Bangkok Metropolis. M.A. Thesis, Mathematics Education, Faculty of Education, Kasetsart University.

53. Adae K. (2005). A construction of an instructional package through the cippa model learning on the relationships among types of two and three dimensional objects for mathayomsuksa-1 students. M.Ed. Thesis, Mathematics Education, Faculty of Education, Thaksin University.

54. Kitpredaborisut, B. (2008), Social Science Research Methodology (ระเบียบ

Copyright by Mahidol University

วิธีการวิจัยทางสังคมศาสตร์), Jarmjuree Product, Tenth Edition.

55. Nueangchompoo S. (2006). The Development of Multimedia Assisted Instruction Program of Mathematics in Foundation of Geometry for Mathayomsuksa 1 Porncharoenwittaya School. M.Ed. Thesis, Curriculum and Instruction, Faculty of Education, Rajabhat Mahasarakham University.
56. Indhison W. (2004). The effects of using the geometer's sketchpad on the development of geometrical concepts and attitudes towards mathematics learning of lower secondary school students. M.Ed. Thesis, Mathematics Education, Curriculum, Instruction and Educational Technology, Faculty of Education, Chulalongkorn University.
57. Koijapoa W. (2004). การพัฒนาบทเรียนคอมพิวเตอร์ เรื่อง พื้นฐานทางเรขาคณิต กลุ่มสาระการเรียนรู้คณิตศาสตร์ ชั้นมัธยมศึกษาปีที่ 1, M.Ed. Independent Study, Educational Technology, Mahasarakham University.
58. Suthtakeit W. (1999). Development of computer-based geometry lesson. PhD. Thesis, Mathematics Education, Srinakharinwirot University.

Copyright by Mahidol University

APPENDIX

Copyright by Mahidol University

APPENDIX A

Name……..……Surname……room…….

Pretest

Chapter 5: the relationship of 2D-3D pictures Grade 7

Direction: Draw all pictures in the given conditions

1. Draw the following pictures

1) Trapezoid	2) Cylinder

3) Parallelogram	4) Pyramid

Copyright by Mahidol University

2. Draw the following 3D pictures in daily life

1) Box	2) Bottle
3) Dice	4) Vase

Copyright by Mahidol University

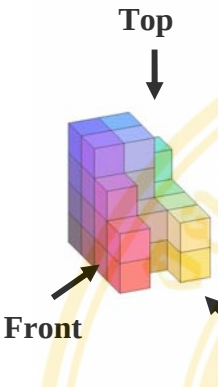
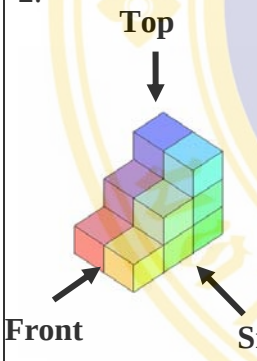
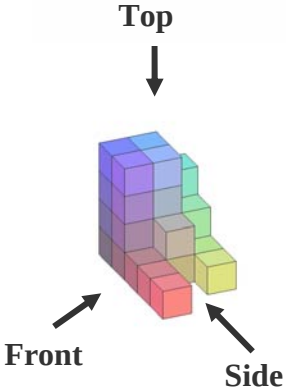
3. Draw the cross-section of the following materials

Fruit	The cross-section
Pineapple	

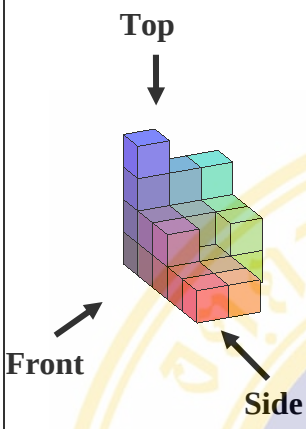
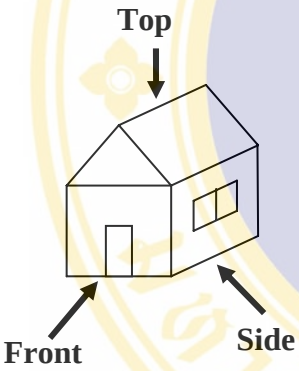
Fruit	The cross-section
Mangosteen	

