



Procedure for generating competency in exploring the living world for high school students in the Vietnamese Mekong Delta

Tien Thi Kieu Nguyen^{a,b,*}, Duan Nguyen^c, Thuy Thi Da Dang^b

^a Faculty of Biology, University of Education, Hue University, Hue 530000, Vietnam

^b Department of Biology, An Khanh High School, Can Tho 900000, Vietnam

^c Hue University, Hue city, Hue 530000, Vietnam

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Abstract

The study aims to explore procedures for increasing high school students' competency in exploring the living world. We developed an approach for improving this competency, including competency-based instruction, experiential learning activities, deriving processes from experience, continual practice, skill enhancement, and evaluation. After a year of using this procedure, high school students in Can Tho City, Soc Trang, and Ca Mau provinces in the Mekong Delta were effectively given this competency. Both male and female students performed similarly on the questionnaire, with no significant variations in replies among students from the three locations. Focusing the educational process on project-based learning, mainly when teaching applicable "cell biology" components, significantly increased students' grasp of the subject. Integrating project-based learning helped students understand and internalize the intricacies of the living world. This strategy resulted in revolutionary growth in their cognitive talents, fostering long-term competency in exploring the living world.

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Introduction

Competency refers to a person's ability to use their current knowledge and skills in their field of expertise, especially when their intervention is required. Biology is an experimental discipline that allows students to examine the natural world through hands-on activities. This strategy helps students apply their knowledge in real-world situations and leads them in their post-secondary career direction. It is essential in assisting students in

achieving competency in exploring the living world (CELW) (Ministry of Education and Training, 2018b).

The 2018 general education curriculum emphasized the significance of competency development, including three broad competencies (self-regulation, communication and collaboration, and problem-solving) and specific competencies. The biology curriculum, in particular, stresses the acquisition of three different biology-specific competencies, including the CELW (Ministry of Education and Training, 2018b; Nguyen et al., 2024a).

* Corresponding author.

E-mail address: ntktien@thptankhanh.edu.vn (Nguyen, T. T. K.).

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This skill enables people to study and explain biological occurrences. Improving students' CELW fosters successful learning and research approaches, encourages proactive and creative thinking, and helps apply information to real problems (Nguyen et al., 2025). These skills are becoming more critical in our quickly changing scientific and technological context (Ministry of Education and Training, 2021).

According to Cooper et al. (2000); Grant (1997); Nguyen et al. (2024d), well-structured outdoor education and fieldwork dramatically improve long-term memory by providing powerful experiences. Such experiential learning improves personal growth and social skills, assisting in developing critical abilities for future success. This study in Vietnam's Mekong Delta, a region with diverse educational contexts, evaluated high school students' CELW in central, suburban, and distant locations (Nguyen et al., 2024a). The study used nine sample high schools to find regional variances in skill levels. The findings of this study will assist educators in developing successful lesson plans and instructional practices to improve students' CELW.

Project-based learning is an educational approach that prioritizes student-centered experiences based on three core constructivist principles: learning within a contextual framework, active student participation, and achieving goals through collaborative social interactions that facilitate the exchange of knowledge and insights (Cocco, 2006; Nguyen et al., 2024c). This method is viewed as a subset of inquiry-based learning in which genuine questions and real-world problems are presented to generate authentic contexts (Al-Balushi & Al-Aamri, 2014), resulting in meaningful educational experiences (Nguyen et al., 2024b; Wurdinger et al., 2007). Blumenfeld and colleagues described the project-based science process, emphasizing that students should build knowledge by tackling real-world problems, including developing and refining questions, planning and carrying out investigations, gathering, analyzing, and interpreting data, making conclusions, and presenting findings (Blumenfeld et al., 2000).

In project-based learning, students had to perform the following activities and content (Figure 1):

Through the implementation of learning projects, students developed many corresponding competencies, such as problem-solving and creativity, self-study skills, communication and cooperation skills, mathematical competencies, and information technology skills. Additionally, project-based learning contributed to forming specific subject competencies, such as scientific research capabilities, practical application of knowledge, field competencies, experimental skills, and especially the CELW. From the factors listed above, the authors found that the project-based learning method was utterly suitable for developing students' CELW.

While foundational research has established a theoretical framework for increasing biological awareness among Vietnamese students, there is a notable lack of research on improving high school students' mathematical literacy in ecology and environmental biology. This study seeks to determine how to form and develop CELW for high school students in the Mekong Delta.

Literature Review

In Biology, scientific competence was developed through exploring and solving issues related to the natural world and living organisms (Stoddart et al., 2002). This affirmed that scientific exploration enhanced students' understanding of scientific concepts and positive thinking skills. The study analyzed the inquiry-based learning model, focusing on student-centered activities with teachers as guides. The three main features were: (1) Problem-solving and knowledge integration, (2) Student-centered approach, and (3) Combining new and existing knowledge (Saab et al., 2007). Other authors also highlighted the importance of scientific inquiry skills for students and factors affecting this competence, including teachers' planning and lesson design (Chaerunisa et al., 2023; Malik, 2015; Nilawati et al., 2017; Yamashita et al., 2016).

Outdoor Education (OE) techniques are widely utilized to teach and improve CELW (Nguyen et al., 2025). Prior research has shown that active learning procedures promote knowledge retention (Cooper et al., 2000;

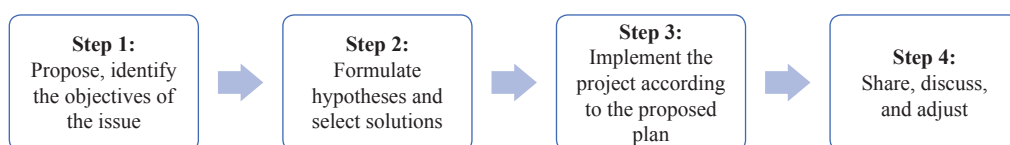


Figure 1 Steps to implement project-based learning

Grant, 1997), boost motivation and engagement (Kern & Carpenter, 1986), and help students build practical skills (Kent et al., 1997; Nguyen et al., 2024b). Several studies in Vietnam have looked into how students' perception of the living world evolves. For example, Pham et al. (2020) surveyed 10th-grade students at Hanoi National University of Education and discovered that cell observation experiments significantly improve students' biological comprehension. Similarly, Dang and Nguyen (2020) created a framework for enhancing cognitive skills relevant to the living world, including 14 competency indicators and a procedure for generating experimental activities to increase students' knowledge. Additionally, hands-on investigations in Biology grade 11 effectively promote students' CELW (Nguyen et al., 2024b).

Project-based learning is implemented into a blended teaching paradigm for university students to meet the needs of the digital age in current classrooms, improving student outcomes by preparing them for real-world difficulties through critical thinking, memory, and creativity (Lou et al., 2012). It has been shown to improve student achievement (Duke & Halvorsen, 2017), and a high-quality project-based learning framework with authentic projects engages students in meaningful problems, increasing academic performance. High school teachers understand the value of collaboration in project-based learning, emphasizing the significance of conflict resolution in group situations (de la Torre-Neches et al., 2020). During the COVID-19 pandemic, mixed-method project-based learning increased student involvement while reducing online fraud and ensuring trustworthy and valid assessment of learning outcomes (Nguyen et al., 2024b; Saba' Ayon & Harb, 2021).

