THE APPLYING OF KWL STRATEGY IN TEACHING WAVE OPTICS TO FIRST-YEAR ELECTRICAL ENGINEERING STUDENTS

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Abstract

In this study, the Wave Optics chapter, which is part of the General Physics A2 course for first-year Electrical Engineering students at Thu Dau Mot university, will be taught using the KWL (Know-Want to know-Learned) strategy. Creating a three-step KWL instructional process for four major Wave Optics chapter topics, creating learning scenarios that use the KWL strategy, and evaluating the technique's effects on students' critical thinking, active learning, and knowledge retention are all parts of the research objectives. Both qualitative and quantitative data analysis techniques are used in this study. Two classes were chosen at random: the experimental group (49 students) was taught using the KWL strategy, while the control group (49 students) followed a traditional instructional method. Data were collected through test scores, post-lesson surveys, and classroom observations. The findings show that the experimental group achieved an average score of 7.31, higher than the control group's 6.13. Post-lesson surveys indicated that all 15 evaluation criteria reached a "Good" level, with mean scores ranging from 4.24 to 4.54. Students responded positively, expressing enjoyment in being able to ask questions, synthesize information, and engage more deeply in learning. The study confirms that the KWL technique is an effective teaching method that enhances instructional quality and promotes students' active learning skills. This strategy holds potential for broader application across other STEM subjects to maximize learner-centered knowledge acquisition.

Keywords: active learning, critical thinking skills, KWL strategy, self-directed learning, Wave Optics instruction

1. Introduction

In the context of modern higher education, developing students' self-study and independent research capabilities has become a key objective. To achieve this, lecturers are encouraged to innovate teaching methods, particularly by applying active learning strategies that stimulate interest in learning and promote students' self-regulation in the knowledge acquisition process (Hải, 2023).

One of the most prominent active learning techniques is the KWL strategy (Know – Want to know – Learned), proposed by Donna Ogle (1986) to support learners in developing comprehension skills for informational texts. This strategy has recently been widely adopted in educational research. This method has been proven effective in fostering critical thinking, improving reading comprehension, and enhancing self-learning abilities. Originally applied in literature and reading comprehension, the technique has since been extended to various disciplines such as history, natural sciences, and especially in STEM-oriented classrooms (Vacca & Vacca, 2005; Choo, 2011; Alsalhi, 2020; Liu, 2026).

Ogle emphasized that KWL not only encourages active thinking but also helps instructors accurately assess students' background knowledge to adjust content and teaching methods accordingly (Ogle, 1986). Numerous studies have demonstrated the effectiveness of the KWL strategy in improving comprehension, memory retention, and learner engagement (Alsalhi, 2020; Liu, 2026). In particular, Bogdanović et al. (2022) found that KWL supports the development of metacognitive awareness, planning skills, information management, and the ability to evaluate learning outcomes.

In practical subjects, the KWL technique has also proven feasible and effective. Wrinkle and Manivannan applied the strategy in a General Physics laboratory setting, enabling students to reflect on prior knowledge, ask questions want to learn, and synthesize their understanding after experiments. This approach enhanced both engagement and conceptual understanding in physics (Wrinkle & Manivannan, 2009).

At Thu Dau Mot University, fostering students' self-directed learning and research capabilities is a central educational objective. The institution actively encourages faculty to adopt innovative teaching approaches that empower learners. Within this context, researching and applying the KWL strategy in teaching the Wave Optics chapter of the General Physics A2 course represents a necessary and highly practical initiative to promote active learning among first-year students.

2. Theoretical Basis

The KWL (Know – Want to know – Learned) strategy was developed by Donna Ogle (1986) as a method to help learners approach informational texts in a proactive manner. The strategy comprises three steps:

1. K – What I Know: Students activate prior knowledge through discussion and categorize information by topic.

2. W – What I Want to Learn: Students generate personal questions based on gaps in their understanding to guide their reading.

