Enhancing Students' Understanding Statistics with TinkerPlots: Problem-Based Learning Approach

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Abstract

The purpose of the research study was to explore the effectiveness of using TinkerPlots dynamic software and problem-based learning approach in statistics classes. The research study was conducted in the Education Year of 2009. The subjects were students and teachers from secondary school in Bangkok, Thailand. The pre-test and post-test control group design was used in the study. The experimental group learned statistics using TinkerPlots dynamic software and problem-based learning approach. The control group learned statistics through problem-based learning. The data collection included quantitative and qualitative methods. The research finding showed that if it is appropriately employed, TinkerPlots dynamic software can be used as an effective tool in enhancing active learning and students' understanding in statistics. In addition, the students had positive attitude toward statistics after they learned statistics using TinkerPlots dynamic software.

Introduction

This paper aims to explore the effectiveness of using TinkerPlots and problem-based learning approach in statistics classes and to describe how TinkerPlots enhance students' understanding on the topic of descriptive statistics such as central tendency, statistical dispersion, and data presentation. Statistics knowledge can be divided into two parts: conceptual and procedure. The statistics conceptual knowledge includes symbols, and notation, abstract concepts formulas, and proofs. The abstract concept of the *variance* is one of the topics that students learned without understanding. That is because the students have to work on this topic through drill, practice and memorize the formulas without understanding.

Problem-Based Learning (PBL) Approach

From year 1996 until present, student-centered learning is compulsory method of teaching in Thailand (Ministry of Education, 1996). The problem-based learning (PBL) is one of the student-centered learning activities, and it is integrated in the teaching and learning in secondary mathematics curriculum. PBL is an instructional method that challenges students to "**learn to learn,**" working cooperatively in groups to seek solutions to real world problems. Students engage in PBL generally work in cooperative groups for extended periods of time, and seek out multiple sources of information (Oon - Seng Tan, 2003). According to Savin-Baden, M & Howell Major (2004) the problem-based learning

promotes collaboration among students, between students and the teacher, and between students and the community as well.

According to Sierpinska (1994), understanding is the mental experience of a person by which he/she relates an object to another object. Personal understanding of a concept is grasping or acquiring the meaning of the object. Understanding is a matter of being able to do a variety of thought-provoking things with a topic, such as explaining, finding evidence and examples general listing, applying and representing the topic in new ways. (Blythe,1998). Richard Skemp (1978) made a powerful statement about mathematical understanding. He described two different meanings generally associated with "understanding". They are *relational understanding* and *instrumental understanding*. He explained the first one as "knowing both what to do and why" where as the instrumental understanding he described as "rules without reasons." According to Skemp, *relational understanding* involves understanding structures and connections within concepts. Relational knowledge of statistics is characterized by the possession of conceptual structures that enable the student to construct several plans for performing a given task. In contrast, *instrumental understanding* demonstrates ability to manipulate formulas and carry out operation. The instrumental knowledge of statistics is knowledge of a set of "fixed plans" for performing statistics tasks. The characteristic of these plans is that they prescribe a step-by-step procedure to be followed in performing a given task, with each step determining the next. (Skemp, 1978, p.14).

However, learning statistics concepts and skills are active process. The students should learn by investigating, exploring, and collecting data by themselves. These activities shall enable students to create relationships in their own minds and constructing their own knowledge derived from basic knowledge and experiences during statistics classes. In addition, by using the dynamic software in statistics such as "TinkerPlots" the students are able to develop their understanding in statistics including grasp of basic concepts before they study advanced topics in Normal distribution.

Therefore, in order to help students learn statistics with understanding the teacher should facilitate the construction of ideas concepts and processes through a careful selection of resource materials and relevant with the real world problems. The students should be actively involved in the learning process and work as a team.

