



An eight-step process of revitalizing living understanding competency for high school students in biology teaching

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

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

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

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

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Abstract

The living understanding competency is essential in helping students become more interested in subjects and life. However, developing this ability for students in the Mekong Delta is still fragmentary. Therefore, this study was conducted to determine how high school students can develop the ability to learn about the living world by teaching biology and applying it to high school. We have proposed an eight-step process to develop students' ability to understand the living world in biology teaching at high school, including determining goals, developing a teaching plan, encouraging curiosity, creating research opportunities, supporting information search, fostering discussion and sharing, assessment and feedback, and linking reality. Through the purposive sampling method with 450 students studying at high schools in the Mekong Delta, the results showed that step two is project-based learning in the present study. Current research delves into the practical application of the “microorganisms and applications” segment of the Biology 10 curriculum. This pedagogical strategy catalyzes a comprehensive understanding of microorganism technology and virus applications and progressively nurtures a profound comprehension of the broader biological concepts that govern our intricate living world. Thus, incorporating project-based learning equips students with practical knowledge and ignites a gradual metamorphosis of their cognitive landscape, fostering a profound appreciation for the intricate tapestry of life surrounding us.

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* Corresponding author.

E-mail address: nguyenduan@hueuni.edu.vn (D. Nguyen).

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Introduction

Project-based learning encompasses various designations like project-based education or project-centered learning. It is an intricate pedagogical approach in which students construct knowledge and competencies by tackling real-world challenges, adhering to the curriculum, and combining abstract concepts with hands-on applications to generate tangible results. The practice of project-based instruction has gained extensive exploration and adoption at all levels of education, including the educational landscape of Vietnam. In other words, “project teaching” is a form of teaching or a complex teaching method in which, under the guidance of teachers, learners acquire knowledge and develop skills by solving problems in a real-life case study (project), which involves adhering to the curriculum, integrating theory with practice and producing tangible outcome (Dang & Nguyen, 2020).

Educators can combine pedagogical techniques within project-based instruction, such as presentations, dialogues, investigations, problem formulation, collaborative teamwork, and more. Project-based learning, which is a dynamic application of education, engages learners actively in the knowledge acquisition process rather than having them passively absorb information. Consequently, each lesson becomes captivating to students due to its association with real-life predicaments. The 2018 general education curriculum underscored the importance of fostering Students’ capacities, encompassing three main competencies: the ability to self-directed learn and autonomy, effective communication and cooperative aptitude, and skill in problem-solving and promoting creativity. Furthermore, the evolution of the biology curriculum explicitly articulates the imperative to cultivate three distinct specialized competencies in biology for students, encompassing their capacity to comprehend the realm of living organisms (Ministry of Education and Training [MET], 2018a). The prowess of students to delve into the intricacies of the living world constitutes their proficiency in navigating the process of unraveling its mysteries, which encompasses a series of sequential steps: initiating inquiries pertinent to the living world, formulating astute judgments and hypotheses, strategizing, and executing plans for testing these hypotheses, and subsequently conveying and deliberating upon the outcomes of their research endeavors.

Competence in comprehending the realm of living organisms entails the ability to investigate and uncover

natural and life-related phenomena within the domain of biology. Cultivating this capability of apprehending the living world not only equips learners with techniques for acquiring knowledge and conducting research but also fosters their proactive and innovative thinking, enabling them to adeptly employ their knowledge to resolve real-world challenges. These proficiencies assume profound significance in our contemporary era, marked by the increasing advancement of science and technology (Ministry of Education and Training [MET], 2021). This ability is essential in helping students become more interested in subjects and life. However, developing this ability for students, especially in the Mekong Delta, is still fragmentary. Therefore, this study was carried out to determine how to develop high school student’s ability to learn about the living world through teaching biology and applying it to high school.

Literature Review

Discovery plays a vital role in teaching and developing the ability to explore the living world and acquire knowledge of the natural sciences. This notion has sparked inspiration among numerous scholars who believe that first-hand encounters with natural phenomena are a conduit for Students’ involvement in scientific research endeavors. Mayer, in 2004, expounded that, in each instance, guided discovery surpasses pure exploration in its efficacy to facilitate learning and knowledge transfer. In the constructivist learning paradigm, optimal support is provided through an instructional approach that emphasizes cognitive engagement over behavioral actions, instructional guidance instead of unadulterated discovery, and a directed emphasis on the curriculum instead of unstructured investigative pursuits (Mayer, 2004).

