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The Use of KWDL Learning Management in the Development of 9 Graders' Learning Achievement of Quadratic Functions

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Abstract

The study aimed to assess the impact of the KWDL technique on the learning achievement of grade 9 students in quadratic function and their satisfaction with this instructional approach. Forty-four ninth-grade students from a Thai public secondary school participated, recruited by cluster random selection. The instruments comprised a KWDL learning management plan, an achievement test, and a satisfaction assessment. Data analysis involved mean scores, standard deviation, and a paired samples t-test. Results revealed significant differences between pre and posttest scores, alongside high levels of satisfaction with the method. The findings contribute to the field by demonstrating the effectiveness of the KWDL technique in teaching complex mathematical problem-solving concepts.

Keywords: KWDL technique, quadratic function, mathematics education

1. Introduction

Quadratic functions are of utmost importance in mathematics instruction in school. These fundamental mathematical notions are the foundational elements on which many other mathematical disciplines depend. Comprehending quadratic functions not only provides students with crucial problem-solving abilities but also improves their general mathematical proficiency (Bowden, 2018). Furthermore, having expertise in this particular domain establishes a solid groundwork for pursuing advanced education, particularly in disciplines that provide lucrative degrees with substantial financial gains, such as engineering, economics, and sciences. Mastering the complexities of quadratic functions enables students to confidently approach increasingly advanced mathematical problems, paving the way for academic achievement and opening doors to future professional prospects (Bruskiewich, 2015; Daniels & Armendariz, 2011).

Nevertheless, it is crucial to recognize that quadratic functions can be complex notions for certain students as they must not only understand the fundamental ideas but also employ them in diverse problem-solving situations (Dencha et al., 2015; Fitzmaurice et al., 2021). The complexity stems from the necessity to comprehend the interconnections among variables, as well as the intricate characteristics of quadratic equations (Makonye, 2014). Therefore, it is not unexpected that numerous students face difficulties when trying to comprehend these essential concepts (Akhter & Akhter, 2018; Golding, 2018; Trujillo et al. 2023). The complex characteristics of quadratic functions require a focused and thorough approach to studying, which can often be challenging for pupils.

Quadratic functions have been formally integrated into Thailand's current educational curriculum, specifically designated for instruction at the grade 9 level (Ministry of Education, 2008). The curriculum encompasses a wide array of topics within this domain, spanning from the foundational understanding of quadratic equations to the exploration of parabolic characteristics. Upon completion of the course, students are expected to proficiently apply fundamental mathematical principles in practical problem-solving scenarios. However, it is evident that Thai students often encounter challenges in this area, given the inherent complexity of these concepts. Thailand faces a critical issue regarding the mathematical proficiency of its students, as evidenced by consistently low average scores in national tests, falling significantly below the maximum achievable score (National Institute of Educational Testing Service, 2022). This aligns with outcome of the Programme for International Student Assessment (PISA), which evaluates reading, maths, and science education in 2022. In comparison to PISA 2018, Thailand's average scores in all three domains declined, with mathematics lowering by 25 points, and

science and reading declining by 17 and 14 points, respectively. (Thairath, 2023). Moreover, Thailand's ranking in international tests places it in the lower half of participating countries (OECD, 2022). This situation underscores the severity of the problem and underscores the urgent need for attention, development and reform in mathematics instruction.

Given the intricacy of quadratic functions, an instructional approach prioritizing active learning, critical thinking skill development, and meta-cognition offers potential in addressing students' challenges with these complex mathematical concepts. In this regard, the KWDL method emerges as a promising solution. Derived from the KWL approach, KWDL guides learners through stages aimed at problem-solving and knowledge acquisition. Initially proposed by Ogle (1986) and further developed, this method enhances memory, cognition, and problem-solving abilities. By prompting students to assess their existing knowledge, identify learning objectives, engage in problem-solving, and summarize their learning, KWDL fosters active participation and ownership of the learning process. This constructivist approach, as advocated by Raines (2018), facilitates reflection, critical thinking, and decision-making. By guiding students through inquiry and problem-solving stages, KWDL holds potential for improving both mathematical understanding and thinking skills in the classroom.