TinkerPlots in Thailand

TinkerPlots is one of the dynamic statistics software that provides opportunities for students to explore real data investigate and discover statistics concepts such as data presentation and concepts. TinkerPlots©2005 is a trademark of the University of Massachusetts. The Software Designers are Clifford Konold, and Craig D. Miller. The Publisher of TinkerPlots©2005 is Steven Rasmussen of Key Curriculum Press. The technical support and more information of TinkerPlots are from the website www.keypress.com.

TinkerPlots empower students to use their ability to create graphical representation, which will enable them to develop their visualization skills, thinking skills, concepts and understanding. According to Clifford Konold (2005) students can use TinkerPlots to deepen their understanding of data analysis. Having to create plots from scratch can also help students understand graphs (for example, histogram or bar graphs) are truly doing to data.

TinkerPlots was introduced in Thailand in Year 2008. The Institute for the Promotion of Teaching Science and Technology (IPST) conducted TinkerPlots workshops for pilot group of mathematics teachers. They were trained to use TinkerPlots as a tool in their statistics classes. The research fundings on the implementation and effects of using

TinkerPlots in statistics were granted to at least 30 schools throughout Thailand in Education Year 2009.

Method and Procedure

This study was a case study and the purpose of the study was to explore the effectiveness of using TinkerPlots dynamic software incorporate with problem-based learning approach in statistics classes. The research study was conducted in May –July 2009. The subjects were teachers and Grade 9 students of Thaweetapisek Secondary School, Bangkok, Thailand. They are at 14-15 year-old students. Since it was not possible to randomly assign individual student to experimental class or control class, a quasi-experimental design was employed. The experimental class learned statistics using TinkerPlots dynamic software incorporate with PBL approach. Where as, the control class learned statistics using PBL approach, paper-and-pencil without Information Technology (IT).

The statistics achievement tests were administered to all students in the sample. The test was conducted on two occasions as a pre-test, and post-test. The purpose of the pre-test was to examine the students' prior knowledge in order to provide a baseline before the experiment. The post-test was used to measure the students' knowledge after the treatments had been applied

In addition, the attitude toward statistics questionnaire was administered to assess students' attitude to learning statistics using TinkerPlots. The questionnaire was constructed using a Likert scale, and consisted of ten statements about statistics. The students' responses indicated the degree to which they agreed or disagreed with each statement on a four-point scale of *strongly disagree, disagree, agree* and *strongly agree.*

Research Questions

1. How TinkerPlots can be used to enhance students' understanding in descriptive statistics?
2. What are the effects of TinkerPlots on the statistics achievement of Grade 9 students?
3. What are the effects of TinkerPlots on the students' attitudes towards statistics?

How TinkerPlots can be used to enhance students' understanding in descriptive statistics?

The following examples show how TinkerPlots enhance students' understanding in statistics. The example of PBL problem is as following.

> *The school arranged weekend trip to the beach for 61 students at grade 5, grade 6 and grade 7. The students were told that they have to bring* ***a small backpack and minimum weight****. The PBL questions were*
> - *Which students tend to carry heavier backpacks girls or boys?*
> - *Do students in the higher grades tend to carry heavier backpack than students in the lower grades? and*
> - *What are the reasons that they have to bring a small backpack and minimum weight?*
>
> *The students were assigned to collect data during the weekend trip. They weight all of the backpacks to find out the solutions.*

The display of the survey data on students' backpack using TinkerPlots are as follows:

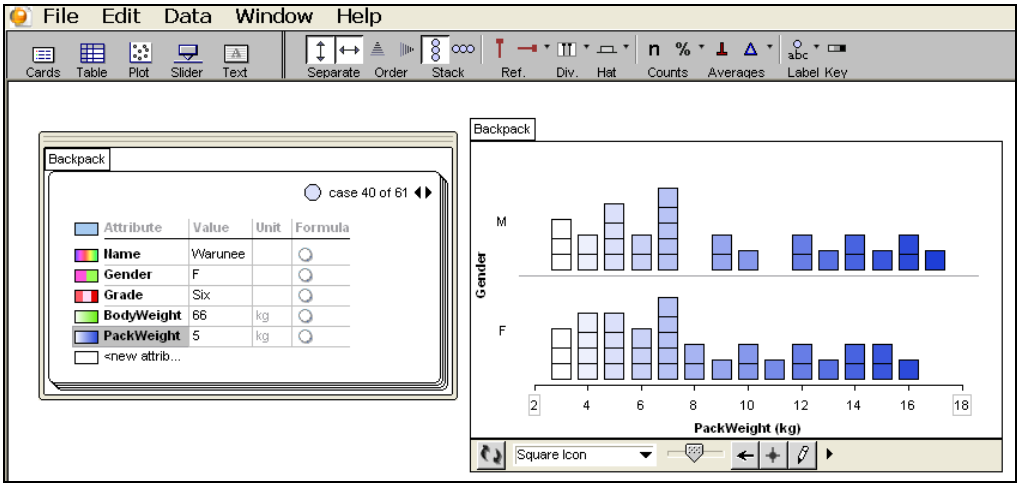


Figure 1: Display Data Cards and Data Presentation using Square Icon

In the area of the graph plot, the students can drag any case icon either to right or up to make two groups or more. Bin lines will appear between the groups. The students can add symbols to a graph to show the location of the mean, median or mode of a numeric attribute. (as shown in Figure 2)

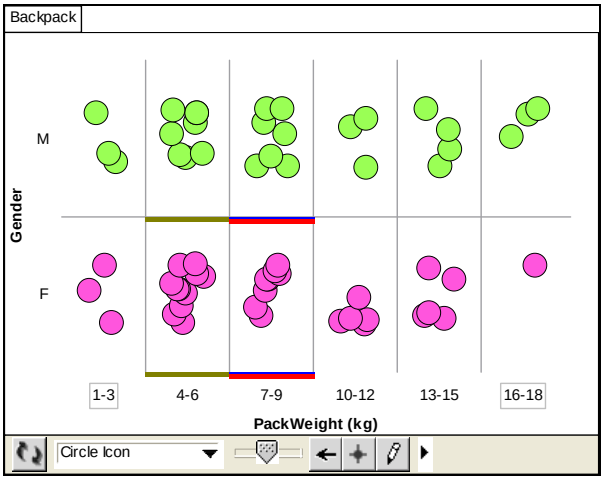


Figure 2 Display Dot Plot Graph of Students' Backpack Weight and Separate Gender

The Histogram display in Figure 3 shows that a male tend to carry heavier backpacks than a female.

The symbol triangles show the mean of weight of male is 8.6 kg, where as the mean of weight of female is 8.0 kg.