In Vietnam, project-based learning research is conducted at several educational levels, including universities (Dang & Nguyen, 2024; Le & Nguyen, 2019) and high schools (Nguyen et al., 2025; Nguyen & Nguyen, 2016). These studies show that, despite differences in content and methodology, the goal is still to improve learners' positivity, initiative, and creativity.

Methodology

This study surveyed 450 high school students in the Mekong Delta using a cross-sectional approach, leveraging quantitative research methodologies (Cohen et al., 2017). Data were gathered through a structured questionnaire, following the method proposed by Pham and Nguyen (2011). A Likert scale was employed to gauge agreement levels (Allen & Seaman, 2007), with intervals of $(5-1)/5=0.8$ (Narli, 2010; Yavuz

et al., 2013). Accordingly, the meanings of the scale were determined as follows: $1.0 \leq M < 1.8$: Strongly disagree; $1.8 \leq M < 2.6$: Disagree; $2.6 \leq M < 3.4$: No idea; $3.4 \leq M < 4.2$: Agree; $4.2 \leq M \leq 5.0$: Strongly agree.

A pilot test was done before the primary survey to check the questionnaire's reliability and make any necessary adjustments (Dinh et al., 2011a, 2011b). The data collected were encrypted and analyzed using SPSS v.21. The Mann-Whitney U test was used to detect potential differences in perspectives between male and female students, whereas the Kruskal-Wallis H test was used to compare students from three distinct regions. All tests were performed with a significance level of $p < .05$.

Results and Discussion

Developing Procedure Principles for Competency in Exploring the Living World

The learners' competency can be formed and developed by applying the following principles: (1) Student autonomy in competency training: Before teaching a specific skill, educators should inform students about the required skills and the significance of the training, ensuring students and teachers actively participate throughout the process, and students should be clear about the goal of their learning and the tasks they are completing. (2) The gradual shift towards increased and decreased teacher roles: Competencies develop with time; therefore, teachers initially advise students on essential skills and processes; as students improve, their role diminishes, allowing them to exercise greater autonomy until they completely understand the abilities. (3) Adherence to competency framework: Setting up a competency framework with particular abilities, criteria, and procedures emphasizes the steps required to achieve each competency, which entails learning each skill separately before integrating them to create a holistic competency. (4) Integration of competency training and knowledge growth: Competency training should supplement students' knowledge development, a technique for increasing competencies and the consequence of active learning; as students' competencies expand, teachers must reinforce their understanding of the subject. (5) Linking the training process to student progress evaluation: Competency training should be carried out in phases, with assessments and modifications made at each stage that should contain an assessment of the training techniques, tools, and stages, as well as the student's achievement levels for each competency criterion (Le & Phan, 2016).

The Basis of Building Development Competency in Exploring the Living World Procedure

The process of forming and developing the CELW in students is complex and multidimensional, requiring a combination of experiential education and family and community support. Key components include (1) Establishing a solid knowledge base across various domains such as history, geography, natural sciences, and culture; (2) Fostering curiosity and research through an engaging learning environment; (3) Improving critical thinking and analytical skills; (4) Practicing through real-world experiences; (5) Providing individualized support to meet each student's needs; (6) Linking students to the community and real-world contexts; and (7) Continuous feedback and assessment to support progress and skill improvement (Ha et al., 2023; Le & Phan, 2016).

Several researchers have added to the corpus of knowledge about competency-based teaching techniques for studying the living world. Research findings and recommendations on teaching and learning practices aimed at developing students' CELW suggest: (1) Teachers should develop specific training programs to cultivate this competency; (2) Educators need to implement appropriate measures to ensure students' thorough exploration of the living world; (3) Development of assessment tools is necessary to evaluate the effectiveness of these competency development measures (Ha et al., 2023).

Process of Developing Competency in Exploring the Living World

Based on the competency development method described by Le and Phan (2016), we identified five critical steps for learner training, including:

(1) Introduction to competency-based teaching: In order to provide a clear understanding, teachers should introduce the broad concept of competency-based education, detailing its components and the proactive efforts students must make before their training begins.

(2) Experiential learning activities: During this phase, teachers facilitated activities to develop specific competencies, using focused resources to practice the skills and actions essential to competency-based teaching.

(3) Deriving competency-based processes from experience: Students acquired particular approaches for developing competency-based teaching strategies through hands-on activities using individual and collaborative learning techniques, which marked the beginning of practical competency-based training.

(4) Continued practice and skill enhancement: Students improved their skills and advanced to higher proficiency levels within the competency-based teaching framework.

(5) Evaluation and adjustment: This final phase entailed measuring students' competency progress and adjusting to get better results.

The Initial Result After Application in Some Vietnamese Mekong Delta High Schools

The research encompassed a varied cohort of 450 individuals, comprising 228 females (50.67 percent) and 222 males (49.3 percent) selected through random sampling for the survey. Notably, all survey respondents attend educational establishments in the Mekong Delta region, focusing on Can Tho City (145 students), Soc Trang province (31 students), and Ca Mau province (274 students). For a comprehensive breakdown of participant demographics, please refer to Figure 2 for pertinent information.

Proficiency in The Field of "Cell Biology" Equips Students With the Ability to Delve Into The Intricacies of The Living World

Cell biology is a discipline of biology that studies cell behavior, structure, and function. This discipline investigates the core components and operating mechanisms of cells, both prokaryotic and eukaryotic. Cell metabolism, communication, the cell cycle, biochemistry, and cellular composition are covered in cell biology.

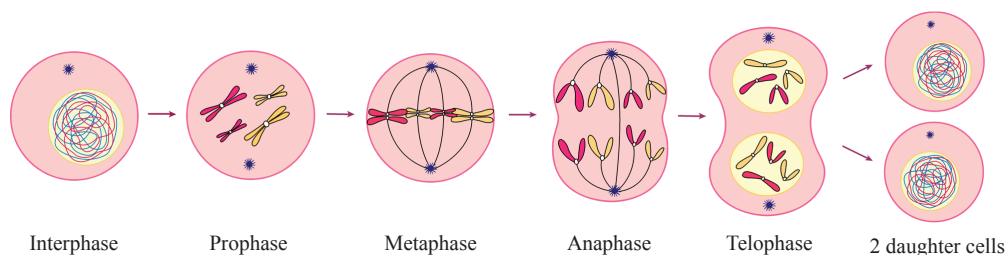


Figure 2 Diagram of the cell reproduction stages by etiological mechanism
Adapted from Mai et al., 2020

Remembering

The eukaryotic cell cycle is divided into four distinct phases: G₁ phase, S phase (synthesis), G₂ phase (also known as interphase), and M phase (mitosis and cytokinesis) (Israel & Israel, 2000). Understanding the cell cycle was critical because it provided the foundation for increased understanding at higher education levels. When asked about the order of these phases, the majority of students firmly agreed on the sequence G₁ → S → G₂ → M (M = 4.23 ± 0.04). The analysis found no significant difference in replies between male and female students (Mann-Whitney U, $p > .05$ in all cases) (Table 1).