Hence, in pursuit of an effective educational approach, this study has strategically embraced KWDL as a core principle in the formulation of a robust learning management plan tailored to the specific needs of grade 9 students. By teaching students to ask critical questions about what they are learning to increase their metacognitive skills, this plan is designed to provide students with a dynamic and engaging platform for comprehending the intricacies of quadratic functions. Through a meticulously designed curriculum that emphasizes hands-on activities, problem-solving tasks, and real-world applications, this approach aims to not only enhance students' understanding of these mathematical concepts but also cultivate their ability to apply them effectively. Moreover, by fostering an environment that encourages participation and teamwork, the plan seeks to motivate learners and establish a solid foundation for their future mathematical pursuits, ultimately addressing the existing challenges in mathematics education.

2. Literature Review

2.1 Quadratic Function Learning Achievement

Specifically in academic fields like mathematics, learning achievement refers to the accomplishment of specified educational objectives (Bolt, 2011; Phye, 2011; Steinmayr et al., 2014). Learning success with quadratic functions goes beyond memorization of formulas or isolated concept comprehension. It goes on to the capacity to solve problems, evaluate circumstances, and establish links between mathematical ideas and practical applications (Bruskiewich, 2015). Students who want to become proficient with quadratic functions need to grasp their characteristics and behaviors in great detail. These cover seeing trends, knowing how coefficients relate to the graph's form, and recognizing important elements such the vertex, axis of symmetry, and roots (Bowden, 2018). Learning to solve quadratic equations also means learning how to factor, complete the square, and use the quadratic formula—problem-solving techniques specifically designed for quadratic equations.

Beyond procedural knowledge, learning achievement also encompasses the development of critical thinking skills (Firdaus et al., 2015). Students must assess problem-solving methodologies, provide justifications for their answers, and evaluate the logical validity of the outcomes. They should be able to analyze complex problems, break them down into manageable parts, and apply appropriate mathematical techniques to solve them effectively (Gradini et al., 2024). Furthermore, learning achievement in quadratic functions involves fostering metacognitive skills. Students should reflect on their learning process, monitor their understanding, and adapt their strategies as needed. They need to recognize misconceptions, seek clarification when necessary, and persist in solving challenging problems.

Academic achievement in mathematics, particularly in the context of quadratic functions, is crucial for individuals and societies alike. Quadratic functions are mathematical expressions of the form $(x)=ax2+bx+cf(\mathrm{x})=ax2+bx+c$, where a, b, and c are constants, and x is a variable (Bowden, 2018; Phye, 2011). They represent a fundamental concept in algebra and are used to model various real-world phenomena. Mastery of quadratic functions involves understanding their properties, such as vertex, axis of symmetry, and roots, and applying this knowledge to solve equations and analyze situations (Daniels & Armendariz, 2011). Therefore, it could be concluded that quadratic function learning achievement involves not only acquiring procedural and declarative knowledge but also developing problem-solving skills and the ability to apply mathematical concepts to practical scenarios.

2.2 KWDL Technique

The KWDL (Know, Want, Do, Learn) teaching technique, derived from Ogle's KWL method (1986), finds its roots

in constructivist learning theory, particularly in the work of Donna Ogle. Ogle's KWL method is a widely recognized instructional strategy that encourages students to engage actively in the learning process by prompting them to reflect on what they already know (Know), what they want to learn (Want), and what they have learned (Learned) after completing a lesson or task. The addition of the "Do" stage in KWDL extends Ogle's original framework by incorporating a hands-on problem-solving component, emphasizing the importance of active learning and application of knowledge (Carr & Ogle, 1987; Ogle, 1986).

