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The Use of The K-W-D-L Technique in the Development of Grade 10 Students' Mathematical Problem-Solving Abilities

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Abstract

The purposes of the study were to investigate the effectiveness of the K-W-D-L technique on grade 10 students' mathematical problem-solving abilities and to study the students' attitudes toward learning mathematics after participating in learning management designed using the K-W-D-L technique. The participants were 40 grade 10 students in a public school in Thailand selected using a purposive sampling method. The instruments were learning management designed using the K-W-D-L technique to teach the fundamental concept of counting in mathematics class, a mathematic problem-solving test, and an attitude survey questionnaire. The data were analyzed using percentage, mean score, standard deviation, single sample t-test, and effectiveness index. The study's findings indicate that the K-W-D-L learning management was effective in developing Thai participants' mathematical problem-solving abilities and that the participants expressed satisfaction with the method. The study's findings may have implications in both educational and academic settings.

Keywords: K-W-D-L technique, Mathematical problem-solving, Mathematics education

1. Introduction

Mathematics is a foundational topic for students at all educational levels, including elementary, middle, and high schools, as well as further education (in the science-related majors). Students who have a strong grasp of mathematics skills can solve equations, correct chemistry issues, write computer commands, and do a variety of other tasks (Cockcroft, 1986). However, it should be highlighted that teaching mathematics requires learners to engage in extensive cognitive processing and provides opportunities for learners to engage in organized activities that aid in their comprehension of how the mathematical system works. This takes time and effort on the part of both the learner and the teacher, therefore it's unsurprising that mathematics is regarded as one of the most challenging topics in schools (Scarpello, 2007).

It's worth noting that mathematical problem-solving ability is widely believed to be a critical component of mathematics class achievement. To put it another way, strengthening students' ability to solve mathematical issues benefits their thinking processes. The learning experience received when attempting to solve mathematical problems allows students to practice applying mathematical components in real-world situations. The process of problem-solving is the underlying concept of mathematics since it not only allows students to comprehend the subject but also aids in the development of higher-order thinking such as analytical and critical thinking skills that are essential in learning scientific fields (Kannan et al., 2016). Therefore, it is not hyperbole to assert that developing mathematical problem-solving skills is just as critical in a math curriculum as teaching mathematical content (Tao, 2006).

Mathematical problem-solving abilities, on the other hand, are not acquired easily. Students may struggle to think of mathematical elements that can be used to solve a problem or an appropriate answer in certain circumstances. One of the difficulties in teaching mathematics is that students are more concerned with the superficial qualities of issues than with discovering a model that may be utilized as a solution (Degrande et al., 2016). At a contextual level, Thai students also appear to struggle with maths and developing mathematical problem-solving abilities. According to Janponto et al. (2020), Thai school students were unable to recognize mathematical elements and apply mathematical methods to solve mathematical problems. This impairs their ability to study mathematics and degrades the overall quality of national education.

Notably, strengthening students' ability to answer mathematical issues requires an instructional strategy that allows them to practice thinking methodically and utilizing an appropriate model to solve mathematical problems. The K-W-D-L technique (what we know-what we want to know-what we did-what we learned) was developed by Shaw et al. (1997) to be an alternative method for KWL teaching strategy (Carr & Ogle, 1987) in mathematical problem-solving. In the K-W-D-L learning processes, learners are trained to ask a systematic set of questions leading to mathematical problem-solving. The questions consist of what we **k**now about the problems, what elements we **w**ant to solve the problems, what we **d**id in solving the problems, and what we **l**earn after using the solution. This would allow learners to practice applying systematic thinking in mathematical problem-solving.

Given the importance of mathematical problem-solving abilities in mathematics classrooms and the potential for developing these abilities through the K-W-D-L technique, we sought to use the teaching model to create a learning management system that would benefit students' mathematical problem-solving abilities. The purposes of the study were to investigate the effectiveness of the K-W-D-L technique on grade 10 students' mathematical problem-solving abilities and to study students' attitudes toward the teaching technique.