Copyright by Mahidol University

4. Draw the 2D pictures of 3D building blocks following the given directions.

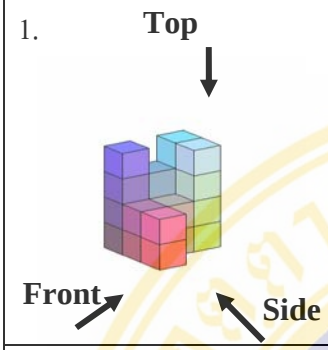
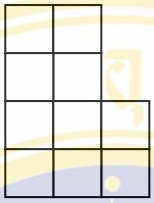
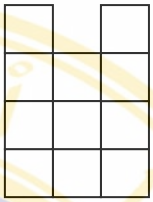
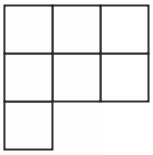
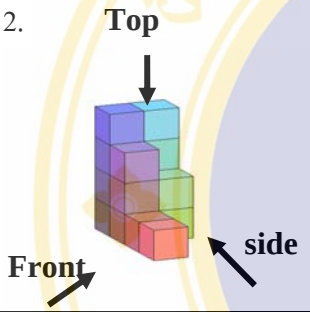
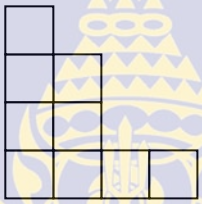
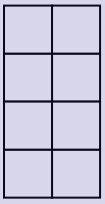
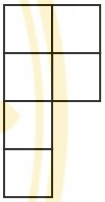
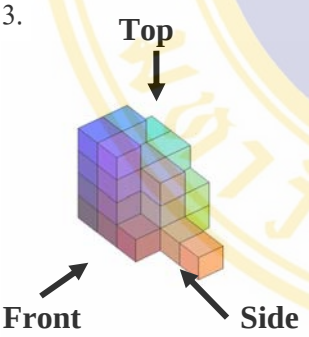
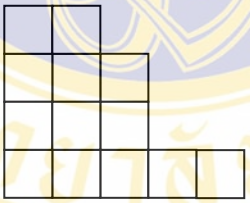
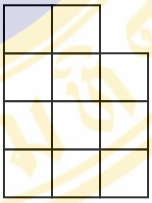
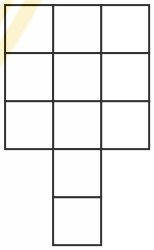
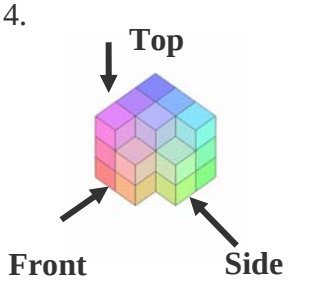
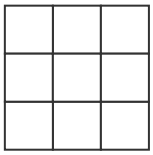
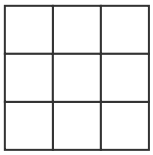
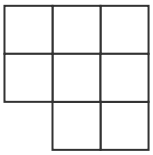
3D blocks	Front-view	Side-view	Top-view
1. 			
2. 			
3. 			

Copyright by Mahidol University

3D blocks	Front-view	Side-view	Top-view
4. 			
5. 			
6.			

Copyright by Mahidol University

5. Write the number of building-blocks following the front-view, side-view, and top-view

Building-blocks	Front-view	Side-view	Top-view
1. 			
2. 			
3. 			
4. 			

Copyright by Mahidol University

APPENDIX B

Name……Surname……room…….