Know (K): This initial stage prompts students to assess their existing knowledge of the topic at hand. They are encouraged to identify and articulate what they already know about the subject matter. In the context of quadratic functions, students might reflect on concepts such as the quadratic formula, vertex form, or characteristics of parabolas. This stage sets the foundation by activating prior knowledge and providing a starting point for further exploration.

Want (W): In the Want stage, students identify what they want to learn or what information they need to acquire to solve a given problem. They articulate their learning goals or objectives, focusing on areas where they need clarification or additional understanding. For quadratic functions, students might express a desire to understand how to find the roots of a quadratic equation or how to graph a quadratic function. This stage encourages student engagement and ownership of the learning process by directing their attention towards specific learning targets.

Do (D): The Do stage involves active problem-solving and application of learned concepts. Students engage in activities or exercises designed to address the identified learning goals from the previous stages. They apply mathematical techniques and problem-solving strategies to tackle quadratic equations or analyze quadratic functions. This stage fosters hands-on learning experiences and encourages students to experiment with different approaches to problem-solving.

Learn (L): Finally, in the Learn stage, students reflect on their learning process and consolidate their understanding. They summarize the key insights gained from their problem-solving efforts and reflect on the effectiveness of their strategies. Students identify what they have learned from the problem-solving experience and how it contributes to their overall understanding of quadratic functions. This stage promotes metacognitive awareness and helps students internalize their learning experiences for future application.

The KWDL teaching method provides an advantageous structure for efficiently instructing quadratic functions. The instructional program directs learners through a methodical progression that commences with the activation of pre-existing knowledge, progresses to the establishment of precise learning objectives pertaining to quadratic functions, culminates in practical problem-solving exercises, and concludes with a self-evaluation of acquired knowledge. Educators are presented with opportunities to scaffold student learning and foster a more profound comprehension of quadratic functions at each stage of the KWDL approach. Through the integration of the KWDL technique into their pedagogical approaches, instructors can establish a nurturing educational milieu in which students are actively involved in the investigation and implementation of quadratic functions. This, in turn, culminates in improved academic achievements and a surge in mathematical proficiency.

2.3 Previous Studies Scholars

Previous studies Scholars (e.g., Alsalhi et al., 2023; Boca & Jermtaisong, 2023; Dolati Miandoab et al., 2019; Heebkaew & Seehamongkon, 2024; Johan et al., 2020; Pongsai & Poonputta, 2023; Sawatpon & Polyiem, 2022; Usta & Yılmaz, 2020) have identified the benefits of the KWDL approach in mathematics teaching, as it effectively enhances both students' understanding of mathematical concepts and their critical thinking skills. Alsalhi et al. (2023) demonstrated that the KWL strategy contributed to improved mathematics achievement. Boca and Jermtaisong (2023), Heebkaew and Seehamongkon (2024), Sawatpon and Polyiem (2022), and Usta and Yılmaz (2020) observed that the KWDL technique, when combined with the Bar Model, enhanced problem-solving abilities in mathematics for grade 7 students. Additionally, Dolati Miandoab et al. (2019) found that KWL was instrumental in fostering critical thinking skills. Johan et al. (2020) discovered that Malcolm's modeling, based on the KWL thinking strategy, facilitated the development of students' reasoning skills. Furthermore, Pongsai & Poonputta (2023) highlighted the technique's effectiveness in enhancing students' understanding of combined operations. It's worth to note that previous studies urges to applied to develop in more area of mathematics teaching. Moreover, previous studies focus on fundamental concepts of mathematics such as problem solving (Boca & Jermtaisong, 2023; Heebkaew & Seehamongkon, 2024; Sawatpon & Polyiem, 2022; Usta & Yılmaz, 2020) and combined operation (Pongsai & Poonputta, 2023).