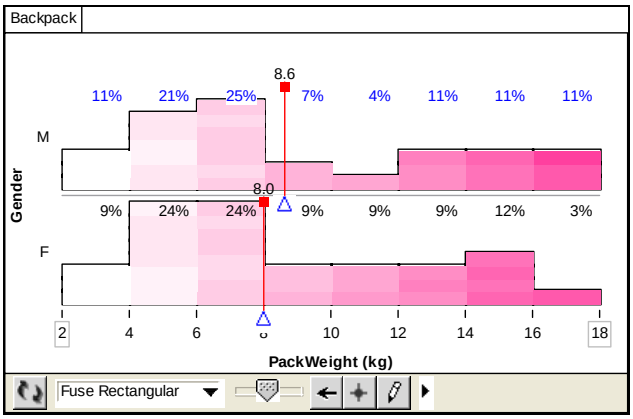


Figure 3 Display Mean and Percentage of the Weight of Students' Backpack

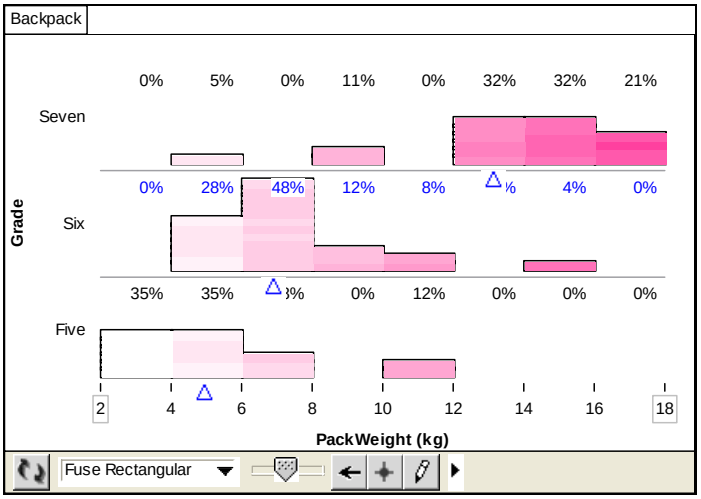


Figure 4 Histogram and Percentage of the Weight of Students' Backpack Separate by Grades

The Histograms in Figure 4 show that grade 7 tend to carry heavier backpacks than grade 5 and grade 6.

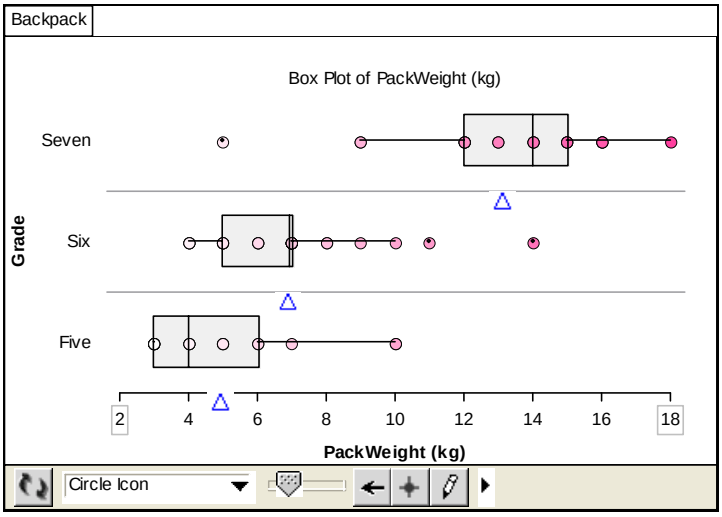


Figure 5 Box Plots, Outliers and Means of the Weight of Students' Backpack Separate by Grades

The Box Plots in Figure 5 show that the older students tend to carry heavier backpacks than the younger students.

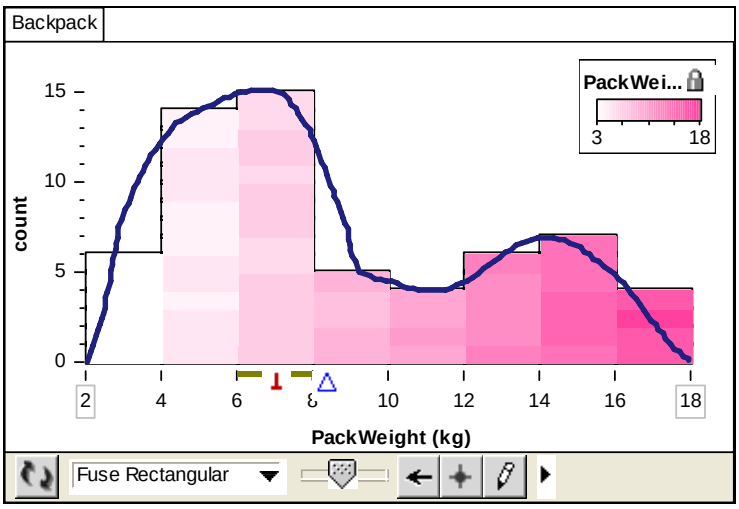


Figure 6 Draw on Plot to show a trend

TinkerPlots enable teacher and students to use a drawing tool to draw on a plot to show a trend or to call attention to particular parts of the graph.

As described, the students were able to build their plots to explore and analyze the data. The students used TinkerPlots to deepen their understanding of data analysis and came up with the solutions to the questions given.