3. L – What I Learned: After reading, students record the knowledge they have acquired and compare it with their initial questions.

The KWL strategy enables learners to construct new understanding based on existing knowledge, while also developing reading comprehension and critical thinking skills (Ogle, 1986; Blachowicz & Ogle, 2008). Numerous studies have confirmed the effectiveness of KWL in fostering metacognitive awareness, promoting independent learning, and enhancing students' ability to comprehend scientific content (Bogdanović et al., 2022; Zouhor et al., 2016).

In teaching physics, prior knowledge plays a vital role in forming new concepts and understanding complex phenomena. According to Martorella, activating background knowledge allows students to connect new content with existing understanding, thereby improving learning outcomes (Martorella et al., 2005).

In the context of natural science instruction, active learning strategies such as KWL help students grasp scientific concepts, understand the nature of physical phenomena, and strengthen their critical thinking skills (Zouhor et al., 2016; Mihardi et al., 2013). Educators such as Draper emphasize that active learning not only increases learner engagement but also reinforces the student's role as an active participant in the learning process (Draper, 2002).

Recent studies have applied the KWL strategy in STEM education with positive results. For instance, Mihardi integrated KWL with project-based learning in Physics and reported significant improvements in students' creativity and problem-solving skills (Mihardi et al., 2013). Research by Riswanto demonstrated that the KWL technique significantly enhanced high school students' reading comprehension and analytical skills in science (Riswanto et al., 2014). Zouhor also confirmed that using KWL charts helps students form physics concepts—such as force, gravity, and friction—through a more active and structured learning process (Zouhor et al., 2016). Furthermore, Panjaitan & Situmorang reported a statistically significant improvement in reading comprehension among students taught using the KWL strategy compared to those taught with traditional methods (Panjaitan & Situmorang, 2018). In addition, Bogdanović found that the modified KWL strategy (mKWL), implemented with the TQHL chart, significantly improved sixth-grade students' cognitive abilities and learning outcomes in Physics, with the TQHL chart consists of four columns: T – "Think" (what I know), Q – "Question" (what I want to know), H – "How" (how to find out), and L – "Learn" (what I learned) (Bogdanović et al., 2022).

The Wave Optics chapter in the General Physics A2 course, taught to first-year Electrical Engineering students at Thu Dau Mot university, is a complex and abstract component of the curriculum. It includes four main topics: fundamentals of wave optics, light interference, light diffraction, and light polarization. This chapter provides essential foundational knowledge for subsequent topics such as quantum optics and quantum mechanics, enabling students to understand and explain related physical phenomena.

In this chapter, the application of the KWL strategy allows for the assessment of student learning at three levels:

At the K level (Background Knowledge), students demonstrate recognition of prior knowledge and basic memory skills. For example, they are able to recognize light as an electromagnetic wave and understand fundamental concepts such as the refractive index.

At the W level (Want to Know), students exhibit critical thinking abilities, curiosity, and the skill to formulate questions. Typical student inquiries at this stage include questions like, "Why is monochromatic light used in interference?" and "What are the applications of polarization?"

Finally, at the L level (Learned), students show evidence of understanding, applying new knowledge, and synthesizing information. They can correctly solve applied problems such as calculating fringe spacing in interference patterns and explaining diffraction phenomena, demonstrating a deeper comprehension of Wave Optics concepts.

Based on this theoretical foundation, the current study applies the KWL strategy in teaching the Wave Optics chapter to first-year Electrical Engineering students at Thu Dau Mot university, with the aim of enhancing their active learning, critical thinking, and knowledge retention.

3. Research Objectives

This study pursues three specific objectives aimed at evaluating and enhancing the effectiveness of applying the KWL technique in teaching the Wave Optics chapter to first-year Electrical Engineering students at Thu Dau Mot university.