Project-based learning is built into a blended teaching design model for university students to meet the needs of the digital age in a modern classroom environment. It is not a new trend, but to improve student outcomes, preparing students for access to the real world through critical thinking, memory, and creativity (Lou et al., 2012). Project learning positively impacts student achievement (Duke & Halvorsen, 2017), and a high-quality project-based learning framework with projects that engage students in challenges for improved academic achievement (Ark & Liebttag, 2018). When interviewed and answering questions about establishing cooperative activities in the project teaching process, many high school teachers said that cooperation is necessary,

but it is essential to resolve friction and conflicts in the group (de la Torre-Neches et al., 2020). During the Covid-19 outbreak, project teaching through mixed method design has attracted students to participate in the learning process, limited online fraud, and ensured reliable and valid assessment of student learning outcomes (Saba 'Ayon & Harb, 2021).

Recent inquiries, exemplified by Dang's (2020) investigation centered on "Teaching Cell Observation Experiments", have characterized improved Students' ability to dive into the living world within the educational domain. Specifically, at the tenth-grade level (high school), the Hanoi National University of Education devised a comprehensive instructional framework for the practical components of the cell biology segment. This deliberates curriculum design aimed to promote Students' proficiency in investigating the natural world, encompassing the intricacies of skillfully organizing experimental pedagogy. As a crucial aspect of this endeavor, cell observation experiments contain the following facets: conceptual evolution and pedagogical guidance within the "cell observation experiments" domain, along with the formulation of instructional blueprints tailored to cultivate Students' ability to navigate the living world (Dang, 2020). Dang and Nguyen (2020) elucidated the structural dimensions of medical assessment capacity, explicitly focusing on exploring the living world. This comprehensive framework comprises a compilation of fourteen distinct benchmarks that underpin the determination of competency. Moreover, it delineates a systematic procedure for formulating and orchestrating hands-on experiments strategically integrated within the teaching process. The ultimate goal of these efforts lies in fostering the capability to explore the living world, an objective realized through dynamic educational practices and practical experiments within biology education at the eleventh-grade level (Dang & Nguyen, 2020).

In addition, research on project teaching in our country is quite diverse in many university subjects (Le & Nguyen, 2019) and high schools (Ha, 2014; Nguyen & Nguyen, 2016; Van & Pham, 2015). These studies show that although the teaching content and project teaching methods differ, they all aim to develop learners' activeness, initiative, and creativity.

Thus, in the world and the country today, there are quite a few authors interested in researching teaching in the direction of developing student capacity and teaching toward developing the capacity of teaching practice for students in the following aspects: different levels and fields. These specific studies have built a basic theoretical system, which is essential for raising biological awareness

among students in Vietnam. However, research on building teaching processes to develop student capacity based on the current situation in each region is still limited. This is the gap that we wanted to fill when choosing a topic. Therefore, this study was conducted to propose and evaluate the effectiveness of "An eight-step process of revitalizing living understanding competency for high school students in biology teaching" to serve as a basis for expanding the research areas and research objects outside the Mekong Delta.

Methodology

Study time and model: This study surveyed 450 students studying at high schools in the Mekong Delta using a cross-sectional survey approach, incorporating quantitative research methodology (Cohen et al., 2007). The research team selected the sample based on the research requirements, which is a targeted sampling method (predictive sampling). The selected samples are subjects suitable for the research scope of the article. For this study, the authors determined the sample size based on the sample size distribution method of Krejcie & Morgan (1970).

Document research method: a method applied to analyze data to develop a theoretical basis such as classification, coding, and comparison (Glaser & Strauss, 2014). Document sources are mainly collected from books, newspapers, scientific journals, summary reports of scientific research topics, master's theses, doctoral theses at home and abroad, and fields related to the problem that the project researches.