What are the Effects of Tinkerplots on the Students' Statistics Achievement?

This section describes the statistical analysis of the students' statistics achievement scores for the experimental class and control class in order to address Research question 2: *What are the effects of TinkerPlots on the statistics achievement of Grade 9 students?* The researcher used the results of the students' statistics achievement to examine the effect of using TinkerPlots on the statistics achievement of Grade 9 students. The means and standard deviations of the score of students' statistics achievements by test occasions and teaching strategies present in Table 1.

Table 1 Means and Standard Deviations for the Statistics Achievement Test by Test Occasions and Teaching Strategy

Test occasions	Teaching Statistics					
	PBL and TinkerPlots (Experiment Class)			PBL without IT (Control Class)		
	n	Mean	SD	n	Mean	SD
Pre-test	51	9.66	2.97	49	9.91	2.80
Post-test	51	13.98	2.67	49	12.51	2.64

In order to decide whether the experimental treatment of using PBL and TinkerPlots had a statistically significant effect on students' statistics achievement, the data from the two occasions of the pre-test and post-test were analysed using the quantitative analysis methods: Student's *t*-test, at a level of significance of $p = 0.05$. The purpose of the pre-test was to measure pupils' prior knowledge as a baseline before the experiment. In addition, the pre-test was used to examine the equivalence between the experimental and control class. The results are shown in Table 2 and Table 3 below.

Table 2 Results of the t-test on Pre-test Scores

Group	df	Mean	SD	t	Sig.
Experimental Class	98	9.66	2.97	-.435	.664
Control Class		9.91	2.80		

$p < .05$

The *t*-value for the differences in means between the experiment class (using PBL and TinkerPlots) was -.435 , which is non-significant at the $p = 0.05$ level. Based on this test, the experiment class and control class were equivalent groups.

Table 3 Results of the t-test on Post-test Scores

Group	df	Mean	SD	t	Sig.
Experimental Class	98	13.98	2.67	2.75*	.007
Control Class		12.51	2.64		

*P** < .05

Base on the data analysis from Table 3, the t-value for the effect (teaching strategy) was 2.75, which is significant at the $p = 0.05$ level. This indicates that the mean of students' statistics achievement of the experiment class (using PBL and TinkerPlots) on the post-test was significantly better than the mean for control class (using PBL without IT). This analysis indicated that the students's statistics achievement in the experimental class performed significantly better than the control class.

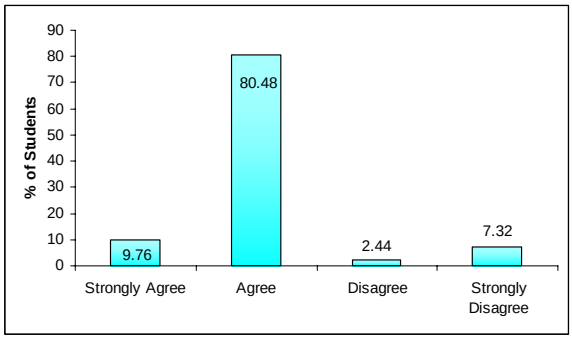
What are the Effects of TinkerPlots on the Students' Attitudes towards Statistics?

The attitude toward statistics questionnaire was administered to students in the experiment class in order to assess students' attitude to learning statistics. The percentage of the students' feedback are shown in Table 4 below.

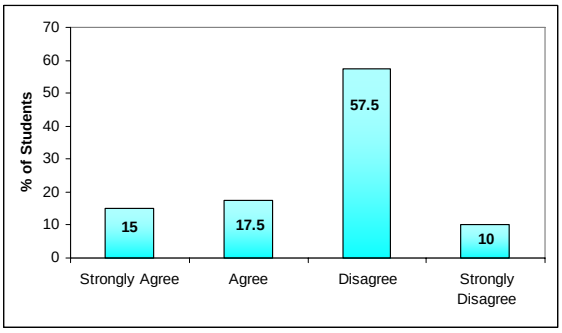
Table 4 Percentage of Students' Attitude Toward Statistics

