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Developing mathematics problem-solving skills among Thai grade 5 students using the KWDL learning management technique

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ABSTRACT

This study investigated the effectiveness of the KWDL technique in improving grade 5 students' problem-solving skills in decimal arithmetic operations. A randomized control group pre-test post-test design was used. The findings revealed a significant improvement in students' ability to solve problems involving decimal arithmetic operations. In addition, the students reported positive experiences and satisfaction with the learning process and management. This study contributes to the field by showing that the KWDL technique can effectively support students in understanding and solving decimal arithmetic problems, providing useful insights for enhancing mathematics teaching practices.

1. Introduction

In mathematics learning, elementary school students move from basic concepts to more complex and demanding ideas (Hook et al., 2007). Decimals, which are the focus of this study, represent one such topic that requires students to advance their understanding in order to perform arithmetic operations with them (Mehmetlioğlu, 2014). Developing problem-solving skills in mathematics is essential, as it strengthens students' self-efficacy and enhances their ability to solve problems effectively. When students meet all aspects of problem-solving competence, they remain motivated, enthusiastic, and able to improve their mathematical thinking (Trirenika et al., 2024; Firmansyah et al., 2024).

Understanding decimals is important because it helps students grasp more advanced mathematical concepts. However, related ideas such as place value in decimals, the connection between decimals and fractions, and the rules of decimal operations can be difficult for learners to master (Kastberg and Morton, 2014). These challenges also make teaching decimals more complex, increasing the burden on teachers and sometimes leading to negative attitudes toward mathematics. Such difficulties may further affect students' overall academic progress.

Consider the struggles of education in the context of Thailand; we can make the connection between mathematics learning and problems in decimal arithmetic operations. To enable the learners of grade 5 to perform the operation, classes should provide them with opportunities to practice thinking systemically. This lies in the learning concept of mathematics, where learners are expected to engage in cognitive processes to link elements of problems to find solutions. This becomes a challenge in Thai education, which is often criticized for its passive and teacher-centered instruction, which does not match the learning of decimal arithmetic operations, as students need active involvement and problem-solving opportunities to apply and practice arithmetic operations in real-life contexts (Dewi et al., 2020; Tiengyoo et al., 2024). This is evident in the national test results, where students across the country have never scored more than 50% of the full mark in the national elementary school mathematics test (NIETS, 2024).

To address these challenges, the KWDL technique can be effectively used in the Thai context as a teaching method that guides students to ask systematic questions while solving problems (Pongsai and Poonputta, 2023; Sawatpon and Polyiem, 2022). This technique is an extension of the KWL method (Ogle, 1986), with the added step "D" to make it more appropriate for mathematical problem-solving. The KWDL process consists of four steps:

- K (Know): What do we know? (What information does the problem give us?)

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- W (Want): What do we want to know? (What are we trying to find?)
- D (Do): What do we do? (Which method should we use to find the answer?)
- L (Learn): What did we learn? (What did we gain from applying the method and solving the problem?)

From a theoretical standpoint, the KWDL technique can help learners succeed in learning mathematics as it sets a circumstance that allows them to engage in the problem-solving process (Ardiyan et al., 2022). Throughout the processes of solving mathematics problems, students are driven to reflect on their existing knowledge (K), identify gaps (W), apply logical steps to find solutions (D), and summarize how the problems are solved (D). Considering cognitive processing, critical thinking, and how it enhances problem-solving skills, it could be seen that the approach has the potential to aid in developing a clear understanding of decimal arithmetic operations.

From a practical point of view, several studies (Alsalhi et al., 2023; Boca and Jermtaisong, 2023; Heebkaew and Seehamongkon, 2024; Pongsai and Poonputta, 2023; Sawatpon and Polyiem, 2022) have examined the impact of the KWDL (Know–Want–Do–Learn) technique in mathematics education. These studies consistently highlight the technique's effectiveness in enhancing students' problem-solving abilities and academic achievement. For instance, Alsalhi et al. (2023) investigated the impact of the Know–Want–Learn (KWL) strategy on mathematics achievement among international students and found that the strategy significantly improved academic performance. Similarly, Boca and Jermtaisong (2023) developed learning activities that integrated the KWDL technique with the Bar Model for lower secondary students, reporting significant gains in problem-solving, comprehension, and overall mathematical skills.