First, the study applies the KWL strategy to the teaching of Wave Optics by designing a three-step instructional process—K (Know), W (Want to know), and L (Learned)—across four key topics: Fundamentals of Wave Optics, Interference of Light, Diffraction of Light, and Polarization of Light. In Step K, students activate background knowledge through group discussions, guiding questions, or real-life contexts. In Step W, they are encouraged to raise questions and record their doubts on individual study sheets. In Step L, students summarize newly acquired knowledge and compare it with their initial questions. This process is implemented through a system of KWL study sheets designed using the Google Forms platform.

Second, the research aims to develop a procedure for organizing and designing specific instructional scenarios that incorporate the KWL strategy. This involves analyzing the content characteristics of each topic in the Wave Optics chapter, designing tailored KWL study sheets, and conducting teaching trials. Based on feedback from students and instructors, the process and lesson content are refined. The expected outputs include: (1) a set of KWL worksheets for each topic, (2) lecture scripts aligned with the KWL framework, and (3) a collection of instructional scenarios designed to stimulate active thinking.

Third, the study evaluates the effectiveness of the KWL technique in improving students' active learning capacity, critical thinking, and knowledge retention. This is carried out through a pedagogical experiment involving two groups: an experimental group (taught using KWL) and a control group (taught using traditional methods).

After the lesson, students will complete a survey to evaluate their level of interest in a lesson using the KWL strategy. The evaluation focuses on three criteria: students' ability to ask questions and think critically, students' initiative in learning, and their capacity to retain and apply knowledge.

The assessment tools include a subject-specific rubric and a 5-point Likert scale survey.

4. Research objects and methods

4.1. Research Subjects

The participants of this study were first-year Electrical Engineering students at Thu Dau Mot University, enrolled in the General Physics A2 course, specifically the Wave Optics chapter. Two classes were selected: an experimental group (49 students) and a control group (49 students). Both groups were randomly assigned to ensure comparable baseline academic levels and similar learning environments.

4.2. Research Methodology

This study adopted a pedagogical action research model, employing a mixed-methods approach that integrates both quantitative and qualitative techniques to evaluate the effectiveness of the KWL strategy in Wave Optics instruction.

Initially, the research team developed lesson plans incorporating the KWL strategy, based on the theoretical underpinnings of social constructivism (Vygotsky, 1978) and the instructional design principles of KWL (Ogle, 1986).

The KWL strategy encourages students to activate prior knowledge (K), identify personal learning goals (W), and consolidate post-instruction knowledge (L). Lessons were structured following the K–W–L model, covering four main topics of the Wave Optics chapter. Activities at individual, group, and whole-class levels were integrated to promote interaction and learner autonomy.

Subsequently, a pedagogical experiment was conducted according to the principles of educational experimentation (Nguyễn, 2006). The experimental group was taught using the KWL strategy, whereas the control group received traditional lecture-based instruction. Both groups were instructed by the same teacher, with identical content, time allocation, and learning objectives. The experimental phase lasted one week.

Following the instruction, students' learning outcomes were assessed through a standardized 40-item multiple-choice test.

The assessment tool was carefully developed according to Bloom's taxonomy, targeting three cognitive domains: Remembering, Understanding, and Applying (Anderson et al., 2001). The questions comprehensively covered the topics of Wave Optics, Interference of Light, Diffraction of Light, and Polarization of Light. Each item provided four answer options (A, B, C, D) with only one correct answer, ensuring consistency and validity across the assessment.

To evaluate additional learning outcomes beyond academic achievement, the research team also administered a student survey. The survey, structured on a 5-point Likert scale, measured changes in students' learning attitudes, initiative, critical thinking skills, memory retention, and the ability to connect concepts. Items assessed interest in the subject, ability to pose questions, autonomy in learning, and retention of knowledge.

Quantitative data, including test scores and survey responses, were analyzed using Microsoft Excel. Statistical measures such as means, standard deviations, and independent samples t-tests were computed to determine the impact of the KWL strategy on learning outcomes.

Meanwhile, qualitative data from classroom observations and student reflections were thematically coded to identify emerging patterns in student perceptions, learning challenges, and to suggest improvements for future instructional practices.