However, many students encounter difficulty in mathematics when faced with complex concepts that require the application of multiple principles to solve (Akhter & Akhter, 2018; Gafoor & Kurukkan, 2015). Therefore, it is worth considering the application of the KWDL technique to the concept of quadratic functions. Hence, the present

study aims to leverage the principles of KWDL in developing a learning management plan tailored to instructing the concept of quadratic functions. The purposes of the study were to investigate the effects of KWDL technique on grade 9 students' learning achievement of quadratic function and to study students' satisfaction with the KWDL technique as an instructional method in learning the concept of quadratic function.

3. Methodology

3.1 Research Design

The study utilized a one-group pre-posttest design. The main treatment involved the implementation of a learning management plan developed using the principles of the KWDL technique. This plan aimed to enhance the knowledge and skills necessary for achieving learning outcomes related to quadratic functions among grade 9 students in the Thai educational context. The effectiveness of the learning management plan was evaluated by comparing students' pre-test and post-test scores. Additionally, participants' satisfaction with the technique was assessed at the conclusion of the data collection period.

3.2 Sample and Data Collection

The study included 44 grade 9 students from a public secondary school in Thailand, selected through cluster random sampling. These students were enrolled in a mathematics class, which is a fundamental subject according to the national core curriculum issued by the Ministry of Education (2008). Prior to participating in the study, the students had already been exposed to essential mathematical concepts required for understanding quadratic functions, including algebraic manipulation, solving equations, graphing linear equations, and understanding the properties of exponents and basic algebraic expressions throughout their education. Additionally, the province where the school is located demonstrates average socio-economic status and academic achievement compared to the rest of the country, making the participants representative of the broader population of Thai students. Ethical considerations regarding human research were carefully observed throughout the study.

3.3 Research Tools

3.3.1 The Treatment

The primary intervention involved implementing a meticulously crafted learning management plan, drawing on the principles of KWL (Ogle, 1986) while considering insights from recent studies utilizing KWDL (e.g., Boca & Jermtaisong, 2023; Heebkaew & Seehamongkon, 2024; Pongsai & Poonputta, 2023; Sawatpon & Polyiem, 2022). As highlighted by Shank and Santiague(2022), an effective learning management system should encompass clearly defined objectives, detailed learning activities, appropriate learning media, contextual relevance, and systematic assessment methods. Accordingly, the learning management plan developed for this study adhered to these criteria. Following the KWDL framework, which prompts questions such as "what we know?", "what we want?", "what we did?", and "what we learned?", the plan was meticulously tailored to incorporate these elements into the learning activities.

What we know

Students were tasked with analyzing the components of quadratic function problems. They reviewed the coefficients and variables present in the equations and recalled the principles governing quadratic functions, such as the quadratic formula and factoring techniques.

What we want

Students articulated their strategies for solving quadratic function problems. They outlined their approaches, including methods for factoring, completing the square, or using the quadratic formula, while receiving guidance and feedback from the teacher to enhance their understanding.

What we did

Students applied their chosen strategies to solve quadratic function problems. They performed operations such as factoring, completing the square, or applying the quadratic formula to find solutions to the given equations.

What we learned

Students presented their solutions to the quadratic function problems and summarized their learning. They reflected on the effectiveness of their chosen strategies and identified key insights gained from the problem-solving process, such as the importance of selecting appropriate methods for different types of quadratic equations.

The learning management plan encompasses six key subtopics for teaching quadratic functions. These include an Introduction to Quadratic Functions, covering their definition, general form ($y = ax^2 + bx + c$), and characteristics

like vertex and axis of symmetry; Graphing Quadratic Functions, focusing on various graphing methods and transformations; Solving Quadratic Equations, teaching techniques such as factoring, completing the square, and using the quadratic formula along with real-life applications; Quadratic Inequalities, introducing methods for solving and graphing quadratic inequalities; Applications of Quadratic Functions, exploring real-world scenarios such as projectile motion and optimization problems; and Review and Practice, dedicating time for consolidating knowledge and providing ample opportunities for practicing quadratic equation solving, function graphing, and application problem-solving. The learning management plan received a remarkably high evaluation score ($\bar{x}$ = 4.80) from a panel of five experts, comprising professional educators and scholars in the field of education.