Questionnaire survey: the survey question was structured as a list to collect information, following the approach outlined by Pham & Nguyen (2011). In addition, the Likert scale was used to measure consent/satisfaction/response (Allen & Seaman, 2007) to facilitate accurate judgments regarding levels of agreement. A five-point Likert scale was employed, with intervals of $(5-1)/5 = 0.8$ (Narli, 2010; Yavuz et al., 2013). Accordingly, the meanings of the scale were determined as follows: $1.0 \leq M < 1.8$: Extremely disagree; $1.8 \leq M < 2.6$: Disagree; $2.6 \leq M < 3.4$: No idea; $3.4 \leq M < 4.2$: Agree; $4.2 \leq M \leq 5.0$: Extremely agree.

Sample collection: the survey form underwent a preliminary assessment of its reliability with a subset of respondents. Subsequently, any necessary adjustments were made to the survey before proceeding with the formal data collection process (Dinh et al., 2011a, 2011b).

Measuring the reliability of questionnaires: The reliability of survey questionnaires was evaluated utilizing Cronbach Alpha (Cronbach, 1951). This approach has proven effective in assessing human resources competence aligned with the demands of businesses within Kien Giang province, as cultivated through training at Can Tho University (Quan et al., 2012).

Data analysis: Following the data collection phase, the collected data were encrypted and processed using SPSS v.21 software. The Mann-Whitney U test was used to discern potential disparities in perspectives between male and female students. Additionally, the Kruskal-Wallis H test was conducted to determine any variations in viewpoints among students from three different locations. For all tests, a significance level of $p < .05$ was adopted.

Results and Discussion

The Process of Developing Students’ Ability to understand the Living World

The eight-step process of developing students’ ability to understand the living world in biology teaching at high school was proposed (Table 1). Step two in the present study is project-based learning. Together, these steps foster a student-centered and inquiry-based approach to biology education. They nurture subject-specific knowledge, critical thinking, problem-solving, research skills, and a passion for science. By engaging students in meaningful ways, educators can prepare them to be active and informed citizens and equip them with valuable skills for their future academic and professional pursuits. Furthermore, these steps align with modern educational

trends that emphasize active learning, inquiry-based instruction, and the development of skills of the 21st century. As educators adapt their teaching methods to incorporate these principles, they can enhance the overall quality of biology education in high schools, ultimately benefiting students and society.

Questionnaire and Participant Information

The analysis of Cronbach Alpha indicated that the questionnaire met the criterion of reliability, as evidenced by a calculated Cronbach Alpha coefficient of .8. This value exceeded the established benchmark of .6, signifying a robust level of internal consistency among the questionnaire items.

The study involved a diverse group of 450 randomly chosen for the survey. Among these participants, 49.33 percent identified as male, while 50.67 percent identified as female students (as shown in Table 2).

Table 2 Information about survey participants

Category		Numbers	Percent (%)
Sex	Female	228	50.67
	Male	222	49.33
High school	An Khanh	67	14.89
	Phan Van Tri	68	15.11
	Thanh An	10	2.22
	Hoang Dieu	14	3.11
	Doan Van To	17	3.78
	Ca Mau City	79	17.56
	Cai Nuoc	154	34.22
	Vam Dinh	41	9.11
Province/City	Can Tho	145	32.22
	Soc Trang	31	6.89
	Ca Mau	274	60.89

Table 1 8-step process of developing Students’ ability to understand the living world

Step	Explanation
Determine goals	Identify precise strategies for cultivating Students’ capacity to explore, investigate, and comprehend the natural world, which encompasses exploring, researching, and understanding their surroundings.
Develop teaching plan	Develop a teaching plan that includes appropriate topics, activities, and materials aligned with the objectives and consider using various learning tools such as textbooks, lectures, videos, websites, and reference materials.
Encourage curiosity	Use open-ended questions, quizzes, and discussions to encourage student curiosity about topics and show students that their inquiry and questioning are meaningful and essential.
Create research opportunities	Establish learning situations and projects that students can investigate, which may involve conducting surveys, library research, or creating creative products based on the information they gather.
Support for information search	Provide students with guidance on searching for information online and in the library and evaluate the credibility of information sources.
Foster discussion and sharing	Provide opportunities for students to discuss what they have learned and share knowledge, which can occur through presentations, speeches, or online forums.
Assessment and feedback	Utilize various assessment methods to measure Students’ development in exploring the living world and provide constructive feedback to help them improve their research skills.
Link to reality	Link the learning content to the real world and Students’ everyday lives to make learning more meaningful and engaging.