5. Experimental design

5.1. Lesson structure according to the KWL model

The implementation of teaching according to the KWL model in the Wave Optics chapter includes three stages corresponding to three columns: K (What you already know), W (What you want to know), L (What you have learned). The study sheets are designed according to the content topics of the Wave Optics chapter (basics of Wave Optics, interference of light, diffraction of light and polarization of light) and implemented throughout the lesson.

5.2. Teaching process integrating KWL strategy

The KWL-integrated instructional process is structured into four phases—pre-lesson, during the lesson, end-of-lesson, and post-lesson—aiming to enhance student autonomy and foster critical thinking, self-study and self-assessment skills.

In the pre-lesson stage, the teacher conducts activate background knowledge (K) and stimulate learning interest (W). Students are asked to access Google Form and fill in two columns: "K – What I already know" (related to background knowledge about the topic) and "W – What I want to know" (questions, curiosities, or things I want to learn). Teachers support by asking open-ended questions such as "What do you remember learning about light interference during your high school studies?" or "Have you ever seen light interference in real life?", then share the survey results for the whole class to observe, creating motivation to learn from what students already know and want to know.

During the lesson phase, the teacher guides students to study according to the personal goals set in section W. The lesson content is directly connected to questions from students, and the teacher organizes group discussions for students to compare newly learned information with what has been stated in sections K and W. Students actively take notes and mark answered questions, thereby practicing oriented learning skills and self-regulation capacity.

End-of-lesson, students are asked to summarize all the knowledge they have learned by filling in the "L – What I learned" column on Google Form. Some students will be invited to present the content they have learned or answer some questions, thereby helping teachers evaluate the level of achievement of each individual. Data from the L section will help teachers identify unclear points, adjust the content and teaching methods for the next lesson.

At the end of the lesson, the teacher synthesizes the answers from the W and L sections to assess the students' progress. In addition, the content in the L section can be used to design test questions or formative assessment activities, contributing to the personalization of the learning assessment process. Completion of the KWL form also serves as a formative assessment criterion, reflecting each student's level of engagement and depth of understanding.

In this study, a 40-item multiple-choice test was constructed, aligned with the core content and cognitive levels addressed in the Wave Optics chapter. The test provided a quantitative measure of students' comprehension following the completion of the lesson.

6. Research results

After instruction, both the experimental and control groups completed a standardized 40-item multiple-choice test aligned with Bloom's taxonomy.

Following the test, reliability was assessed using Cronbach's Alpha, with results showing acceptable internal consistency for educational research (Cronbach, 1951).

The results showed a Cronbach's Alpha of 0.635 for the experimental class and 0.803 for the control class.

While the Alpha value for the experimental group was lower, it still falls within an acceptable range for educational assessments (α ≥ 0.6). This slightly lower internal consistency is consistent with the nature of the KWL strategy, which encourages individualized learning pathways and greater variability in student responses. In contrast, the traditional instructional method likely resulted in more uniform patterns of learning, thus producing a higher Alpha value.

Overall, the 40-item assessment demonstrated satisfactory reliability for evaluating student achievement in Wave Optics, particularly in contexts that promote active, self-directed learning such as the KWL strategy.

TABLE 1. Score statistics of two classes

Score	**3**	**3.25**	**3.5**	**4.5**	**4.75**	**5**	**5.25**	**5.5**	**5.75**	**6**	**6.25**	**6.5**
Number of students in experimental class	0	0	0	0	0	0	2	1	1	4	3	4
Number of students in the control class	1	5	1	5	1	5	0	0	0	3	0	3
Score	**6.75**	**7**	**7.25**	**7.5**	**7.75**	**8**	**8.25**	**8.75**	**9**	**9.25**	**9.5**	**9.75**
Number of students in experimental class	2	4	6	6	4	1	2	1	5	1	1	1
Number of students in the control class	0	2	5	13	2	0	3	0	0	0	0	0

The results of Table 1 show:

• The control class had students with very low scores such as 3.00, 3.25, 4.50, in significant numbers (up to 5 students with 3.25 and 4.50).