3.3.2 Learning Achievement Test

The quadratic function learning achievement test comprises two sections with a total of 20 maximum points. The first section consists of 10 multiple-choice items, each worth 1 point, totaling 10 points. The second section includes 5 problem-solving items, each worth 2 points, resulting in a total of 10 points. The test has been reviewed by three experts to ensure alignment with the learning objectives. The index of congruence (IOC) between the test questions and the learning objectives is required to be 0.50 or higher. The results show that all test questions meet this criterion, with IOC values ranging from 0.67 to 1.00. The multiple-choice items displayed discrimination values ranging from 0.20-0.62, difficult values ranging from 0.70-0.77, and reliability with Lovett Method of 0.77. The problem-solving items displayed discrimination values ranging from 0.53-0.77, difficult values ranging from 0.48-0.61, and reliability with a Cronbach's alpha coefficient of 0.93.

3.3.3 Satisfaction Assessment

The satisfaction questionnaire aims to assess participants' satisfaction with the KWDL learning management plan. It consists of 10 positive statements regarding the learning experience with the method. It has been reviewed by three experts to ensure content validity, assessing the congruence between the test items and the learning objectives (IOC). With a criterion of 0.50 and above, the results showed that all test items met the content validity criterion, with scores ranging from 0.67 to 1.00.

3.4 Analyzing of Data

The data collection followed a one-group experimental design, encompassing pretest, learning activities, posttest, and satisfaction questionnaire administration. Over a span of six weeks, each lasting an hour, participants engaged in activities outlined in the learning management plan. Data analysis involved computing mean scores, standard deviations, and conducting paired samples t-tests to examine changes over time.

4. Results

The study's findings reveal a notable improvement in participants' learning achievement regarding quadratic functions following the implementation of the KWDL learning management plan. The post-test score ($\bar{x}$ = 16.11) was statistically significantly greater than the pre-testscore ($\bar{x}$ = 7.05) at the .05 level, with paired differences of 9.06, df = n-1 = 44-1 = 43, t-value of 33.48, and a p-value below the .05 (Table 1). These results underscore the efficacy of the KWDL technique in enhancing understanding of quadratic functions among ninth-grade participants within the Thai educational setting.

Table 1. The comparison between the learning achievement of participants pre and post treatment

Learning achievement	df	Full Score	$\bar{x}$	S.D.	Paired Differences	t	p
Post-test	43	20	16.11	1.30	9.06	33.48	0.00*
Pre-test	43	20	7.05	1.36			

*p < 0.05.

The results of the study also show that students were highly satisfied with learning using the KWDL technique. Table 2 indicates a very high level of participants' satisfaction ($\bar{x}$ = 4.74, S.D = 0.44) when considered on an itemized basis. In detail, participants perceived the learning management plan as an instructional method that encouraged students to think and express themselves confidently, included materials that stimulated students' interest, facilitated understanding of the content being taught, fostered knowledge and understanding of solving quadratic equations concepts, and promoted collaborative work among students.

Table 2. Students' satisfaction with the learning management plan

No.	Statements	$\bar{x}$	S.D.
1	Learning management encouraged students to think and express themselves confidently.	4.91	0.29
2	The teaching materials stimulated my interest.	4.84	0.37
3	The teaching methods helped students understand the content being taught.	4.82	0.39
4	This learning management plan helped students gain knowledge and understanding of the concepts of solving quadratic equations.	4.80	0.41
5	The aforementioned learning management enabled students to work collaboratively with others.	4.89	0.32
6	It promoted learning through hands-on activities.	4.61	0.49
7	The classroom atmosphere supported learning.	4.59	0.50
8	The learning management plan made learning enjoyable.	4.57	0.50
9	Learning activities allowed me to explore and acquire knowledge on my own.	4.77	0.42
10	I am happy with my learning experience.	4.64	0.49
Average		4.74	0.44