Item	Content	Strongly Agree %	Agree %	Disagree %	Strongly Disagree %
1	I like statistics.	9.76	80.48	2.44	7.32
2.	The teacher should have more statistics lessons each week.	12.19	43.91	34.14	9.76
3	I want to learn statistics more than other subjects.	4.88	29.27	58.53	7.32
4	It is take long time to do the exercise in statistics.	12.50	30.00	42.50	15.00
5	I like to solve problems in statistics.	7.50	57.50	22.50	12.50
6	I find statistics class boring.	7.50	30.00	50.00	12.50
7	I do not look forward to statistics lesson.	5.00	17.50	60.00	17.50
8	Learning statistics is fun.	10.00	50.00	32.50	7.50
9	I do not like statistics because there are too many formulas to memorize.	15.00	17.50	57.50	10.00
10	I don't want to work on problems in statistics.	5.00	22.50	62.50	10.00

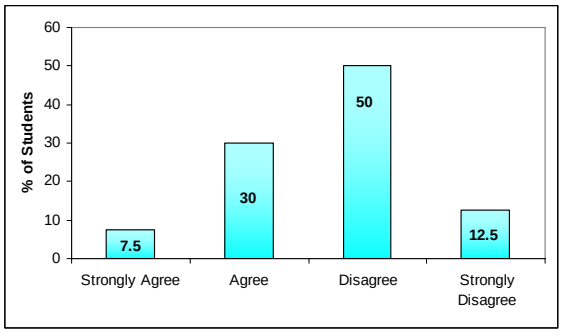
The graphs in the Figures below reveal that in the experimental class, the students' attitudes to learning statistics are consistent.



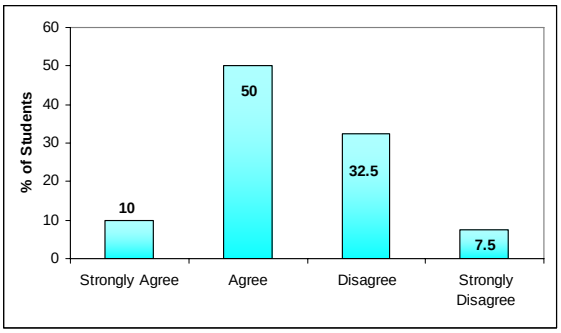
1. I like statistics.



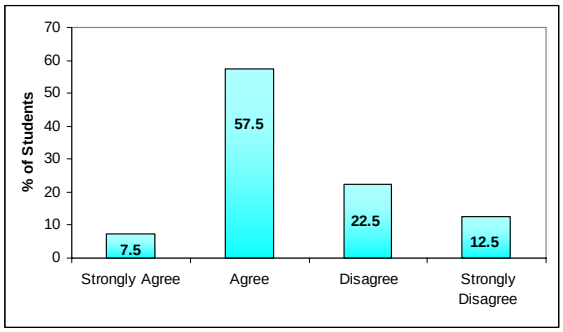
9. I do not like statistics because there are too many formulas to memorize.



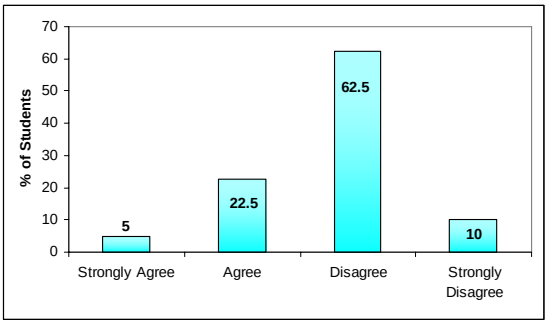
6. I find statistics class boring.