Heebkaew and Seehamongkon (2024) explored the integration of the KWDL technique with Cooperative Learning Management (STAD) to enhance Grade 6 students' problem-solving abilities and academic achievement in decimal operations. Their findings confirmed the effectiveness of this approach in fostering a deeper understanding of and improved performance in decimal-related problems. In a related study, Pongsai and Poonputta (2023) applied the KWDL technique to support Grade 4 students in learning combined mathematical operations. They found that the structured nature of KWDL led to substantial improvements in students' computational abilities.

Further evidence is provided by Sawatpon and Polyiem (2022), who demonstrated that the technique enhanced students' ability to approach and solve complex mathematical problems. Additionally, integrating AI technology with the KWDL technique significantly improved students' mathematical problem-solving skills and overall academic performance.

Both theoretical and empirical findings suggest that the KWDL technique is a promising instructional approach for teaching decimal arithmetic operations in Thai elementary education. In the present study, the principles of KWDL were applied to design a learning management model aimed at developing Grade 5 students' skills in decimal addition, subtraction, multiplication, and division.

This study was conducted within the Thai educational context. According to the 2022 PISA assessment, Thai students had an average mathematics score of 394, marking a 25-point decrease from the 2018 cycle (OECD, 2022). Moreover, the trend in mathematics performance in Thailand has shown a steady decline from PISA 2000 to 2022.

This research was also designed to address gaps in previous studies. While scholars have emphasized the importance of applying the KWDL technique more widely in mathematics instruction, prior research has often relied on limited assessment tools. For example, Heebkaew and Seehamongkon (2024) utilized multiple-choice tests to assess students' problem-solving abilities. However, such assessments may not fully capture students' depth of understanding or the processes they engage in while solving mathematical problems. A more detailed assessment approach, as used in the present study, offers a clearer picture of how learners apply KWDL strategies in problem-solving contexts.

Furthermore, since the KWDL technique promotes systematic thinking and encourages students to ask investigative questions, scholars have advocated for its integration into elementary mathematics instruction. The current study contributes to this body of knowledge by providing evidence that KWDL can effectively support the development of mathematical problem-solving skills at an early stage in students' education. Accordingly, the aim of this study was to implement the KWDL principles to support the development of Thai Grade 5 students' decimal arithmetic problem-solving abilities. The purposes of the study were to examine the effectiveness of the KWDL learning management on Thai grade 5 students' decimal arithmetic operation skills and to examine the participants' satisfaction with the KWDL learning management.

2. Methods

The study employed a randomized control group pre-test-post-test design. The experimental group received instruction through the KWDL learning management approach, while the control group was taught using conventional teaching methods. Both groups were instructed on solving problems involving decimal addition, subtraction, multiplication, and division.

In this study, we focused on Grade 5 students attending a public school in Thailand during the 2024 academic year. They were randomly using a cluster sampling method. The researcher used the classroom as the unit of randomization. The

experimental group consisted of 34 randomly assigned pupils from Class 5/1, whereas the control group comprised 35 students from Class 5/2. The method was chosen to ensure that the sample was representative of the population and to allow for more accurate insights into the effectiveness of the KWDL technique in mathematics education. The treatment of the participants closely adhered to ethical considerations pertaining to human research.

The learning management plan using the KWDL technique for teaching decimal addition, subtraction, multiplication, and division problem-solving for Grade 5 students consists of 6 plans, totaling 6 hours. The plans were reviewed for appropriateness by 3 experts, and all the learning management plans were rated as highly appropriate (with ratings ranging from 4.93 to 4.97).