5. Discussion

The study's findings highlight the efficiency of the KWDL technique for teaching quadratic function principles in mathematics courses. The KWDL technique enhances learners' issue analysis by providing distinct processes to identify the problem's requirements (K), ascertain the information sought (W), and devise a solution strategy (D) before implementation. This enables learners to comprehend the problem, devise a systematic solution strategy, and ultimately summarize the derived solutions (L), facilitating the review and verification of their accuracy (Laowreandee, 2019). This enables learners to derive solutions to issues with greater precision. This study contributes additional evidence to prior research (e.g., Alsalhi et al., 2023; Boca & Jermtaisong, 2023; Dolati Miandoab et al., 2019; Heebkaew & Seehamongkon, 2024; Johan et al., 2020; Pongsai & Poonputta, 2023; Sawatpon & Polyiem, 2022; Usta & Yılmaz, 2020) supporting its utility in mathematical education. Beyond enhancing fundamental mathematical skills such as problem-solving and critical thinking, as well as addressing concepts like combined operations, the technique also demonstrates efficacy in teaching complex mathematical concepts like quadratic functions. Consequently, future studies could explore the application of this technique in teaching advanced concepts in high school mathematics and beyond.

The effectiveness of KWDL hinges on its ability to empower students to pose pertinent questions and assume ownership of the entire mathematical problem-solving process (Carr & Ogle, 1987; Ogle, 1986; Raines, 2018). In the context of learning quadratic functions, participants engage in a structured approach: they assess their existing knowledge of equations, identify the information needed to solve them, attempt problem-solving with feedback from peers and instructors, and ultimately consolidate their learning through summarization. This process fosters the development of analytical skills, hands-on experience, and a deeper comprehension of the concept, as evidenced by the enhanced learning outcomes observed in the study.

Furthermore, the findings indicate that participants experienced a gratifying learning journey through the KWDL process. This satisfaction stemmed from their ability to assume ownership of their learning and engage with both individual and collaborative aspects of the process. Flavell, (1987) and Paris and Winograd (1990) suggests that metacognitive abilities emerge when students gain a deep understanding of the learning process, potentially leading to a sense of enjoyment in learning. These results align with previous studies by Pongsai and Poonputta (2023) and Sawatpon and Polyiem (2022), which similarly demonstrated students' satisfaction with the KWDL method.

6. Conclusion

The study aimed to apply KWDL principles in developing a learning management plan to teach quadratic functions to grade 9 students within the Thai educational setting. Additionally, it sought to assess the satisfaction level of the participants. The results revealed positive effects of the learning management plan on both students' learning achievement and the overall learning atmosphere.

The results of the study can be implicated to pedagogy as they underscore the efficacy of employing the KWDL technique in enhancing students' learning experiences and outcomes. In academic aspects, further studies could explore the application of this technique to teach various mathematical concepts, including more complex topics such as advanced algebra or calculus. Additionally, at a policy level, it is evident that fostering metacognitive skills is beneficial for mathematics education. Therefore, policymakers should consider integrating KWDL or other

techniques that empower students to take control of their learning in mathematical education policies and curricula.

References

Akhter, N., & Akhter, N. (2018). Learning in mathematics: Difficulties and perceptions of students. *Journal of Educational Research, Dept. of Education, IUB, Pakistan*, *21*(1), 147-163. Retrieved from https://jer.iub.edu.pk/journals/JER-Vol-21.No-1/11.pdf

Alsalhi, N. R., Taani, O., Arabi, K. S. A., Al-Qatawneh, S., Annamalai, N., Al-Tarawneh, S., & Eltahir, M. E. (2023). Impact of the Know-Want-Learn (KWL) Strategy on Academic Mathematics Achievements for International Students. *Journal of International Students*, *13*(3), 460-478. Retrieved from https://ojed.org/index.php/jis/article/view/6372