2. Literature Review

2.1 Mathematical Problem Solving

It should be emphasized that the ability to solve mathematical problems is critical in the acquisition of mathematics. Unless being able to apply the mathematical concepts learned in class to answer mathematical problems in exercises or tests, according to Tao (2006), the student's understanding of the subject cannot be deemed complete. It's worth noting that problem-solving requires processes, and teachers must teach problem-solvers mathematical problem-solving abilities by allowing them to transform circumstances into ones that can be solved using mathematical knowledge. This would aid students in making connections between classroom material and real-world applications (Ortiz, 2016).

It should also be noted that mathematics and problem-solving were originally taken from the two principles. Polya (1945) simplified pedagogical problem-solving by introducing four steps: recognizing problems, designing strategies, implementing plans, and reflecting on results. Later, Schoenfeld (1985) extended the principle to mathematical problem-solving abilities, asserting that mathematical thinking and cognition are critical factors in students' capacity to make sense of mathematics. Thus, to tackle mathematical issues efficiently, learners must develop a mathematical mindset. Consequently, learners need to develop their thinking processes to improve their abilities in solving mathematical problems. They need to systemically process the problems to apply appropriate solutions. Mathematical thinking could be developed and used in problem analysis, solution planning, execution, and reflection.

2.2 K-W-D-L Technique

The K-W-D-L technique is introduced with the idea to develop learners' thinking processes using a set of questions leading to the solution to mathematical problems (Shaw et al., 1997). The method was developed from the KWL technique. Therefore, it utilizes memory, cognition, and compensation in designing activities. In detail, the K-W-D-L technique encourages learners to make associations and review the owned knowledge, manipulate them to transform the knowledge using repetition, information processing, and summarizing, and allow learners to utilize the synthesized knowledge in problem-solving (Mahdi, 2018). An example of learning activities in the K-W-D-L technique could be seen below.

2.2.1 What We Know

The activities should be introduced by the direct instruction of the class contents. The students are then given exercises with a set of questions leading the solution to the problems.

The first question is "What do we know" which encourages learners to think about elements that the problems provide.

2.2.2 What We Want

In this stage, students are asked to think about possible solutions to the problems. The information in the first stage could be used. The selected solution must be explained.

2.2.3 What We Did

The third stage is to use the solution in fixing mathematical problems.

2.2.4 What We Learned

In the end, students need to summarize the whole process of problem-solving and give the answers to the questions.

What we know	*What we want*	*What we did*	*What we learned*
What elements are given by the situation? 1…… 2…… 3…… 4……	What is the situation leading to? …… …… …… Possible solutions 1…… 2…… Rationale …… …… ……..	Present mathematical problem-solving	Answer …… …… …… …… Summary …… …… …… ……

Figure 1. An example of the K-W-D-L technique

It could be seen that the processes of the K-W-D-L technique are similar to problem-solving processes presented by Polya (1945). The students analyze information to find plans. The plan is later executed and reviewed. Therefore, it should help learners develop their problem-solving ability.

2.3 Previous Studies

Since the K-W-D-L technique applies the same principle as the KWL strategy, the studies related to the KWL are also considered in the synthesis. In summary, it was found that the teaching strategies were proved to be beneficial in mathematics education in terms of learning achievement (*e.g.*, El-Rahman, 2011; Tok, 2013), learning psychology (*e.g.*, Aseeri , 2020; Moradpour, 2016), and mathematical problem-solving skills (*e.g.*, Smith, 2008; Usta &

Yılmaz, 2020). It can be noted from the results of the previous studies that the instructional model can be used to develop students' abilities in mathematics classes. Moreover, teaching learners to ask appropriate questions helps in developing their thinking processes. However, the number of studies employing the K-W-D-L technique in teaching mathematical problem-solving abilities is still limited. Therefore, this study aims to extend the evidence that supports the instructional technique in developing the students' abilities by employing it in a mathematics class of grade 10 students in Thailand.