Similarly, when students from other provinces (Can Tho, Soc Trang, and Ca Mau) were assessed, there was no significant regional variation in their understanding of the cell cycle stages (Kruskal-Wallis H, $p > .05$ for all cases) (Table 2).

We received 422 replies to the essay-type topic “Observe the picture below and describe the stages of mitosis” in Figure 2, presented in Figure 3.

Figure 3 showed more than 85 percent of students adequately described the mitotic stages. Telophase was correctly identified by 92.42 percent of students, most likely because of its distinctive characteristics. Prophase, on the other hand, had the lowest correct response rate of 85.31 percent, which could be attributed to its complex properties, such as chromosomal shape and nuclear membrane dynamics. The survey result showed students could extract information from photos to answer the question.

Students’ responses to the topic “Characteristics of the process of cytoplasmic division in animal cells during mitosis” differed. While Q32 had the highest average rating (3.37 ± 0.07 SE) for “No idea,” it was evaluated similarly to the incorrect answer Q31 (2.48 ± 0.07 SE) (Table 3). The gender-based analysis found no significant differences in mean scores (Mann-Whitney U, $p > .05$ for all cases) (Table 3).

In contrast, the province-based analysis indicated significant differences in mean scores among students from Can Tho, Soc Trang, and Ca Mau in various categories (Q31 - Q34) with Kruskal-Wallis H, $p < .05$ for all cases (Table 4).

Table 1 Students’ assessment regarding the cell cycle phase sequence

Code	Content	Mean ± SE			Mann Whitney U
		Total	Female	Male	
Q11	G ₁ , G ₂ , S, M	1.59 ± 0.04	1.61 ± 0.06	1.56 ± 0.06	Z = -.875, $p = .381$
Q12	S, G ₁ , G ₂ , M	1.65 ± 0.05	1.68 ± 0.06	1.62 ± 0.07	Z = -1.457, $p = .145$
Q13	G ₁ , S, G ₂ , M	4.25 ± 0.05	4.22 ± 0.08	4.28 ± 0.08	Z = -1.235, $p = .271$
Q14	G ₂ , G ₁ , S, M	1.51 ± 0.04	1.55 ± 0.05	1.46 ± 0.05	Z = -1.532, $p = .176$

Note: 1.0 ≤ M < 1.8: Strongly disagree; 1.8 ≤ M < 2.6: Disagree; 2.6 ≤ M < 3.4: No idea; 3.4 ≤ M < 4.2: Agree; 4.2 ≤ M ≤ 5.0: Strongly agree

Table 2 Spatial variation in students’ assessment regarding phase sequence of cell cycle

Code	Content	Mean ± SE			Kruskal-Wallis H (df = 2)
		Can Tho	Soc Trang	Ca Mau	
Q11	G ₁ , G ₂ , S, M	1.50 ± 0.07	1.87 ± 0.27	1.60 ± 0.05	$\chi^2 = 4.229$, $p = .121$
Q12	S, G ₁ , G ₂ , M	1.56 ± 0.07	1.39 ± 0.15	1.73 ± 0.06	$\chi^2 = 6.560$, $p = .083$
Q13	G ₁ , S, G ₂ , M	4.37 ± 0.09	3.68 ± 0.29	4.25 ± 0.06	$\chi^2 = 3.415$, $p = .280$
Q14	G ₂ , G ₁ , S, M	1.72 ± 0.06	1.52 ± 0.19	1.54 ± 0.05	$\chi^2 = 4.261$, $p = .121$

Note: 1.0 ≤ M < 1.8: Strongly disagree; 1.8 ≤ M < 2.6: Disagree; 2.6 ≤ M < 3.4: No idea; 3.4 ≤ M < 4.2: Agree; 4.2 ≤ M ≤ 5.0: Strongly agree

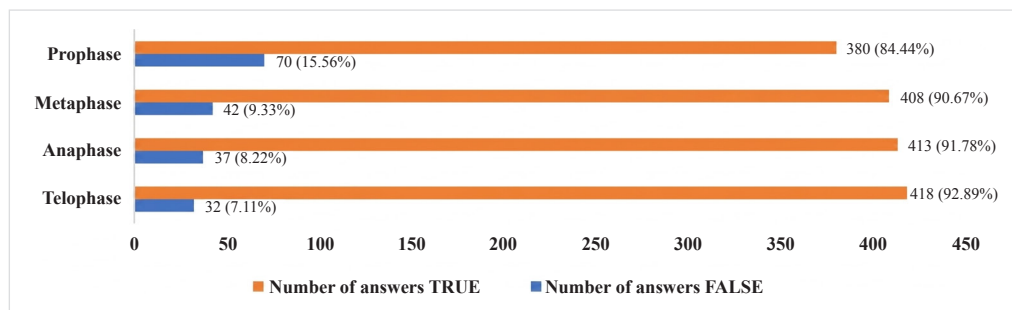


Figure 3 Students’ answers on the characteristics of mitosis stages

Table 3 The students' assessment regarding animal cytoplasm dividing traits in mitosis

Code	Content	Mean $\pm$ SE		Mann Whitney U
		Female	Male	
Q31	Create a partition in the equatorial plane	2.47 $\pm$.10	2.48 $\pm$.11	$Z = -.250, p = .803$
Q32	Tighten the cell membrane in the middle of cells	3.34 $\pm$.11	3.49 $\pm$.11	$Z = -.433, p = .665$
Q33	Cell membrane elongation	1.71 $\pm$.06	1.83 $\pm$.07	$Z = -.419, p = .675$
Q34	Create septa and elongate cell walls	2.09 $\pm$.09	2.20 $\pm$.09	$Z = -.690, p = .490$

Note: $1.0 \leq M < 1.8$: Strongly disagree; $1.8 \leq M < 2.6$: Disagree; $2.6 \leq M < 3.4$: No idea; $3.4 \leq M < 4.2$: Agree; $4.2 \leq M \leq 5.0$: Strongly agree

Table 4 Spatial variation in students' assessment regarding animal cytoplasm dividing traits in mitosis

Code	Content	Mean $\pm$ SE			Kruskal-Wallis H (df = 2)
		Can Tho	Soc Trang	Ca Mau	
Q31	Create a partition in the equatorial plane	2.04 $\pm$ 0.11	2.84 $\pm$ 0.33	2.66 $\pm$ 0.09	$\chi^2 = 19.765, p = .000$
Q32	Tighten the cell membrane in the middle of cells	3.69 $\pm$ 0.13	2.90 $\pm$ 0.31	3.25 $\pm$ 0.09	$\chi^2 = 11.180, p = .004$
Q33	Cell membrane elongation	1.57 $\pm$ 0.08	1.61 $\pm$ 0.20	1.89 $\pm$ 0.06	$\chi^2 = 15.586, p = .000$
Q34	Create septa and elongate cell walls	1.36 $\pm$ 0.10	2.00 $\pm$ 0.25	2.31 $\pm$ 0.08	$\chi^2 = 18.266, p = .000$

Note: $1.0 \leq M < 1.8$: Strongly disagree; $1.8 \leq M < 2.6$: Disagree; $2.6 \leq M < 3.4$: No idea; $3.4 \leq M < 4.2$: Agree; $4.2 \leq M \leq 5.0$: Strongly agree

Survey results for “Remembering” level questions show that students can easily recollect learned material because these questions do not require substantial cognitive effort. Following psychologist Ebbinghaus’s “forgetting curve” strategy, teachers routinely reinforce this knowledge. According to Ebbinghaus (1985), new knowledge is initially kept in short-term memory and must be repeated to prevent quick forgetting.