• The experimental class had no students below 5.25, indicating more uniformity and stability.

• The experimental class focuses strongly on the 7.25 to 9.00 score levels (accounting for over 60% of the total number of students).

• The control class was strongly concentrated in the 7.25 to 7.50 range, but was also quite scattered in the lower score range (from 3.00 to 6.00).

From the scores in Table 1, we conducted descriptive statistics of the scores of both classes as shown in Table 2 below.

TABLE 2. Statistical table describing the learning outcomes of the two classes

Index	**Experimental class (KWL)**	**Control Class (Traditional)**
Highest score	9.75	8.25
Lowest score	5.25	3.00
Average score	7.31	6.13
Standard deviation	1.1383	1.6529
Variance	1.2957	2.7320

From Table 2, it can be seen that: The experimental class achieved a higher average score than the control class (7.31 compared to 6.13), showing that the KWL strategy significantly improved learning efficiency. The lower standard deviation and variance in the experimental class showed stability and uniformity in learning outcomes. Students in the experimental class were able to achieve higher scores, with the highest score being 9.75, while the control class only achieved a maximum of 8.25. No student scored below 5.25 in the experimental class, while the control class had a student with the lowest score of 3.00.

Thus, the KWL strategy not only helps to increase average learning outcomes but also improves stability in learning outcomes, while supporting weak students and promoting the abilities of good students compared to traditional methods.

To clarify, we also plotted the score distribution graph of both classes as shown in Figure 1.

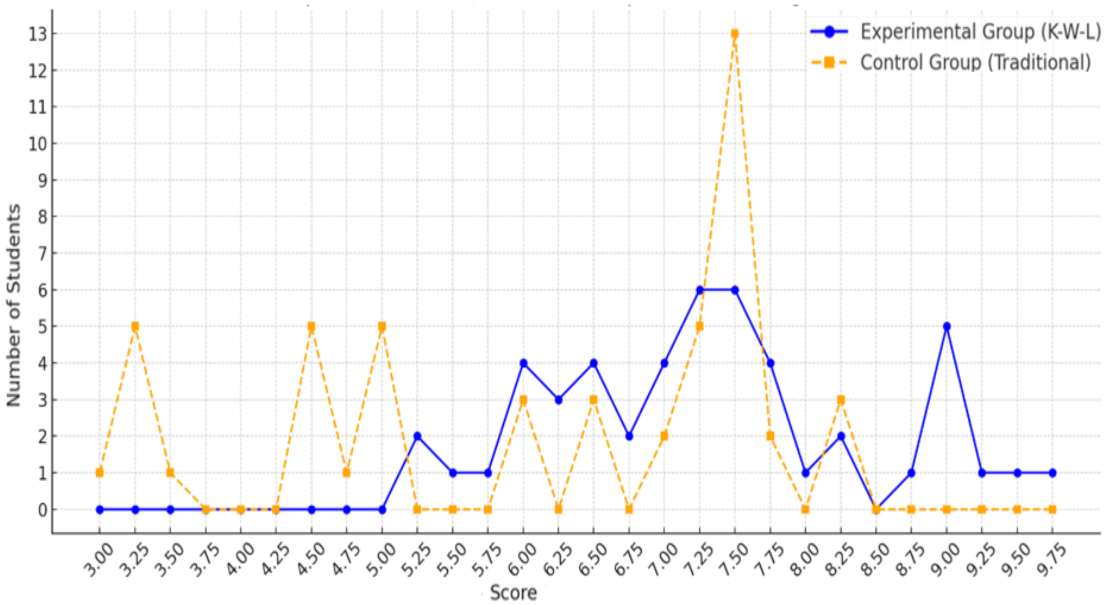

Figure 1. Score distribution chart of two classes

The actual score distribution chart clearly shows the difference between the two classes, showing:

In the experimental class (KWL application): The score spectrum tends to be evenly distributed and expanded from about 6.25 to 9.75, the peaks are relatively even, not concentrated on a specific point, which reflects: the level of absorption is even among students and the effect of KWL strategy in personalizing learning goals. In addition, students are encouraged to build their own questions (W) which also increases the ability to exploit the depth of knowledge, leading to a reasonable dispersion in the high score area instead of focusing on a specific point. There are no students with low scores (<6.0), showing the effectiveness of supporting weak students. Many moderate peaks show the development of personalized and differentiated learning in the class. The variance is smaller, showing stability and uniformity in learning outcomes.

In the control class (traditional teaching): The score distribution has a clear peak in the range of 7.25-7.75, higher than the peak of the experimental class. However, this is a narrow peak and skewed to the right, while the score distribution is more dispersed towards the low score area (below 6.0). This is because the control class is taught according to the same traditional theory - practice - test scenario, the average students - quite easily lead to the same results, without clear differentiation like the experimental class. Most students do the exercises in the direction of "memorization - direct application" without developing critical thinking deeply, thus stopping at a high average score (7.25-7.75). Some students get very low scores (below 5.0), increasing the variance and standard deviation. The score distribution is skewed to the left - a sign of passive learning, lack of creativity, reflecting rote learning.

From the chart in Figure 1, it can be seen that: Although the experimental class does not have a very high peak, the score spectrum is evenly spread, uniform and stable, demonstrating the ability to self-study - self-discover - analytical thinking thanks to the KWL strategy; The control class has a higher peak in quantity in a specific area, but is limited in depth, and at the same time has more low scores, leading to a higher standard deviation and an unbalanced distribution spectrum.

These results show that the KWL strategy has clearly shown its effectiveness in activating background knowledge, enhancing learning motivation and improving students' ability to remember and apply knowledge, as shown clearly in Table 3, a summary table comparing the score distribution of the two classes.

TABLE 3. Summary table comparing the two-class score spectrum

Characteristic	Experimental class (KWL)	Control Class (Traditional)
Score	Widespread, even, well differentiated	Focus, left
Lowest score	5.25	3.00
Peak distribution	Multiple medium-high peaks	A clear peak at 7.25–7.75
Weak students	Maximum limitation	Still low score
Ability to differentiate learners	Clear, effective	Lower
Proactivity and self-learning reflected from the score spectrum	High	Low, passive learning

In order to evaluate the effectiveness of the KWL strategy in developing self-study capacity, critical thinking and memorization ability, the research team also conducted a survey of 49 students in the experimental class after the end of the lesson with a questionnaire of 15 criteria including three contents: questioning and critical thinking skills, active learning behavior, knowledge retention and application, assessed on a 5-level Likert scale shown in Table 4.

The results show that all 15/15 criteria achieved the "Good" rating, with average scores ranging from 4.24 to 4.54. The above results show that students highly appreciate the effectiveness of the KWL strategy, especially in the following aspects:

• Critical thinking: Reflected through students knowing how to ask questions and find many explanations (≥ 4.50).

• Proactive learning: Criteria related to lesson preparation, finding documents and time management all achieved above 4.40 points.

• Remembering and applying knowledge: From synthesizing knowledge in section 'L' to the ability to explain and apply, all achieved from 4.36 to 4.48 points.

Although no criterion achieved a perfect score of 5.0, the uniform, consistent, and close-to-maximum results reflect the positive, honest, and effective reception of the KWL strategy in the university learning environment, especially among first-year students majoring in Electrical Engineering.