3. Methodology

3.1 Research Design

The study utilized a single-group experimental design. The K-W-D-L technique was used to design learning management activities. The ability of participants to solve learning problems while learning in the learning management system at the end of the data collection was used to determine the effectiveness of the method. Additionally, the students' satisfaction with learning was also examined.

3.2 Participants

The participants were 40 grade 10 students in a public school in Thailand. They were selected using a purposive sampling method. The main criterion was their homogenous mathematical skills judged by GPA. They were learning the fundamental concept of counting in the course. The participants took a semester (15 hours) learning with the processes of the K-W-D-L technique. They were treated anonymously.

3.3 Instruments

The instruments were learning management designed using the K-W-D-L technique to teach the fundamental concept of counting in mathematics class, a mathematic problem-solving test, and a satisfaction questionnaire. In detail, the learning management includes 8 lesson plans taking 15 hours. The mathematic problem-solving test was a written test consisting of 8 questions items. The test was proved to have appropriate difficulty (P_E = .2-.59), discrimination (D = .7-.78), and reliability (α = .89). The questionnaire consists of 15 question items related to satisfaction with the learning management. It was developed with the validity of .8-1.0 discrimination of .30-.85, and reliability of .93.

3.4 Data Analysis

The data were analyzed using percentage, mean score, standard deviation, single sample t-test, and effectiveness index.

4. Results

The study's first objective was to determine the effectiveness of a learning management system based on the K-W-D-L technique on the mathematical problem-solving abilities of Thai grade 10 students. The result of the study could be discussed below.

Table 1. The participants' performance after learning the K-W-D-L technique

N	$\bar{x}$	$\mu_0$70%	S.D.	t	Sig.
40	72.53	67	2.46	3.17	.003*

Note. $P < .05$.

The study's findings indicate that participants' mathematical problem-solving abilities improved after they learned about learning management compared to the criterion of 70. A single samples t-test indicates that the participants' mathematical problem-solving abilities were higher ($\bar{x}$ = 72.53, SD = 2.46) than the criteria, t = 3.17, p = .003. It could be interpreted that the K-W-D-L technique could help the participants develop their abilities at a level that reached the determining criterion.

Table 2. Process effectiveness of the K-W-D-L technique on the participants' mathematical problem-solving abilities

Effectiveness	Full mark	$\bar{x}$	S.D.	Percentage
Process effectiveness (E_1)	96	75.75	2.79	78.90
Outcome effectiveness (E_2)	96	72.53	2.46	75.55
The effectiveness index (E_1/E_2) = 78.90/75.55				

The result of the study indicates that participants' average score in exercises during the processes of the K-W-D-L technique was 75.75 out of 96 full marks (E_1 = 78.90) while the average score of the students after using the learning management was 72.53 out of 96 full marks (E_2 = 75.55). Therefore, the effectiveness index of the learning management was 78.90/75.55 meeting the determining criterion of 70/70. It could be argued that students participating in the K-W-D-L activities can improve their mathematical problem-solving ability both during and after the class process is complete.

Moreover, the study also seeks to investigate the participants' satisfaction with learning management. The result of the study can be seen below.

Table 3. Students' attitudes toward learning mathematic

No.	Statement	$\bar{x}$	S.D.
	Positive statements toward mathematics learning		
1	I feel that mathematics helps learners to considerably process information.	4.95	0.22
2	I feel that mathematics is useful in daily life.	4.60	0.50
3	I feel that mathematics makes me sharp.	4.63	0.49
4	I feel that mathematics makes me confident in decision-making.	4.60	0.50
5	I feel that mathematics practices me to think systematically.	4.25	0.44
6	I feel that I like solving mathematical problems.	4.38	0.59
7	I enjoy mathematics activities.	4.55	0.50
8	I am eager to find a new piece of mathematics knowledge.	4.53	0.51
9	I like participating in mathematics activities.	4.23	0.53
	Overall	4.47	0.51
	Negative statements toward mathematics learning		
1	I feel that mathematics is difficult and complicated.	3.63	0.70
2	I feel that mathematics is difficult to learn and stressful.	3.60	0.90
3	I usually avoid doing unfamiliar mathematics exercises.	3.75	0.74
4	I usually avoid answering mathematics questions.	3.65	0.66
5	I feel anxious when taking mathematics tests and do not enjoy mathematics.	3.48	0.75
6	I usually avoid using mathematical problem-solving.	3.53	0.51
	Overall	3.60	0.71
	Overall student attitude	4.15	0.76