Understanding

Bloom defines “understanding” as the ability to grasp, interpret, explain, or infer concepts (predict results). It requires more than just repetition; pupils must communicate topics in their own words. When designing test questions, teachers might utilize verbs such as interpret, differentiate, illustrate, depict, restate, rewrite, give examples, summarize, and explain to assess students’ comprehension.

While asked about the topic “Choose the right idea when talking about meiosis,” students needed to think deeper to recognize wrong answers rather than just

recalling information. Table 5 shows that Q42 was the correct response with the highest average rating (4.07 $\pm$ 0.06 SE). A gender-based analysis revealed no significant differences in average scores (Mann-Whitney U, $p > .05$ for all cases) (Table 5).

In contrast, the province-based analysis revealed significant variations in mean scores among students from Can Tho, Soc Trang, and Ca Mau in several categories (Q41-Q44) (Kruskal-Wallis H, $p < .05$ for all cases) (Table 6).

Students were asked to observe an image (Table 7) and determine the present stage of cell division, “What is the species’ diploid number?” The results showed significant variation in rating levels (Table 7). Although Q54 was the correct response, its average rating (2.74 $\pm$ 0.08 SE) was significantly lower than the wrong Q51 (3.16 $\pm$ 0.08). This indicated that students’ ability to analyze visuals at the “Understanding” level was limited. The average ratings of male and female students did not differ significantly (Mann-Whitney U, $p > .05$ for all cases) (Table 7).

Table 5 Students' assessment regarding meiosis traits

Code	Content	Mean $\pm$ SE			Mann Whitney U
		Total	Female	Male	
Q41	Each cell can undergo meiosis once or many times	1.86 $\pm$ 0.05	1.79 $\pm$ 0.07	1.86 $\pm$ 0.08	$Z = -0.096, p = .923$
Q42	Meiosis undergoes two cell divisions, but chromosomes only duplicate once	4.07 $\pm$ 0.06	4.17 $\pm$ 0.08	4.05 $\pm$ 0.09	$Z = -0.112, p = .911$
Q43	Meiosis occurs in every cell of the sex organ	2.05 $\pm$ 0.06	1.90 $\pm$ 0.08	2.10 $\pm$ 0.09	$Z = -0.920, p = .357$
Q44	Meiosis does not undergo cytoplasmic division	1.79 $\pm$ 0.05	1.79 $\pm$ 0.07	1.73 $\pm$ 0.07	$Z = -0.669, p = .503$

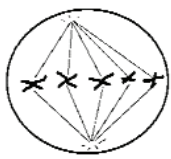
Note: $1.0 \leq M < 1.8$: Strongly disagree; $1.8 \leq M < 2.6$: Disagree; $2.6 \leq M < 3.4$: No idea; $3.4 \leq M < 4.2$: Agree; $4.2 \leq M \leq 5.0$: Strongly agree

Table 6 Spatial variation in students' assessment regarding meiosis traits

Code	Content	Mean $\pm$ SE			Kruskal-Wallis H (df = 2)
		Can Tho	Soc Trang	Ca Mau	
Q41	Each cell can undergo meiosis once or many times	1.65 $\pm$ 0.09	1.52 $\pm$ 0.19	1.94 $\pm$ 0.07	$\chi^2 = 14.772$, $p = .001$
Q42	Meiosis undergoes two cell divisions, but chromosomes only duplicate once	4.33 $\pm$ 0.09	4.00 $\pm$ 0.26	4.01 $\pm$ 0.07	$\chi^2 = 10.751$, $p = .005$
Q43	Meiosis occurs in every cell of the sex organ	1.66 $\pm$ 0.09	1.84 $\pm$ 0.23	2.20 $\pm$ 0.08	$\chi^2 = 18.985$, $p = .000$
Q44	Meiosis does not undergo cytoplasmic division	1.63 $\pm$ 0.08	1.74 $\pm$ 0.21	1.83 $\pm$ 0.06	$\chi^2 = 9.047$, $p = .011$

Note: 1.0 $\leq M < 1.8$: Strongly disagree; 1.8 $\leq M < 2.6$: Disagree; 2.6 $\leq M < 3.4$: No idea; 3.4 $\leq M < 4.2$: Agree; 4.2 $\leq M \leq 5.0$: Strongly agree

Table 7 Students' assessment in a specific cell cycle stage determining

Image	Code	Content	Mean $\pm$ SE			Mann Whitney U
			Total	Female	Male	
	Q51	Metaphase, 2n = 10	3.16 $\pm$ 0.08	2.94 $\pm$ 0.11	3.33 $\pm$ 0.11	$Z = -2.348$, $p = .091$
	Q52	Prophase, 2n = 10	1.78 $\pm$ 0.05	1.71 $\pm$ 0.07	1.77 $\pm$ 0.07	$Z = -.282$, $p = .778$
	Q53	Prophase I, 2n = 10	1.80 $\pm$ 0.05	1.82 $\pm$ 0.07	1.77 $\pm$ 0.08	$Z = -0.994$, $p = .320$
	Q54	Metaphase I, 2n = 10	2.74 $\pm$ 0.08	2.87 $\pm$ 0.11	2.55 $\pm$ 0.11	$Z = -1.935$, $p = .053$

Note: 1.0 $\leq M < 1.8$: Strongly disagree; 1.8 $\leq M < 2.6$: Disagree; 2.6 $\leq M < 3.4$: No idea; 3.4 $\leq M < 4.2$: Agree; 4.2 $\leq M \leq 5.0$: Strongly agree

The Kruskal-Wallis H test revealed considerable variation in the average assessment of Q51 (Metaphase, 2n=10) between provinces ($\chi^2 = 16.028$, $p = .000$). Students from Can Tho (2.82 $\pm$ 0.14 SE), Soc Trang (2.65 $\pm$ 0.33 SE), and Ca Mau (3.36 $\pm$ 0.99 SE) had significant disparities in their ratings, with the majority of Ca Mau students believing Q51 was the correct response. There were no significant variations in average evaluation scores for Q52, Q53, and Q54 across provinces (Q52: $\chi^2 = 9.197$, $p = .010$; Q53: $\chi^2 = 5.469$, $p = .065$; Q54: $\chi^2 = .944$, $p = .624$) (Table 8).