The problem-solving ability test was initially developed with 10 items, from which 6 were selected for actual implementation. Each item was scored using an analytical rubric, with a maximum of 3 points per item, yielding a total possible score of 18. The test content included two questions on decimal addition, two on decimal subtraction, one on decimal multiplication, and one on decimal division. Content validity was assessed through expert review using the Item-Objective Congruence (IOC) index, which ranged from 0.67 to 1.00, indicating acceptable alignment between test items and learning objectives. A pilot test was conducted with 35 students who were not part of the study sample. The results showed a difficulty index (P) ranging from 0.204 to 0.287 and a discrimination index (D) ranging from 0.333 to 0.556, both within acceptable thresholds. The reliability of the test, calculated using Cronbach's alpha, was 0.864, indicating a high level of internal consistency. This instrument was administered as both a pre-test and a post-test to evaluate students' problem-solving skills in decimal arithmetic operations before and after the instructional intervention.

The satisfaction survey form on the KWDL learning management was designed using a 5-point Likert scale with 10 questions related to the participants' experiences learning with the KWDL techniques. It was developed with a content validity (IOC = 0.67-1.0).

Data collection was conducted following a two-group experimental design (Table 1). Initially, participants in both the experimental and control groups completed a pre-test to assess their existing understanding of decimal arithmetic operations. Subsequently, the experimental group received instruction through the KWDL learning management approach, while the control group was taught using conventional methods. Upon completion of the instructional period, both groups took a post-test to measure learning outcomes. Additionally, students in the experimental group completed a satisfaction survey to evaluate their perceptions of the KWDL learning experience.

We compared experimental and control groups using an independent sample t-test. A paired t-test was used to compare pre-test and post-test scores in the experimental group. While questionnaire data were analyzed using mean scores and standard deviation.

3. Results

Prior to the intervention, the researchers assessed the problem-solving abilities of both the experimental and control groups and found no statistically significant differences between them (Table 2). Following the implementation of the experimental treatment, the results indicated that the students in the experimental group demonstrated significantly higher problem-solving skills than those in the control group, with the difference reaching statistical significance at the .05, It can be seen that the experimental group ($\bar{x}$ = 12.91, SD = 3.52) outperformed the control group ($\bar{x}$ = 4.37, SD = 4.32) on the post-test, $t = 9.02$, $p < 0.05$ $p < .05$, Cohen's d = 2.16. According to Cohen's (1988) criteria, the result represents a very large effect size, suggesting a stronger positive impact of the KWDL approach than traditional learning (Table 3).

Table 1: Data collection

Group	Pre-test	Method of teaching	Post-test
Experiment	The problem-solving skill test	KWDL learning	1. The problem-solving skill test 2. Satisfaction survey form
Control	The problem-solving skill test	Traditional learning	The problem-solving skill test

Table 2: Comparison of problem-solving skills between experimental and control groups before the intervention

Test	Group	n	Score total	$\bar{x}$	S.D.	t	p
Pre-test	Experiment	34	18	1.94	2.96	1.06	0.15
	Control	35	18	1.31	1.78		

S.D.: Standard deviation

Table 3: Comparison of decimal arithmetic problem-solving skills between experimental and control groups

Test	Group	n	Score total	$\bar{x}$	S.D.	t	p	Effect size (Cohen's d)
Post-test	Experiment	34	18	12.91	3.52	9.02	0.00*	2.16
	Control	35	18	4.37	4.32			

*: $p < .05$

A comparison of participants' problem-solving skills in decimal arithmetic operations before and after the implementation of the KWDL learning management approach revealed a statistically

significant improvement. The mean post-test score ($\bar{x}$ = 12.91) was substantially higher than the mean pre-test score ($\bar{x}$ = 1.94), t = 21.77, p < .05, Cohen's d = 3.37. According to Cohen's (1988) criteria, this represents a very large effect size, suggesting a strong positive impact of the KWDL approach on participants' problem-solving abilities (Table 4).