It can be seen that the participants' overall attitude toward learning mathematics after using the learning management was at a high level ($\bar{x}$ = 4.15, S.D. = 0.76). In detail, the participants agreed with the positive statements related to mathematical learning ($\bar{x}$ = 4.47, S.D. = 0.51) and disagreed with the negative statements on the subject ($\bar{x}$ = 3.60, S.D. = 0.71) after participating in the learning management designed using the K-W-D-L technique. Therefore, it could be concluded that the participants experienced the K-W-D-L technique as an instructional model that could assist them in learning mathematics more effectively, and they expressed an eagerness to learn how to solve mathematical problems and develop their thinking processes. As a consequence, one could argue that participants were satisfied with their experience learning mathematical problem-solving through the K-W-D-L activities.

5. Discussion

Regarding the results of the study, we noticed that there are some features worth discussing.

5.1 The Benefit of the K-W-D-L Technique on Students' Mathematical Problem-Solving

First, the study's findings confirm the K-W-D-L technique has efficacy in developing students' problem-solving abilities in mathematics classes. Our findings corroborate previous research (Smith, 2008; Usta & Yılmaz, 2020), which indicates that employing inquiry-based teaching strategies such as KWL and K-W-D-L can help improve mathematical problem-solving abilities. In the current study, it could be noticed that the leading question in the activities helped learners to process information to make plans. Plans are then considered thoroughly again by another leading question before they are executed in solving maths problems. Lastly, the reflection processes would allow learners to review what they did, what they achieved, and what they learned. This helped them practice thinking systematically and resulted in the development of mathematical problem-solving abilities.

5.2 The Practice of Thinking Through Questioning

It could also be noted that developing mathematical problem-solving abilities need practical activities of thinking. In this study, meaningful questioning provided by the K-W-D-L activities played an important role in making the participants achieve their goals in learning. The results of the study confirm the benefits of systematical questioning in the development of mindful learning. According to Carr and Ogle (1987) and Shaw et al. (1997), learning activities should encourage learners to ask questions and find the answer themselves. The role of the teachers is to verify the thinking practice and guide learners back to the way the activities lead them to ask the right questions.

5.3 Participants' Positive Attitudes Toward the Instructional Technique

Moreover, the findings of the second purpose support the findings carried out by other researchers, as the teaching technique was practical and brought about a learnable class atmosphere (Moradpou et al., 2016). In Moradpou et al. (2016) the K-W-D-L technique was found to increase students' self-efficiency and reduce test anxiety in mathematics classes. Likewise, the results of the study also signify participants' positive attitude toward the instruction. This could be an account of the meaningful learning experience and facilitation given by teachers in the K-W-D-L processes.

6. Conclusion

The study's findings indicate that the K-W-D-L learning management was effective in developing Thai grade 10 students' mathematical problem-solving abilities and that the students expressed satisfaction with the method. The study's findings may have implications in the educational setting, as teachers may use the K-W-D-L teaching method in their classes to help students develop their thinking processes, particularly when solving mathematical problems. Additionally, because the method emphasizes information processing, planning, execution, and revision, it can be applied to studies relating to scientific knowledge development.

As a result, additional research should be conducted to determine how the K-W-D-L technique can be used to develop other critical abilities and content in math classes. Qualitative approaches are also encouraged, as they can be used to examine how learners progress through each step of the model. Finally, a quasi-experimental design may reveal differences between SSCS and conventional mathematics instruction.

For the limitations of implementing the method in a mathematical classroom, we found that the K-W-D-L strategy is unfamiliar to schoolteachers. The time factor was also critical in implementing the strategy, as teachers and students had deadlines for completing each mathematical task.

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