Posttest

Chapter 5: the relationship of 2D-3D pictures Grade 7

Direction: Draw all pictures in the given conditions

1. Draw the following pictures

1) Hexagon	2) Cone

3) Sphere	4) Trigonal pyramidal

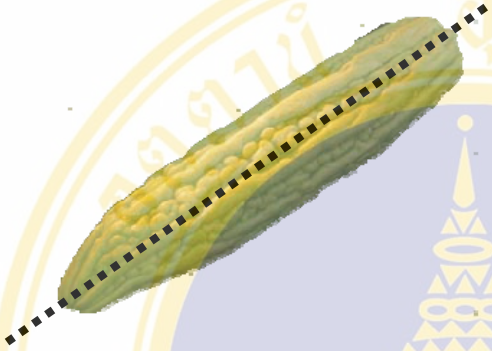
Copyright by Mahidol University

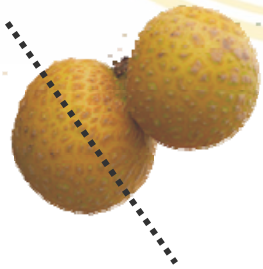
2. Draw the following 3D pictures in daily life

1) Present box	2) Tube
3) Triangular prism	4) Bowl

Copyright by Mahidol University

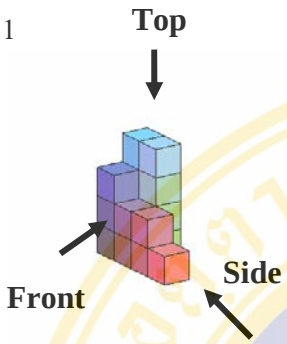
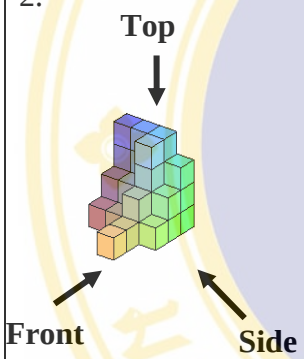
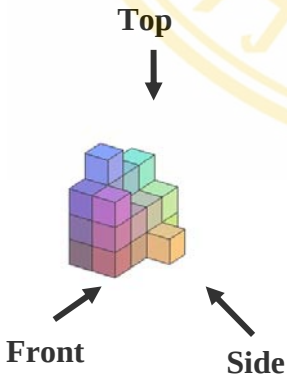
3. Draw the cross-section of the following materials