Boca, A. B., & Jermtaisong, R. (2023). The Development of Learning Activity through the KWDL Technique Combined with the Bar Model to Improve Problem-Solving Ability in Math for Secondary 1 (Grade 7) Students. *Turkish Online Journal of Educational Technology-TOJET*, *22*(4), 210-221. Retrieved from http://www.tojet.net/articles/v22i4/22420.pdf

Bolt, N. (2011). Academic Achievement. In S. Goldstein, & J. A. Naglieri (Eds.), *Encyclopedia of Child Behavior and Development* (pp. 8-9). Springer, US. https://doi.org/10.1007/978-0-387-79061-9_20

Bowden, S. A. (2018). *Introductory Algebra: Linear and Quadratic Equations and Functions*. CreateSpace Independent Publishing.

Bruskiewich, P. (2015). *An Introduction to Relations, Expressions and Functions*. Pythagoras Publishing.

Carr, E., & Ogle, D. (1987). K-W-L Plus: A Strategy for Comprehension and Summarization. *Journal of Reading*, *30*(7), 626-631. Retrieved from http://www.jstor.org/stable/40031872

Daniels, M., & Armendariz, E. P. (2011). *Functions in Mathematics: Introductory Explorations for Secondary School Teachers*. Cognella.

Dencha, T., Seangarun, K., Inprasitha, M., & Srichumpoo, S. (2015). Sudents' mathematical understanding levels on exponent in classroom using taught by open approach. *Veridian E-Journal, Silpakorn University*, *8*(2), 1719-1734. Retrieved from https://he02.tci-thaijo.org/index.php/Veridian-E-Journal/article/view/40433/33366

Dolati Miandoab, A., Dortaj, F., & Farrokhi, N. (2019). Comparison of effect of kwl educational strategy and concept mapping strategy on students' critical thinking. *Iranian Journal of Educational Sociology*, *2*(3), 27-35. https://doi.org/10.29252/ijes.2.3.27

Firdaus, F., Kailani, I., Bakar, M., & Bakry, B. (2015). Developing Critical Thinking Skills of Students in Mathematics Learning. *Journal of Education and Learning (EduLearn)*, *9*, 226. https://doi.org/10.11591/edulearn.v9i3.1830

Fitzmaurice, O., O'Meara, N., & Johnson, P. (2021). Highlighting the Relevance of Mathematics to Secondary School Students—Why and How. *European Journal of STEM Education*, *6*(1). https://doi.org/10.20897/ejsteme/10895

Flavell, J. H. (1987). Speculations about the nature and development of metacognition. In F.E. Weinert & R.H. Kluwe, *Metacognition, motivation, and understanding* (pp. 21-29). Lawrence Erlbaum.

Gafoor, K. A., & Kurukkan, A. (2015). Why High School Students Feel Mathematics Difficult? An Exploration of Affective Beliefs. In *Online Submission*. Retrieved from https://eric.ed.gov/?id=ED560266

Golding, J. (2018). Mathematics education in the spotlight: Its purpose and some implications. *London Review of Education*, 16(3), 460-473. https://doi.org/10.18546/LRE.16.3.08

Gradini, E., Umar, A., Firmansyah, F., Effendi, Y., & Winardi, W. (2024). Fostering Higher Order Thinking Skills in Mathematics Learning: A Scoping Review of Teacher Development Initiatives. *Unram Journal of Community Service*, *5*, 9-14. https://doi.org/10.29303/ujcs.v5i1.570

Heebkaew, C., & Seehamongkon, Y. (2024). The Development of the Ability to Solve Mathematical Problems and Academic Achievement Decimal Problem of Prathomsuksa6 Students through Cooperative Learning Management STAD and KWDL Technique. *Journal of Education and Learning*, *13*(1), 150-161. https://doi.org/10.5539/jel.v13n1p150

Johan, A., Suyitno, A., Mashuri, & Sayekti, I. (2020). Enhancement of reasoning skills of 7th grade students

using Malcolm's modeling based on KWL thinking strategy. *Journal of Physics: Conference Series*, *1521*(3), 032074. https://doi.org/10.1088/1742-6596/1521/3/032074

Laowreandee, W. (2017). *Active learning Instructional Strategies forThinking Development and Educational Improvement of the 21st Century*. Thailand, TL: Phet Kasem Printing Group.