When asked about the field of biotechnology, students identified Q61 ("In vitro environment for the maintenance and proliferation of cells and tissues, thereby producing products for human use") as the correct answer, receiving the highest average score (3.99 $\pm$ 0.06 SE) (Table 9). Male and female students did not have significantly different average scores (Mann-Whitney U, $p > .05$ for all cases) (Table 9).

There was no significant difference in the average assessments for Q62, Q63, and Q64 between students from Can Tho, Soc Trang, and Ca Mau (Kruskal-Wallis H, $p > .05$ for all responses) (Table 10).

Proficiency in cell biology enables students to delve into the intricacies of the living world. Cell biology not only provides foundational knowledge about cell structures and functions but also enhances understanding of processes such as cell metabolism, intercellular communication, and the cell cycle. By mastering the cell cycle (including G1, S, G2, and M phases), students can build a solid foundation for exploring advanced biological concepts, such as molecular and developmental biology. Interestingly, despite the complexity of the subject, research shows no significant gender or regional differences in students' grasp of the cell cycle stages. This indicates that with proper guidance, all students have equal potential to access this knowledge.

Table 8 Spatial variation in students' assessment in a specific cell cycle stage determining

Code	Content	Mean $\pm$ SE			Kruskal-Wallis H (df = 2)
		Can Tho	Soc Trang	Ca Mau	
Q51	Metaphase, 2n = 10	2.82 $\pm$ 0.14	2.65 $\pm$ 0.33	3.36 $\pm$ 0.99	$\chi^2 = 16.028$, $p = .000$
Q52	Prophase, 2n = 10	1.64 $\pm$ 0.09	1.74 $\pm$ 0.22	1.79 $\pm$ 0.06	$\chi^2 = 9.197$, $p = .010$
Q53	Prophase I, 2n = 10	1.76 $\pm$ 0.10	1.68 $\pm$ 0.19	1.83 $\pm$ 0.06	$\chi^2 = 5.469$, $p = 0.065$
Q54	Metaphase I, 2n = 10	2.78 $\pm$ 0.14	2.87 $\pm$ 0.30	2.66 $\pm$ 0.90	$\chi^2 = 0.944$, $p = .624$

Note: 1.0 $\leq M < 1.8$: Strongly disagree; 1.8 $\leq M < 2.6$: Disagree; 2.6 $\leq M < 3.4$: No idea; 3.4 $\leq M < 4.2$: Agree; 4.2 $\leq M \leq 5.0$: Strongly agree

Table 9 Students' assessment regarding in vitro role cell technology

Code	Content	Mean $\pm$ SE			Mann Whitney U
		Total	Female	Male	
Q61	In vitro (in vitro) maintains and increases cells and tissues, producing products that serve human life	4.04 $\pm$ 0.06	4.04 $\pm$ 0.08	4.04 $\pm$ 0.08	Z = 0.256 p = .798
Q62	The biological environments maintain and increase cells and tissues, producing products to serve human life	2.33 $\pm$ 0.07	2.30 $\pm$ 0.09	2.36 $\pm$ 0.10	Z = -0.135 p = .893
Q63	Water maintains and increases cells and tissues, producing products that serve human life	1.94 $\pm$ 0.05	1.99 $\pm$ 0.08	1.89 $\pm$ 0.07	Z = -0.840 p = .401
Q64	A shallow medium maintains and increases cells and tissues, producing products that serve human life	1.90 $\pm$ 0.05	2.84 $\pm$ 0.11	2.86 $\pm$ 0.11	Z = -0.468 p = .627

Note: 1.0 $\leq$ M < 1.8: Strongly disagree; 1.8 $\leq$ M < 2.6: Disagree; 2.6 $\leq$ M < 3.4: No idea; 3.4 $\leq$ M < 4.2: Agree; 4.2 $\leq$ M $\leq$ 5.0: Strongly agree

Table 10 Spatial variation in students' assessment regarding in vitro role cell technology

Code	Content	Mean $\pm$ SE			Kruskal-Wallis H (df = 2)
		Can Tho	Soc Trang	Ca Mau	
Q61	In vitro (in vitro) maintains and increases cells and tissues, producing products that serve human life	4.39 $\pm$ 0.09	3.16 $\pm$ 0.32	3.95 $\pm$ 0.08	χ^2 = 11.062 p = .004
Q62	The biological environments maintain and increase cells and tissues, producing products to serve human life	2.01 $\pm$ 0.11	2.29 $\pm$ 0.28	2.50 $\pm$ 0.08	χ^2 = 3.175 p = .204
Q63	Water maintains and increases cells and tissues, producing products that serve human life	1.79 $\pm$ 0.09	2.13 $\pm$ 0.26	1.99 $\pm$ 0.06	χ^2 = 3.829 p = 0.147
Q64	A shallow medium maintains and increases cells and tissues, producing products that serve human life	1.80 $\pm$ 0.10	2.03 $\pm$ 0.25	1.93 $\pm$ 0.06	χ^2 = 2.448 p = .294

Note: 1.0 $\leq$ M < 1.8: Strongly disagree; 1.8 $\leq$ M < 2.6: Disagree; 2.6 $\leq$ M < 3.4: No idea; 3.4 $\leq$ M < 4.2: Agree; 4.2 $\leq$ M $\leq$ 5.0: Strongly agree

Arranging Instructional Endeavors to Cultivate Competency in Exploring the Living World Using Project-Based Learning Approaches

The project-based teaching process consisted of ten steps: (1) deciding on the project topic; (2) defining the result; (3) structuring the project; (4) preparing information gathering requirements; (5) collecting information; (6) preparing data analysis requirements; (7) synthesizing and analyzing information; (8) preparing reporting requirements; (9) presenting the final product; and (10) evaluating the project (Du & Han, 2016). The procedure for adapting to Vietnamese educational conditions was divided into three phases: preparation, implementation, and evaluation (Vu & Nguyen, 2022). This approach was used to construct instructional activities for "Cell Biology". The procedure is as follows:

Step 1: Prepare

The requirement to "Perform a project or topic to learn about the application of cell multiplication" is mentioned in the Biology 10 program (Ministry of Education and Training, 2018a). The content of the project is shown in Table 11.

The preparation steps to organize the activity are carried out as follows:

- The teacher described knowledge and skill objectives, emphasizing the activity's goal of developing students' CELW. The teacher explained the competency framework and activity procedures.