8. Learning statistics is fun.



5. I like to solve problems in statistics.



10. I don't want to work on problems in statistics.

Figure 7 Display the consistency of students' attitude toward statistics

The data pertaining to statements relating to the attitude of students toward statistics reveal that in the experiment class, the students had consistence in their answer to the questionnaire. As can be seen from the Figure7, the statements in each row consist of positive and negative statements but they are similar meaning. The bar charts in Figure 7 show that the students had their perceptions in the same direction. For example, Statement item: 1 *I like statistics* and Statement item: 9 *I do not like statistics because there are too many formulas to memorize.* And Statement item: 6. *I find statistics class boring* and Statement item: 8. *Learning statistics is fun.*

Students' Perception on the Use of TinkerPlots in Statistics

The summary of students' perception on the use of TinkerPlots, which derived from the interviews with the students in the experimental class and the findings are as follows:

- I think using TinkerPlots save a lot of time, faster and convenience (20%);
- Using TinkerPlots is very useful, I learn better and faster. now, the statistics class is fun and interesting (20%);
- TinkerPlots is friendly user, however if the program is in Thai language it will be much better. (26%)
- TinkerPlots is very useful in data presentation and it made things faster for us (16%)
- TinkerPlots took time to get used to. I was confused in the first week but once I get to know what to do, it can help me a lot (17%).

Conclusion

The research finding showed that if it is appropriately employed, TinkerPlots dynamic software can be used as an effective tool in enhancing active learning and students' understanding in statistics. In addition, the students had positive attitude toward statistics after they learned statistics using TinkerPlots dynamic software.

References

Brodesky, A., Doherty, A., & Stoddard, J. (2008). *Digging into Data with TinkerPlots*. Emeryville, CA: Key Curriculum Press.

Blythe, T. (1998). *Teaching for understanding guide.* San Francisco, CA: Jossey-Boss Inc.

Demana, F., & Waits, B. (1990). Enhancing mathematics teaching and learning through technology. *NCTM 1990 Yearbook* (pp. 145–154). Reston, VA: National Council of Teachers of Mathematics.

Demana, F., & Waits, B. (1990). The role of technology in teaching mathematics. *The Mathematics Teacher, 82*(1), 345–350.

Konold, C. (2005). *Exploring Data with TinkerPlots.* Emeryville, CA: Key Curriculum Press.

Key Curriculum Press. (2009). *TinkerPlots Dynamic Data Exploration.* Retrieved August12, 2009. from www.keypress.com/x5715.xml

Ministry of Education, Thailand. (1996). *Education reform at the Ministry of Education Thailand.* Bangkok: External Relations Division, Ministry of Education.

Ministry of Education. (2006). *Education in Thailand 2005/2006.* Bangkok: OEC Publication.

Oon-Seng, Tan (2003). *Problem-based learning Innovation: Using problems to power learning in the 21st Century*. Singapore: Seng Lee Press

Savin Baden, M. & Howell Major,C. (2004). *Foundations of Problem-Based Learning*. England: Open University Press.

Sierpinska, A. (1994). *Understanding in mathematics.* London: The Falmer Press.

Skemp, R.R. (1978). Relational understanding and instrumental understanding. *Arithmetic Teacher,* 26(3), 9-15.

Stodolsky, S. S. (1985). Telling math: Origins of math aversion and anxiety. *Educational Psychologist, 20,* 125–133.

Vidic, A.D. (2006). A Model of Teaching Basic Engineering Statistics in Slovenia. *Metodoloski Zvezki*, Vol. 3 No.1 2006, 163-183.

Walsh, T. (2009). *The Survey Toolkit: Collecting Information, Analyzing Data, and writing Reports*. Emeryville, CA: Key Curriculum Press.

Wiske, M. S. (1998). *Teaching for understanding: Linking research with practice.* San Francisco: Jossey-Boss Inc.

The author gratefully acknowledges to the Principal of Thaweetapisek School, Bangkok, Thailand, students and the teachers who were involved in this research, especially Miss Piromya Kurustien for their cooperation and contribution. The author also acknowledges her gratitude to Suan Sunandha Rajabhat University Bangkok, Thailand for supporting and funding this research project.