Makonye, J. P. (2014). Teaching Functions Using a Realistic Mathematics Education Approach: A Theoretical Perspective. *International Journal of Educational Sciences*, *7*, 653-662. https://doi.org/10.1080/09751122.2014.11890228

National Institute of Educational Testing Service. (2022). *ONET result 2018-2021*. Retrieved from https://www.niets.or.th/th/content/view/11821

OECD. (2022). *Thailand Student performance (PISA 2022)*. Retrieved from https://gpseducation.oecd.org/CountryProfile?primaryCountry=THA&treshold=10&topic=PI

Ogle, D. M. (1986). K-W-L: A Teaching Model That Develops Active Reading of Expository Text. *The Reading Teacher*, *39*(6), 564-570. https://doi.org/10.1598/RT.39.6.11

Paris, S. G., & Winograd, P. (1990). How metacognition can promote academic learning and instruction. In B. F. Jones, & L. Idol (1990), *Dimensions of thinking and cognitive instruction* (pp. 15-51). Lawrence Erlbaum.

Phye, G. D. (Ed.). (2011). *Handbook of Classroom Assessment: Learning, Achievement, and Adjustment*. Academic Press.

Pongsai, N., & Poonputta, A. (2023). The Use of the KWDL Technique in Developing Grade 4 Elementary School Student Combined Operations. *Higher Education Studies*, *13*(3), 95-100. https://doi.org/10.5539/hes.v13n3p95

Raines D. A. (2018). Using a K-W-L Chart to Bridge the Theory-Practice Gap. *Nursing education perspectives*, *39*(3), 182-183. https://doi.org/10.1097/01.NEP.0000000000000256

Sawatpon, N., & Polyiem, T. (2022). The Use of the K-W-D-L Technique in the Development of Grade 10 Students' Mathematical Problem-Solving Abilities. *Journal of Educational Issues*, *8*(1), 470-479. https://doi.org/10.5296/jei.v8i1.19799

Shank, M. K., & Santiague, L. (2022). Classroom Management Needs of Novice Teachers. *Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *95*(1), 26-34. https://doi.org/10.1080/00098655.2021.2010636

Steinmayr, R., Meißner, A., Weidinger, A., & Wirthwein, L. (2014). Academic Achievement. *Oxford Bibliographies Online*. https://doi.org/10.1093/obo/9780199756810-0108

Thairath. (2023, December 6). The cause of "Thai children" low PISA test scores Reading and analyzing the crisis. *Thairath*. Retrieved from https://www.thairath.co.th/scoop/theissue/2746105

The Ministry of Education. (2008). *The basic education core curriculum*. Thailand: The Ministry of Education.

Trujillo, M., Atarés, L., Canet, M. J., & Pérez-Pascual, M. (2023). Learning Difficulties with the Concept of Function in Maths: A Literature Review. *Education Sciences*, *13*, 495. https://doi.org/10.3390/educsci13050495

Usta, N., & Yılmaz, M. (2020). Impact of the KWL reading strategy on mathematical problem-solving achievement of primary school 4th graders. *The Journal of Educational Research*, *113*(5), 343-363. https://doi.org/10.1080/00220671.2020.1830017

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Authors contributions

Amphon Puttharaksa were responsible for study design, create research tools, responsible for data collection, analyze and write report; Piyanee Janthapoom were edit research tools, responsible for data collection and write report; Apantee Poonputta were responsible for study design, revising, edit research tool and edit report.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.