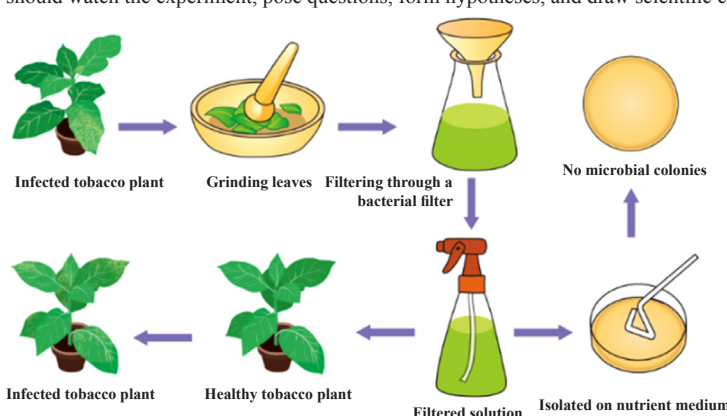
- The teacher began the activity using the content from Table 11. The activity sheet contained a complete list of activity needs. Student groups indicated activity needs, and the teacher clarified processes and tracked progress, making necessary adjustments.

Step 2: Develop an implementation plan

- Teachers organized students into groups for classroom or home activities. Students used photographs to capture their group activities and record the results. They debated and evaluated the data to test the hypothesis. If the theory was validated, they reached study conclusions. Teachers help pupils write scientific reports, potentially utilizing poster templates. If results do not support the hypothesis, students should discover the cause or develop and test a new theory.

- After completing the assignment, students gave a scientific report (poster or PowerPoint) to defend their findings. Other groups could ask questions, and the teacher might ask open-ended questions to stimulate discussion and reasoned answers.

Table 11 Teaching content of the project “Cell Biology”

Dmitri Ivanovsky demonstrated in 1892 that sap from a diseased tobacco plant could infect a healthy tobacco plant even after it had been filtered via bacteria-trapping filters. No microbiological colonies were found when the filtrate was grown on nutritional media. Students should watch the experiment, pose questions, form hypotheses, and draw scientific conclusions.					
 The diagram illustrates the experimental process. It starts with an 'Infected tobacco plant' (top left) which leads to 'Grinding leaves' (top middle). This is followed by 'Filtering through a bacterial filter' (top right), resulting in a 'Filtered solution' (bottom middle). The 'Filtered solution' is then 'Isolated on nutrient medium' (bottom right), showing 'No microbial colonies' (top right). Finally, the 'Filtered solution' is used to infect a 'Healthy tobacco plant' (bottom left), which then becomes an 'Infected tobacco plant' (bottom left).					
The research question is:					
The scientific hypothesis is:					
The scientific conclusion is:					

Step 3: Evaluate Research question

A research question outlines the subject under investigation and should be adequately stated. For the information in Table 9, an applicable inquiry was, “Why does the sap of a diseased tobacco plant transmit disease to a healthy plant even after bacterial filtration?” The result showed a considerable variation in the proportion of students who answered correctly and wrongly (30.23% and 69.77%).

The scientific hypothesis

The scientific hypothesis was a challenging and complex problem and was studied by many authors. Duong (2002) states, “Hypothesis is the predictive solution to a research problem and is expressed in the form of generalizations or propositions”. Le and Nguyen (2004) revealed that “Scientific hypothesis is a hypothetical model or a probabilistic prediction about phenomena’ nature, interrelationships, and causes. It was a prediction of the expectations of the research process”. The scientific hypothesis had the following characteristics: Orientation, prediction of research results, authenticity not known, and need verification. A hypothesis was defined as a relationship between two or more variables.

The scientific hypothesis for the teaching project we are working on was that “the virus’s genetic material has been introduced into the tobacco sap cells”. The survey results for this question showed that 77.53 percent of students answering incorrectly and 22.47 percent answering correctly.

Scientific conclusion

For the above activity, the appropriate scientific conclusion was made: “What is filtered out is only the shell of that virus, and the genetic material has been introduced into the cell”. The results showed that the difference between the percentage of students who answered correctly and students who answered incorrectly is quite significant, with the percentage of students who responded correctly being only 24.17 percent while the percentage of students who answered incorrectly accounted for 75.83 percent.

This result reflected the student’s CELW through project teaching with the “Cell Biology” theme. As mentioned above, forming the CELW required a long-term accumulation process to be successful. The percentage of students who could identify the research question when implementing a learning project shows that students are gradually building the CELW.

The project-based learning (PBL) approach was a vital tool for cultivating students’ CELW. This process included selecting topics, defining outcomes, gathering information, analyzing data, and presenting final results. In cell biology, an example project like “application of cell cloning” enabled students to conduct experiments and address real-world problems. Results showed this method enhances critical thinking, analytical skills, and student engagement. However, the percentage of students who correctly answered research questions or provided accurate scientific conclusions remained low (below 30%).

This highlighted that developing CELW requires long-term accumulation and support from teachers, especially in guiding hypothesis building and result evaluation. Recently, the application of project-based learning to develop competencies related to exploring the natural world for students from elementary to high school levels demonstrated effectiveness in various subjects through several studies by many authors (Han & Do, 2023; Nguyen et al., 2024; Pham & Bui, 2023; Vu & Nguyen, 2022).

Conclusions and Recommendations

This study demonstrated the effectiveness of competency-based and project-based learning methods in enhancing high school students' CELW in Vietnam's Mekong Delta. By applying a structured framework of experiential learning, students significantly improved their comprehension, particularly in cell biology. The findings indicated that gender and geographic differences did not affect student performance, confirming the universal applicability of the teaching methods. Although students showed promising results in cognitive growth and long-term skill development, challenges such as low hypothesis-building success rates suggest continuous teacher support and instructional refinement.

Based on these compelling findings, an innovative and forward-looking idea arises, suggesting the deliberate and systematic broadening of research horizons. This expansion should encompass a broader range of geographical regions and delve into various thematic areas. Applying this approach across different subjects within the 11th and 12th-grade biology curriculum would be advisable. To further enhance student's CELW, educators should: (1) Expand the application of project-based learning to other biological subjects for grades 11 and 12 to provide a holistic understanding; (2) Offer more intensive training in hypothesis formulation and scientific analysis; (3) Implement regular feedback mechanisms to refine teaching methodologies and address student challenges; (4) Encourage collaboration between schools and communities to enrich experiential learning opportunities; (5) Explore the application of this competency-based approach across diverse educational contexts to validate its adaptability and impact. This would allow for a more comprehensive evaluation of the strategy's effectiveness in improving high school students' CELW.

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Declaration of conflicting interests

The authors declare no potential conflicts of interest concerning the research.