TABLE 4. Survey of learners after the lesson using KWL strategy

Review content	Level 1 (Strongly disagree)	Level 2 (Disagree)	Level 3 (Uncertain)	Level 4 (Agree)	Level 5 (Strongly agree)	Average score	Evaluate
SECTION 1: QUESTIONING AND CRITICAL THINKING SKILLS							
I know how to ask appropriate questions related to the lesson content.	0	0	1	24	25	4.48	Good
I often think critically before accepting information.	0	0	1	29	20	4.38	Good
I can find multiple ways to explain a problem.	0	0	2	20	28	4.52	Good
Formulating 'What I want to know' (W) questions helps me learn better.	0	0	2	29	19	4.34	Good
I am confident in asking questions in front of the class and to the lecturer.	0	0	4	27	19	4.30	Good
SECTION 2: ACTIVE LEARNING BEHAVIOR							
I prepare the lessons before class.	0	0	4	23	23	4.38	Good
I actively search for additional learning resources.	0	0	4	24	22	4.36	Good
I organize my study time effectively.	0	0	2	24	24	4.44	Good
I actively participate in group discussions in class.	0	0	1	21	28	4.54	Good

The KWL strategy encourages me to learn more actively.	0	0	5	27	18	4.26	Good
SECTION 3: KNOWLEDGE RETENTION AND APPLICATION							
I remember knowledge longer by summarizing it in the 'What I Learned' section.	0	0	2	24	24	4.44	Good
I understand the lesson better when I express what I have learned.	0	0	4	30	16	4.24	Good
I can explain the knowledge in my own words.	0	0	2	30	18	4.32	Good
I know how to apply the knowledge I have learned in real-life situations.	0	0	5	27	18	4.26	Good
The KWL strategy helps me organize knowledge more clearly.	0	0	5	22	23	4.36	Good

Through the results of the student survey after the lesson, it shows that students feel that stating what they "want to know" (W) helps them clearly orient their learning goals, the "learned" part (L) helps students consolidate knowledge and self-evaluate the learning process, the KWL strategy increases active participation in class, especially through group discussion and individual sharing.

Thus, the application of KWL strategy not only brings positive learning effects but is also well received and appreciated by students. The survey results show that the level of satisfaction is even and consistent, and there is no large differentiation in the response - this confirms the suitability of KWL for first-year students in the introductory Physics course. This is a solid basis for recommending the expansion of KWL application in STEM subjects, especially in teaching programs that aim to develop self-study and critical thinking skills.

The results obtained above are also completely consistent with the results of previous research works when using KWL strategys in teaching History, Natural Sciences and especially in STEM-oriented classes (Vacca & Vacca, 2005; Choo, 2011; Alsalhi, 2020; Liu, 2026; Zouhor et al., 2016; Mihardi et al., 2013).

7. Conclusion and recommendations

The findings of this study indicate that the KWL (Know – Want to know – Learned) strategy is an effective active teaching method that can significantly influence students' academic performance and learning attitudes, particularly at the university level. The application of this strategy in teaching the Wave Optics chapter—part of the General Physics A2 course for first-year Electrical Engineering students—has shown that learners are better able to grasp content and gain a deeper understanding of abstract physics concepts. This is achieved through their active engagement in connecting with prior knowledge (K) and formulating guiding questions (W). The learning process becomes more flexible and personalized, encouraging students to think independently, explore actively, and synthesize the knowledge they have acquired (L). The KWL strategy contributes to the development of essential competencies in modern education, such as self-directed learning, critical thinking, and knowledge application. In addition to its evident impact on academic achievement, the KWL strategy fosters the formation of active learning habits and enhances interaction and collaboration in the classroom.

Based on these findings, the application of the KWL strategy can be expanded beyond the Wave Optics chapter to other units within the General Physics A2 course, as well as to other subjects within the fields of Natural Sciences, Engineering, Technology, and Mathematics (STEM)—especially those involving abstract concepts and high levels of applicability. It is recommended that training sessions and experience-sharing workshops be organized to support instructors in adopting the KWL strategy, thereby promoting its replication as a learner-centered instructional model. Furthermore, integrating the KWL strategy with soft skills training programs—such as critical thinking, communication, and teamwork—can contribute to building a more comprehensive and sustainable learning environment for students.

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