It is important to note that all the individuals who participated in the survey are currently enrolled in educational institutions in the Mekong Delta region, specifically in places like Can Tho, Soc Trang, and Ca Mau. For a more detailed breakdown of the participants involved in the research, you can find the relevant information in Table 2.

Knowledge Base of the Topic “Microorganisms and Applications” Forms the Living World Understanding Competency

Biology plays a dual role in nurturing students’ understanding of biological concepts while also contributing to the growth of other subjects and broader educational activities by fostering essential skills and general capabilities (MET, 2018a). The focus of biology studies revolves around the biological aspects of the world that are closely intertwined with students’ daily experiences. Biology is rooted in experimentation, progressively bridging the gap between fundamental theoretical knowledge and applied technology. As a result, investigation serves as an essential method for biological research and an integral teaching approach for this subject. By facilitating hands-on experiments and practical activities, biology empowers students to delve into the natural world, cultivate their capacity to apply acquired knowledge in real-world scenarios, and chart their career paths beyond general education (MET, 2018a).

To assess the effectiveness of instructional approaches in nurturing Students’ ability to explore the realm of life sciences through biology projects,

we opted to focus on “Microorganisms and Application” for our investigation. The survey questionnaires were meticulously designed based on three cognitive levels (knowledge, comprehension, and application) aligned with Bloom’s taxonomy.

Remembering level

With the question “For microorganisms: purple sulfur bacteria (chromatids), sulfur-oxidizing bacteria, hydrogen-oxidizing bacteria, nitrifying bacteria, which of the mentioned microorganisms has a different nutritional pattern?”, the research team obtained the following results: Most Students agree with the answer Q94 ($3.74 \pm 0.07 SE$), which is the correct answer. At the same time, the remaining incorrect answers have an average low rating with Q91 ($2.23 \pm 0.07 SE$), Q92 ($1.91 \pm 0.05 SE$), and Q93 ($2.04 \pm 0.06 SE$) (Table 3).

When it comes to gender, there is no difference in the mean of male and female students (Mann-Whitney U, $p > .05$ for all cases) (Table 4).

Similarly, when looking at provinces, there was a different assessment of students among Can Tho, Soc Trang, and Ca Mau for all the answers (Kruskal Wallis H, $p > .05$) (Table 5).

Table 3 The student’s cognition in terms of remembering

Code	Content	Mean $\pm$ SE	Viewpoint
Q91	Sulfur oxidizing bacteria	2.26 $\pm$ 0.07	Disagree
Q92	Hydrogen oxidizing bacteria	1.99 $\pm$ 0.12	Disagree
Q93	Nitrifying bacteria	2.00 $\pm$ 0.06	Disagree
Q94	Purple sulfur bacteria	3.73 $\pm$ 0.07	Agree

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

Table 4 The sexual variation in student’s cognition in terms of remembering

Code	Content	Mean $\pm$ SE		Mann-Whitney U
		Female	Male	
Q91	Sulfur oxidizing bacteria	2.10 $\pm$ 0.08	2.43 $\pm$ 0.10	$Z = -0.896, p = .370$
Q92	Hydrogen oxidizing bacteria	1.88 $\pm$ 0.07	2.10 $\pm$ 0.08	$Z = -1.308, p = .191$
Q93	Nitrifying bacteria	1.99 $\pm$ 0.08	2.00 $\pm$ 0.09	$Z = -0.556, p = .578$
Q94	Purple sulfur bacteria	3.88 $\pm$ 0.08	3.58 $\pm$ 0.10	$Z = -0.970, p = .332$

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

Table 5 The spatial variation in student’s cognition in terms of remembering

Code	Content	Mean $\pm$ SE			Kruskal-Wallis H (df = 2)
		Can Tho	Soc Trang	Ca Mau	
Q91	Sulfur oxidizing bacteria	2.26 $\pm$ 0.12	2.35 $\pm$ 0.27	2.26 $\pm$ 0.08	$\chi^2 = 0.696, p = .706$
Q92	Hydrogen oxidizing bacteria	2.03 $\pm$ 0.34	2.23 $\pm$ 0.25	1.93 $\pm$ 0.06	$\chi^2 = 5.835, p = .054$
Q93	Nitrifying bacteria	1.84 $\pm$ 0.09	2.26 $\pm$ 0.27	2.05 $\pm$ 0.07	$\chi^2 = 5.191, p = .075$
Q94	Purple sulfur bacteria	3.66 $\pm$ 0.12	3.52 $\pm$ 0.27	3.79 $\pm$ 0.08	$\chi^2 = 0.775, p = .686$