Therefore, it can be concluded that the KWDL technique effectively supported the development of participants' problem-solving skills in decimal arithmetic operations. This improvement may be attributed to the structured and active engagement required at each stage of the KWDL process. For instance, when solving a decimal multiplication problem, participants in the K (Know) step identified the given numbers and the problem context; in the W (Want to know) step, they clarified the unknown element or objective; during the D (Do) step, they applied appropriate computational methods; and in the L (Learned) step, they reflected on both the accuracy of their solution and the reasoning behind each step (Raines, 2018).

Table 4: Comparison of participants' problem-solving skills before and after KWDL learning management

Test	n	Score total	$\bar{x}$	S.D.	Paired differences		t	p	Effect size (Cohen's)
					$\bar{x}$	S.D.			
Pre-test	34	18	1.94	2.96	10.97	2.94	21.77	0.00*	3.37
Post-test	34	18	12.91	3.52					

*: p < .05

This process cultivates systematic thinking and experiential learning by engaging students in independent problem-solving, while also enhancing metacognitive growth through reflection and strategic approaches. Data for the study were obtained from two distinct sources to ensure reliability:

1. During the instructional process, use KWDL-based exercises. The research findings indicated that most students were able to develop problem-solving skills by following the KWDL framework. The following observations were made:

- Step K and Step W: Students were able to identify what information was given in the problem and what was required. However, a minority of students provided incomplete details; some copied the entire problem statement verbatim, while others skipped these steps and moved directly to Step D. An analysis of these students' backgrounds revealed that they tended to think quickly and lacked careful attention to detail.
- Step: D: Performing Problem-Solving. This step posed more difficulties compared to other steps. The following points were observed: 1) Students who followed the K and W steps in sequence were generally able to write symbolic representations correctly. 2) Most students showed appropriate steps in solving the problem and calculated the answers in an orderly manner, though a few still made calculation errors.
- Step L: Solution/Thinking Process. Students were generally able to write their answers; however, some only provided a numerical answer without units or an explanation of their thought process. In such cases, the instructor provided feedback to guide students in verifying their answers for accuracy.

2. After the instructional process using the problem-solving skill Test. The results were as follows:

- Some students were able to complete the test correctly. These students then successfully wrote symbolic representations, performed calculations, and provided accurate answers.
- Some students provided incomplete responses, such as omitting units, although they showed the steps used to find the answer.
- Some students wrote the symbolic equations and correct answers, but failed to show the method used to derive those answers.

Moreover, the findings revealed a very high level of participant satisfaction with the KWDL learning management approach ($\bar{x}$ = 4.61, S.D. = 0.53). Based on the content of the survey items, it can be inferred that participants expressed satisfaction with various aspects of the learning experience, including the instructional techniques, learning materials, classroom environment, and learning activities (Table 5).

4. Discussions

The findings of this study demonstrate that the KWDL learning management technique significantly improved participants' problem-solving skills in decimal arithmetic operations. The post-test results indicated a substantial increase in performance compared to the pre-test, highlighting the instructional value of the KWDL approach. These results are consistent with previous studies (Alsalhi et al., 2023; Boca and Jermtaisong, 2023; Heebkaew and Seehamongkon, 2024; Pongsai and Poonputta, 2023; Sawatpon and Polyiem, 2022; Puttharaksa et al., 2025), which also reported the positive effects of KWDL in mathematics education. However, the current study contributes further by providing evidence of deeper cognitive processing, as participants were able to accurately formulate symbolic expressions, follow procedures systematically, use appropriate mathematical symbols, and correctly include units, skills that go beyond surface-level problem-solving.

The effectiveness of the KWDL technique can be explained through cognitive and metacognitive frameworks. Each step of the KWDL process engages different levels of thinking: The K (Know) step

activates prior knowledge and schema retrieval; the W (Want to know) step fosters goal setting and problem definition; the D (Do) step requires procedural application and strategic thinking; and the L (Learn) step engages reflective thinking, which is essential for metacognitive awareness. This sequence aligns with theories of self-regulated learning (Zimmerman, 2007), in which learners plan, monitor, and evaluate their cognitive processes. By making students explicitly reflect on what they have learned, KWDL cultivates ownership of the learning process, thereby reinforcing both conceptual understanding and long-term retention.