References

- Al-Balushi, S. M., & Al-Aamri, S. S. (2014). The effect of environmental science projects on students' environmental knowledge and science attitudes. *International Research in Geographical and Environmental Education*, 23(3), 213–227. <https://doi.org/10.1080/10382046.2014.927167>
- Allen, I. E., & Seaman, C. A. (2007). Likert scales and data analyses. *Quality Progress*, 40(7), 64–65. <https://www.bayviewanalytics.com/reports/asq/likert-scales-and-data-analyses.pdf>
- Blumenfeld, P., Fishman, B. J., Krajcik, J., Marx, R. W., & Soloway, E. (2000). Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. *Educational Psychologist*, 35(3), 149–164. https://doi.org/10.1207/S15326985EP3503_2
- Chaerunisa, Z. F., Ramli, M., & Sugiharto, B. (2023). Students' inquiry skills progression based on STEM approach and inquiry lab. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 9(2), 206–216. <https://doi.org/10.22219/jpbi.v9i2.25698>
- Cocco, S. (2006). *Student leadership development: The contribution of project-based learning* [Unpublished master's thesis]. Royal Roads University. https://central.bac-lac.gc.ca/.item?id=MR17869&op=pdf&app=Library&oclc_number=271429340
- Cohen, L., Manion, L., & Morrison, K. (2017). Surveys, longitudinal, cross-sectional and trend studies. In *Research methods in education* (pp. 334–360).
- Routledge, Cooper, J. L., MacGregor, J., Smith, K. A., & Robinson, P. (2000). Implementing small-group instruction: Insights from successful practitioners. *New Directions for Teaching and Learning*, 2000(81), 63–76. <https://doi.org/10.1002/tl.8105>
- Dang, T. D. T., & Nguyen, T. D. P. (2020). Tổ chức hoạt động thực hành thí nghiệm theo định hướng phát triển năng lực tìm hiểu thế giới sống trong dạy học phần sinh học cơ thể ở trung học phổ thông [Organizing experimental practice activities towards developing inquiring about the world of life competence for students in teaching module "Biology body" at high school]. *Vietnam Journal of Education*, 480, 25–30. [In Vietnamese]
- Dang, V. D., & Nguyen, T. N. (2024). Áp dụng mô hình lớp học đảo ngược (flipped classroom) trong đổi mới phương pháp dạy học ở khoa Địa lý, Trường Đại học Sư phạm Hà Nội theo định hướng phát triển năng lực [Applying the flipped classroom model in innovating teaching methods at the Department of Geography, Hanoi University of Education according

- to the orientation of capacity development]. *Journal of Educational Equipment: Applied Research*, 1(304), 69–72. [In Vietnamese]
- de la Torre-Neches, B., Rubia-Avi, M., Aparicio-Herguedas, J. L., & Rodríguez-Medina, J. (2020). Project-based learning: An analysis of cooperation and evaluation as the axes of its dynamic. *Humanities and Social Sciences Communications*, 7(1), 167. <https://doi.org/10.1057/s41599-020-00663-z>
- Dinh, M. Q., Nguyen, T. K. T., & Tran, T. B. (2011a). Kết quả khảo sát bước đầu về tình hình sử dụng “Hai giờ tự học” của sinh viên Trường Đại học Cần Thơ [The primary survey results on the using of “two self-study periods” by students at Can Tho University]. *Can Tho University Journal of Science*, 20a, 183–192. [In Vietnamese]
- Dinh, M. Q., Nguyen, T. K. T., & Tran, T. B. (2011b). Kết quả nghiên cứu bước đầu về việc xây dựng mô hình sinh hoạt chi đoàn theo học chế tín chỉ tại Trường Đại học Cần Thơ [The primary results of the survey about the way to form “an activity model of the youth branch” based on the credit-based system at Cantho University]. *Can Tho University Journal of Science*, 20a, 176–182. [In Vietnamese]
- Du, X., & Han, J. (2016). A literature review on the definition and process of project-based learning and other relative studies. *Creative Education*, 7(7), 1079–1083. <https://doi.org/10.4236/ce.2016.77112>
- Duke, N. K., & Halvorsen, A.-L. (2017). *New study shows the impact of PBL on student achievement*. Edutopia. <https://www.edutopia.org/article/new-study-shows-impact-pbl-student-achievement-nell-duke-anne-lise-halvorsen>
- Duong, T. T. (2002). *Research methods in educational and psychological sciences* (Vol. 2). <https://fr.slideshare.net/slideshow/phng-php-nghin-cu-khoa-hc-gio-dc-v-tm-l/250358123>
- Ebbinghaus, H. (1985). Remembering Ebbinghaus. *Contemporary Psychology*, 30(7), 519–523. <https://doi.org/10.1037/023895>
- Grant, R. (1997). A claim for the case method in the teaching of geography. *Journal of Geography in Higher Education*, 21(2), 171–185. <https://doi.org/10.1080/03098269708725423>
- Ha, V. D., Pham, T. H. T., Nguyen, T. H. N., Duong, T. T., & Nguyen, N. T. (2023). Nguyên tắc và quy trình đánh giá năng lực tìm hiểu thế giới sống trong dạy học môn Sinh học ở trường trung học phổ thông [Principles and procedures for assessing the ability to understand the living world in teaching biology in high schools]. *Vietnam Journal of Education*, 23(11), 12–17. [In Vietnamese]
- Han, T. H. T., & Do, H. T. (2023). Tổ chức dạy học dựa trên vấn đề bài học STEM “hiện tượng bay hơi và ngưng tụ” (Khoa học tự nhiên 6) nhằm phát triển năng lực khoa học tự nhiên cho học sinh [Organizing teaching based on the STEM lesson problem “evaporation and condensation” (Natural Science 6) to develop students’ natural science capacity]. *Vietnam Journal of Education*, 23(13), 29–35. [In Vietnamese]
- Israels, E., & Israels, L. (2000). The cell cycle. *The Oncologist*, 5(6), 510–513. <https://doi.org/10.1634/theoncologist.5-6-510>
- Kent, M., Gilbertson, D. D., & Hunt, C. O. (1997). Fieldwork in geography teaching: A critical review of the literature and approaches. *Journal of Geography in Higher Education*, 21(3), 313–332. <https://doi.org/10.1080/03098269708725439>
- Kern, E. L., & Carpenter, J. R. (1986). Effect of field activities on student learning. *Journal of Geological Education*, 34(3), 180–183. <https://doi.org/10.5408/0022-1368-34.3.180>
- Le, D. T., & Phan, T. T. H. (2016). *Dạy học theo định hướng hình thành và phát triển năng lực người học ở trường phổ thông* [Teaching oriented towards forming and developing learners’ capacity in high school]. University of Education Publishers. [In Vietnamese]
- Le, T. C., & Nguyen, V. D. (2004). *Phương pháp nghiên cứu khoa học giáo dục* [Scientific research methodology]. Hanoi Pedagogical University Publishing House. [In Vietnamese]
- Le, T. K. N., & Nguyen, T. T. (2019). Organizing project-based teaching in teaching “object-oriented programming” for college students of applied informatics at Quang Tri Pedagogical College. *Vietnam Journal of Education*, 474(2), 1–5.
- Cohen, L., Manion, L., & Morrison, K. (2017). Surveys, longitudinal, cross-sectional and trend studies. In *Research methods in education* (pp. 334-360). Routledge.
- Mai, S. T., Dinh, Q. B., Le, T. P. H., Tran, T. T., Ngo, V. H., & Doan, V. T. (2020). *Sách giáo khoa Sinh học 10 - Cánh Diều* [Biology textbook grade 10 - Kite series]. Ho Chi Minh City University of Education Publishing House. [In Vietnamese]
- Malik, A. (2015). Model pembelajaran problem based instruction untuk meningkatkan penguasaan konsep dan keterampilan proses sains mahasiswa. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 1(1), 9–16. <https://doi.org/10.21009/1.01102>
- Ministry of Education and Training. (2018a). *Chương trình giáo dục phổ thông - Chương trình Sinh học (Ban hành kèm theo Thông tư số 32/2018/TT-BGDĐT)* [General education program - Biology curriculum]. Ministry of Education and Training. [In Vietnamese]
- Ministry of Education and Training. (2018b). *Chương trình giáo dục phổ thông - Chương trình tổng thể (Ban hành kèm theo Thông tư số 32/2018/TT-BGDĐT)* [General education program - Master plan]. Ministry of Education and Training. [In Vietnamese]
- Ministry of Education and Training. (2021). *Thông tư số 39/2021/TT-BGDĐT: Ban hành danh mục thiết bị dạy học tối thiểu cấp Trung học phổ thông* [Circular No. 39/2021/TT-BGDĐT: Promulgating the list of minimum teaching equipment for high school level]. Ministry of Education and Training. <https://datafiles.chinhphu.vn/cpp/files/vbpq/2022/01/39-bgddt.pdf> [In Vietnamese]
- Narli, S. (2010). An alternative evaluation method for Likert type attitude scales: Rough set data analysis. *Scientific Research and Essays*, 5(6), 519–528.
- Nilawati, W., Desnita, D., & Akbar, N. (2017). Perangkat perkuliahan terpadu berbasis KPS untuk meningkatkan kompetensi mahasiswa pendidikan fisika mengembangkan lembar kerja siswa. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 3(1), 103–110. <https://doi.org/10.21009/1.03114>
- Nguyen, T. H. V., & Nguyen, T. H. (2016). Tổ chức dạy học dự án trong dạy học Sinh học trung học phổ thông [Organizing project teaching in high school biology teaching]. *Vietnam Journal of Education*, 392, 56–59. [In Vietnamese]
- Nguyen, T. H., Pham, T. H. T., Nguyen, T. T., Ha, V. D., & Nguyen, T. H. N. (2024). Vận dụng phương pháp khoa học để phát triển năng lực tìm hiểu thế giới sống cho học sinh trong dạy học chủ đề “Sinh học vi sinh vật và virus” (Sinh học 10) [Applying scientific methods to develop students’ inquiry skills in teaching the topic “Microbial biology and viruses” (Biology 10)]. *Vietnam Journal of Education*, 24(5), 11–16. [In Vietnamese]
- Nguyen, T. K. T., Nguyen, D., & Dang, T. D. T. (2024a). Educational status of high school biology teachers to develop living world understanding competency in students: A case study in the Mekong Delta, Vietnam. *The International Journal of Interdisciplinary Social and Community Studies*, 19(2), 63–83. <https://doi.org/10.18848/2324-7576/CGP/v19i02/63-83>
- Nguyen, T. K. T., Nguyen, D., & Dang, T. D. T. (2024b). An eight-step process of revitalizing living understanding competency for high school students in biology teaching. *Kasetsart Journal of Social Sciences*, 45(4), 1259–1268. <https://doi.org/10.34044/j.kjss.2024.45.4.19>
- Nguyen, T. K. T., Nguyen, D., & Dang, T. D. T. (2024c). Teaching equipment and assessment methods, techniques, and tools used by Biology teachers to enhance living world understanding competency for high school students in the Vietnamese Mekong Delta. *Kasetsart Journal of Social Sciences*, 45(3), 791–802. <https://doi.org/10.34044/j.kjss.2024.45.3.10>