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

Microorganisms become a topic that students become acquainted with during their middle school years. An analysis of the survey results regarding questions classified at the “remembering” level indicates that students readily recall information related to questions with lower cognitive demands. This phenomenon is attributed to the fact that these questions do not require extensive contemplation and involve fundamental knowledge that instructors repeatedly emphasize throughout the teaching process. Consequently, this foundational knowledge becomes firmly ingrained in the Students’ memory. This instructional strategy aligns with the principles of Ebbinghaus’s concept of a “forgetting curve”. Ebbinghaus’s theory postulates that newly acquired information is initially stored in short-term memory during learning. However, without regular repetition or frequent application, this information is prone to rapid forgetting (Ebbinghaus, 1985).

Understanding level

With the request “observing the growth curve of bacteria during intermittent culture and answering questions about the characteristics of the bacterial biomass of the phases”, most students agree with Q101, Q102, and Q104 because this is the correct answer. In contrast, the incorrect answer is Q103, which has a significantly lower average rating (2.32 ± 0.06 SE) (Table 6), showing that students can exploit knowledge through observation of images.

When it comes to gender, there is no difference in the average rating of male and female students (Mann-Whitney U, $p > .05$ for all cases) (Table 7).

Similarly, when looking at provinces, we also do not see a difference between the average assessment of students in Can Tho, Soc Trang, and Ca Mau for all the answers (Kruskal Wallis H, $p > .05$) (Table 8).

As stated by MET, the capacity of students to delve into the intricacies of the living world involves a sequence of actions that include identifying pertinent issues within the living world, making assessments and crafting hypotheses, orchestrating and executing plans to test these hypotheses, and subsequently presenting and deliberating upon the research problem (MET, 2018b). Acquiring a comprehensive understanding of topic-related knowledge is fundamentally important. Once they master this knowledge, the students lay the foundation to express their curiosity about the surrounding world. This, in turn, equips them to address inquiries about the living world. The results derived from the survey focusing on cell biology content indicate that students have forged their biological and cognitive proficiencies by engaging with questions situated at the levels of recollection and comprehension. In particular, factors such as gender and educational context do not influence the ability of students to explore the living world. These results collectively signify that students have initiated the development of their ability to investigate the living world within the scope of the “microorganism and applications” domain.

Table 6 The student’s cognition in terms of understanding

Code	Content	Mean±SE	Viewpoint
Q101	In the latent phase, although nutrients are adequate, bacteria gradually adapt to the environment; they synthesize metabolic enzymes and DNA, so the density of bacterial cells in the population does not seem to change.	3.83±0.06	Agree
Q102	Bacterial biomass reached the highest standard at the end of the exponential phase. Because of adequate nutrition, bacteria divide vigorously, where relatively few cells die.	3.64±0.06	Agree
Q103	Bacterial biomass reached the highest standard at the end of the equilibrium phase. Because of adequate nutrition, bacteria divide vigorously.	2.29±0.06	Disagree
Q104	Dead cells gradually increase from equilibrium to death because nutrients are progressively depleted, and toxic substances accumulate gradually.	3.62±0.07	Agree

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

Table 7 The sexual variation in student’s cognition in terms of understanding

Code	Content	Mean±SE		Mann-Whitney U
		Female	Male	
Q101	In the latent phase, although nutrients are adequate, bacteria gradually adapt to the environment; they synthesize metabolic enzymes and DNA, so the density of bacterial cells in the population does not seem to change.	3.81±0.08	3.85±0.09	$Z = -0.896$ $p = .370$
Q102	Bacterial biomass reached the highest standard at the end of the exponential phase. Because of adequate nutrition, bacteria divide vigorously, where relatively few cells die.	3.57±0.09	3.72±0.09	$Z = -1.308$ $p = .191$
Q103	Bacterial biomass reached the highest standard at the end of the equilibrium phase. Because of adequate nutrition, bacteria divide vigorously.	2.30±0.08	2.29±0.09	$Z = -0.556$ $p = .578$
Q104	Dead cells gradually increase from equilibrium to death because nutrients are progressively depleted, and toxic substances accumulate gradually.	3.57±0.09	3.66±0.10	$Z = -0.970$ $p = .332$