Vegetable	The cross-section
 Chinese bitter	

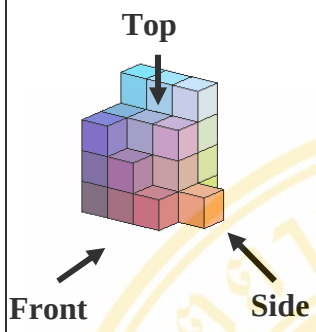
Fruit	The cross-section
 longan	

Copyright by Mahidol University

4. Draw the 2D pictures of 3D building blocks following the given directions.

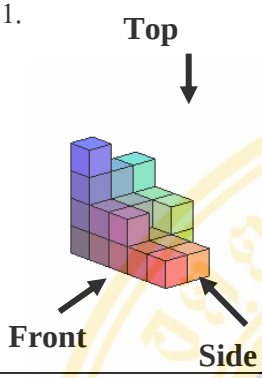
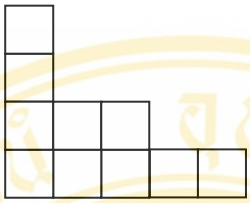
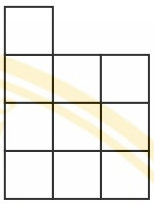
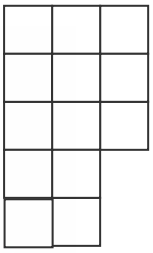
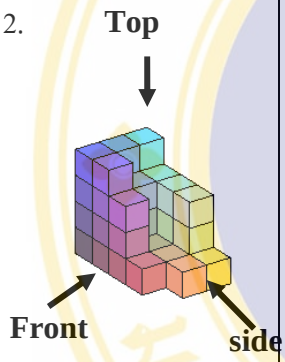
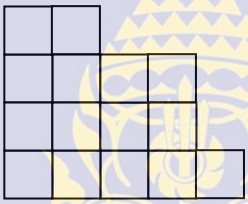
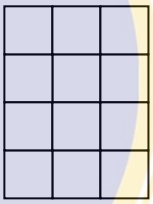
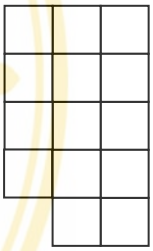
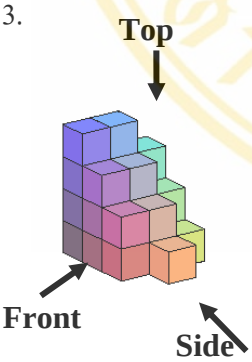
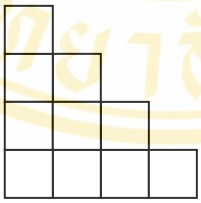
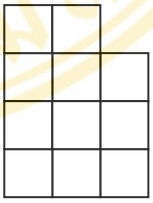
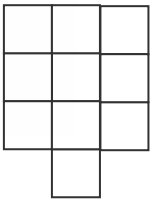
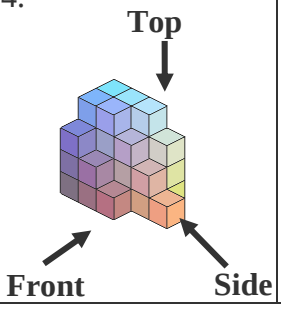
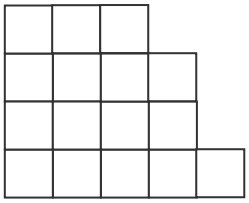
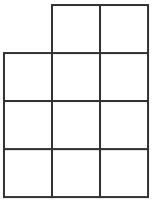
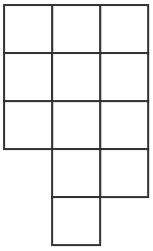
3D blocks	Front-view	Side-view	Top-view
1 			
2. 			
3. 			

Copyright by Mahidol University

3D blocks	Front-view	Side-view	Top-view
4. 			
5.			
6.			

Copyright by Mahidol University

5. Write the number of building-blocks following the front-view, side-view, and top-view

Building-blocks	Front-view	Side-view	Top-view
1. 			
2. 			
3. 			
4. 			

Copyright by Mahidol University

APPENDIX C

Geometry attitude test about 2D-3D pictures

Direction: Fill the blank of 15 items and tick the level channel which you agree with:

5 = strongly agree, 4 = agree, 3 = undecided, 2 = disagree, 1 = strongly disagree

Item	5	4	3	2	1
1. Geometry has no relevance in my life.					
2. I can see ways of using geometry concepts to solve everyday problems.					
3. I believe that I will need geometry for my future.					
4. Geometry problems are boring.					
5. I often have trouble solving geometry problems.					
6. I feel sure of myself when doing geometry problems.					
7. I am confident that if I work long enough on a geometry problem, I will be able to solve it.					
8. I am sure that I can learn geometry concepts.					
9. Geometry is an interesting subject to study.					
10. I often have trouble solving geometry problems.					
11. Expressing ideas through drawing seems to be a waste of time.					
12. I get nervous when I am asked to drawing.					
13. I would enjoy submitting my drawing for evaluation and publication.					
14. I enjoy drawing.					
15. I don't think I draw as well as other people.					

Copyright by Mahidol University

BIOGRAPHY

NAME	Miss Oradee Noipuk
DATE OF BIRTH	8 June 1982
PLACE OF BIRTH	Suphanburi, Thailand
INSTITUTIONS ATTENDED	Kasetsart University, 2004: Bachelor of Science Srinakharinwirot University, 2005: Diploma, Teaching Profession
SCHOLARSHIP	"The 60th Year Supreme Reign of His Majesty King Bhumibol Adulyadej" in 2007
POSITION&OFFICE	Debsirin Nonthaburi School, Nonthaburi, Thailand Position: Teacher Tel. 085-8009569 Email: lekgy@hotmail.com
HOME ADDRESS	83 Songpeenong, Songpeenong District, Suphanburi, 72110, Thailand

Copyright by Mahidol University