Moreover, the results also revealed a high level of student satisfaction with the KWDL learning experience. According to Deci and Ryan's (2000) self-determination theory, the learning environment created by KWDL satisfies three basic psychological needs: Autonomy, competence, and relatedness. The step-by-step structure provided by KWDL allowed students to take charge of their learning (autonomy), build mastery through clear procedures (competence), and engage with peers during shared problem-solving (relatedness). This fulfilment of psychological needs likely contributed to both emotional and cognitive engagement.

Table 5: Participants' satisfaction with KWDL learning management

No.	Items	$\bar{x}$	S.D.	Levels of satisfaction
1	The learning activities helped me understand the content more deeply.	4.62	0.49	Very high
2	The learning activities helped me develop skills in thinking, analyzing, and drawing conclusions from the learning process.	4.53	0.61	Very high
3	I felt that I understood the content better through practicing the skills.	4.56	0.50	Very high
4	The learning activities allowed me to exchange knowledge with the instructor.	4.53	0.61	Very high
5	I felt that I understood the content better by studying various sample problems.	4.59	0.50	Very high
6	I was able to apply the KWDL learning management technique to solve other problems.	4.62	0.49	Very high
7	The teaching materials allowed me to engage in hands-on activities and offered variety.	4.56	0.56	Very high
8	The instructor was responsible and punctual in teaching.	4.71	0.52	Very high
9	The instructor's teaching was structured in a step-by-step process that was easy to understand.	4.68	0.53	Very high
10	The instructor was well-prepared with content, teaching materials, and equipment for the learning activities.	4.76	0.43	Very high
	Overall	4.61	0.53	Very high

Additionally, the classroom environment established through KWDL promoted a safe and structured space for learning. The process encouraged both individual effort and collaboration, allowing students to engage at their own pace while benefiting from peer support. This balance between independence and social interaction enhanced students' confidence in their mathematical abilities, as evidenced by improved test scores and qualitative satisfaction with instructional techniques, materials, and class activities.

The results indicate that KWDL is effective in enhancing mathematical problem-solving skills and in promoting meaningful learning experiences that support students' cognitive, metacognitive, and emotional development. The findings reinforce those of prior research (Heebkaew and Seehamongkon, 2024; Pongsai and Poonputta, 2023; Sawatpon and Polyiem, 2022; Puttharaksa et al., 2025) and suggest that the integration of structured, reflective learning techniques such as KWDL can yield both academic and affective benefits in mathematics education.

5. Conclusion

The present study investigated the effectiveness of the KWDL technique in enhancing students' ability to solve decimal arithmetic operation problems. The results indicate that the KWDL approach significantly improved students' problem-solving performance and provided more satisfying instructional experiences than traditional learning methods. These findings contribute to the growing body of research by suggesting that KWDL not only facilitates conceptual understanding, as demonstrated in previous studies, but also strengthens students' ability to apply problem-solving strategies effectively.

The results have practical implications for classroom practice, particularly in environments that value structured and systematic instructional approaches. The KWDL technique can support students in developing both cognitive and metacognitive skills essential for successful mathematical problem-solving. However, several limitations should be acknowledged. The study involved a relatively small sample size from a single educational institution, which may limit the generalizability of the findings. Additionally, the absence of a long-term follow-up restricts understanding of the sustained impact of the KWDL technique over time. Moreover, the study employed only quantitative methods; the lack of qualitative data presents a limitation in capturing students' in-depth learning experiences and perceptions. Future research should address these limitations by expanding the sample size, including diverse educational settings, incorporating longitudinal designs, and integrating qualitative approaches to gain a more comprehensive understanding of the KWDL technique's effectiveness across different contexts.

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Compliance with ethical standards

Ethical considerations

Participation was voluntary, and informed consent was secured from all experts and students involved. All data were anonymized to safeguard participants' privacy.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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