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

Table 8 The spatial variation in student's cognition in terms of understanding

Code	Content	Mean±SE			Kruskal-Wallis H (df= 2)
		Can Tho	Soc Trang	Ca Mau	
Q101	In the latent phase, although nutrients are adequate, bacteria gradually adapt to the environment; they synthesize metabolic enzymes and DNA, so the density of bacterial cells in the population does not seem to change.	3.98±0.09	3.42±0.29	3.79±0.07	$\chi^2 = 4.025$ $p = .134$
Q102	Bacterial biomass reached the highest standard at the end of the exponential phase. Because of adequate nutrition, bacteria divide vigorously, where relatively few cells die.	3.66±0.10	3.26±0.26	3.67±0.08	$\chi^2 = 3.013$ $p = .222$
Q103	Bacterial biomass reached the highest standard at the end of the equilibrium phase. Because of adequate nutrition, bacteria divide vigorously.	2.33±0.11	2.26±0.24	2.28±0.08	$\chi^2 = 0.043$ $p = .979$
Q104	Dead cells gradually increase from equilibrium to death because nutrients are progressively depleted, and toxic substances accumulate gradually.	3.55±0.11	3.87±0.25	3.62±0.08	$\chi^2 = 2.213$ $p = .331$

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

Organizing Teaching Activities to Develop Students' Living World Understanding Competency Via 8-Stept Process with Project-Based Teaching Method

In this study, we have applied the 8-step approach to the topic of “microorganisms and applications”. The eight steps included determining goals, developing a teaching plan, encouraging curiosity, creating research opportunities, supporting information search, fostering discussion and sharing, assessment and feedback, and linking to reality. In Step 2, we used the project-based teaching method. The project-based learning process consisting of three distinct phases, each comprising three specific steps, is introduced: (1) preliminary research; (2) active execution, and (3) Effectiveness assessment (Vu & Nguyen, 2022). Using this three-phase framework,

the research team systematically designed instructional activities for “microorganisms and applications.” In this context, the topic involves the use of knowledge about microorganisms in the fermentation of sauerkraut. The procedure unfolds as follows:

Step 1 Preparation

We derived such from the stipulation outlined in the Biology 10 curriculum, which emphasizes completing a “project or subject focused on understanding microbial technology products” (MET, 2018b). We decided to pursue the project “Production of various fermented foods using microorganisms” within this realm; our focal point is the creation of pickled products. The detailed details of the project's scope can be found in Figure 1.

Make Some Fertilized Products From Microorganisms

(Fermentation of pickles)

Prepare

- Ingredients: cabbage or mustard greens, salt, sugar, green onions, boiled and cooled water.
- Tools: knife or scissors, fermentation vessel (crocker, porcelain or glass), bamboo wattle, purple litmus paper.

Proceed

- Step 1. Wash vegetables and onions with clean water, dry the vegetables.
- Step 2. Cut the mustard greens into pieces about 3–4 cm, and cut the scallions 3–4 cm long.
- Step 3. Mix the vegetables and onions and put them in the fermentation pot.
- Step 4. Add 3 percent brine solution containing 0.5–1 percent sugar to submerge vegetables about 5 cm.
- Step 5. Incubate at 35–40°C for two days to obtain pickle products.
- Step 6. Collect data
- + Observe the color and appearance, determine the taste, and measure the pH in step 4 and the pickled product.
- + Record the characteristics of the melon in step 4 and the product in step 5 according to the following table form.

Comparison of starting materials and pickles products

Characteristic	Color	Taste	Appearance	pH
Step 4 (starting material)	?	?	?	?
Pickle products (after two days)	?	?	?	?