- Nguyen, T. K. T., Nguyen, D., & Dang, T. D. T. (2024d). Understanding of the living world of high school students in the Mekong Delta, Vietnam. *Kasetsart Journal of Social Sciences*, 45(1), 95–102. <https://doi.org/10.34044/j.kjss.2024.45.1.10>
- Nguyen, T. K. T., Nguyen, D., & Dang, T. D. T. (2025). Assessing the competency in exploring the living world of high school students through practical examples: A case study in the Mekong Delta, Vietnam. *Kasetsart Journal of Social Sciences*, 46(2), 460222. <https://doi.org/10.34044/j.kjss.2025.46.2.22>
- Pham, H. H., & Bui, T. T. H. (2023). Phát triển năng lực nghiên cứu khoa học cho sinh viên dựa trên dạy học tích hợp nghiên cứu [Developing students' scientific research capacity through integrated research-oriented teaching]. *Vietnam Journal of Educational Sciences*, 19(11), 1–9. <https://doi.org/10.15625/2615-8957/12311101>. [In Vietnamese]
- Pham, T. H. T., Dang, T. T. H., & Hoang, A. T. (2020). Dạy học thực hành thí nghiệm nhằm phát triển năng lực cho học sinh ở trường trung học phổ thông [Teaching practical experiments to develop Biology competence for high school students]. *Vietnam Journal of Education*, 483(8), 38–43. [In Vietnamese]
- Pham, V. Q., & Nguyen, Q. T. (2011). *Phương pháp nghiên cứu xã hội học* [Methods of sociological research]. Hanoi National University Publishing House. [In Vietnamese]
- Saab, N., Van Joolingen, W. R., & Van Hout-Wolters, B. H. (2007). Supporting communication in a collaborative discovery learning environment: The effect of instruction. *Instructional Science*, 35, 73–98. <https://doi.org/10.1007/s11251-006-9003-4>
- Saba 'Ayon, N., & Harb, G. (2021). Authentic project-based learning in times of crisis. *International Journal of Business and Applied Social Science*, 7, 1–11. <https://doi.org/10.33642/ijbass.v7n12p1>
- Stoddart, T., Pinal, A., Latzke, M., & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. *Journal of Research in Science Teaching*, 39(8), 664–687. <https://doi.org/10.1002/tea.10040>
- Vu, L. C., & Nguyen, T. H. (2022). Tổ chức dạy học dự án trong dạy học kiến thức ứng dụng của chủ đề “Sinh học vi sinh vật và virus” (Sinh học 10) [Organizing project teaching in teaching applied knowledge of the topic “Biology of microorganisms and viruses” (Biology grade 10)]. *Vietnam Journal of Education*, 22(15), 18–23. [In Vietnamese]
- Wurdinger, S., Haar, J., Hugg, R., & Bezon, J. (2007). A qualitative study using project-based learning in a mainstream middle school. *Improving Schools*, 10(2), 150–161. <https://doi.org/10.1177/1365480207078048>
- Yamashita, K., Fujioka, R., Kogure, S., Noguchi, Y., Konishi, T., & Itoh, Y. (2016). Practices of algorithm education based on discovery learning using a program visualization system. *Research and Practice in Technology Enhanced Learning*, 11, 1–19. <https://doi.org/10.1186/s41039-016-0041-5>
- Yavuz, G., Günhan, B. C., Ersoy, E., & Narli, S. (2013). Self-efficacy beliefs of prospective primary mathematics teachers about mathematical literacy. *Journal of College Teaching & Learning*, 10(4), 279–287. <https://doi.org/10.19030/tlc.v10i4.8124>