Figure 1 Teaching content of the project “Microorganisms and Applications”

Step 2 Develop an implementation plan

The project execution is estimated to span one week, during which students will engage in various tasks. These tasks include research, gathering, and sorting pertinent details regarding the utilization of microbiological technology in food processing. Additionally, students will consider how the resultant products of their group are effectively showcased. Throughout this projected one-week timeframe, students will be actively involved in project implementation, with the teacher serving as a guiding presence, offering assistance and recommendations whenever groups encounter challenges. Subsequently, the anticipated duration for each team’s product presentation is estimated to be between 5 and 7 minutes.

Step 3 Evaluation

Table 9 reveals that the categories” Research Question” and ”Scientific Hypothesis” produced comparable results. Most of the students surveyed expressed an agreement feeling (with scores falling within the range of 3.41 to less than 4.2) about the impact of factors such as temperature, the size of the raw materials (cabbage, onion), and the amount of salt and sugar on the quality of the pickle. On the contrary, pH garnered a No Idea rating from students. The average rating is 2.77 ± 0.07 SE, while the ”Scientific Hypothesis” gets an average rating of 3.10 ± 0.07 SE. This disparity in ratings signifies that within the surveyed student population, one subset recognizes pH as a determinant of pickle quality. In contrast, another subgroup believes that this factor exerts no influence.

Pickles emerge as an application in the domain of ”Microorganisms”, in which lactic acid bacteria participate in fermentation. Lactic acid fermentation

represents a prevalent biochemical phenomenon that orchestrates converting glucoside substances into lactic acid under the direct influence of lactic acid bacteria. According to Dam and Vu’s research, temperature and pH are two crucial determinants of fermentation, directly affecting the resultant product’s quality (Dam & Vu, 2019). Another study led by Nguyen’s research team underscores the intricate nature of lactic fermentation, elucidating that technical parameters encompassing raw material dimensions and processing scale intricately shape fermentation duration and product excellence (Nguyen et al., 2013). The investigation of Vuong delves into the role of lactic acid bacteria, which produce lactic acid, contributing to the distinct flavor characteristic during fermentation. Further dimensions unfold as the salt influences osmotic pressure alterations, extracting solutes from the cellular fluid, preserving vegetables at optimal firmness, and preventing decay, even while imbuing the product with its distinct tangy and crisp attributes. Sugar emerges as a vital source of nutrients for microorganism’s fermentation endeavors (Vuong, 2020). Collectively, these studies emphasize that an interplay of temperature, pH, raw material dimensions, and the proportions of salt and sugar collectively govern the caliber of pickles produced.

This outcome mirrors the Students’ competence to investigate the world of life sciences through project-based instruction centered on the theme of ”microorganisms and applications”. As discussed previously, establishing the skillset necessary to explore the living world requires a sustained process of accumulation to achieve success. The students’ proficiency in identifying research inquiries and scientific hypotheses during the execution of learning projects attests to their incremental development of the aptitude to explore the living world.

Table 9 Students’ assessment of factors affecting product quality

Code	Content	Mean±SE	Viewpoint
Research question			
Q811	Does temperature affect the quality of pickles?	3.53±0.07	Agree
Q812	Does pH affect the quality of pickles?	2.88±0.07	No idea
Q813	Do different ingredient sizes affect the quality of pickles?	3.49±0.06	Agree
Q814	Does the amount of added salt sugar affect the pickle quality?	3.87±0.06	Agree
Scientific hypothesis			
Q821	Does temperature affect the quality of pickles?	3.45±0.07	Agree
Q822	Does pH affect the quality of pickles?	3.18±0.07	No idea
Q823	Do different ingredient sizes affect the quality of pickles?	3.56±0.06	Agree
Q824	Does the amount of added salt sugar affect the pickle quality?	3.92±0.06	Agree

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

Conclusions and Recommendations

We have outlined an eight-step process to improve Students' grasp of the living world in the context of high-school biology education. These steps include setting clear learning objectives, designing a comprehensive teaching plan, fostering curiosity, providing research opportunities, facilitating information retrieval, encouraging discussion and knowledge sharing, conducting assessments and offering feedback, and connecting the learning to real-world applications. Step 2 focuses on implementing appropriate teaching methods, and in our study, we utilized project-based learning. Our research explicitly investigates the practical application of the “microorganisms and applications” segment within the Biology 10 curriculum. Research results of 450 students showed that this pedagogical approach acts as a catalyst, enabling a holistic understanding of microorganism technology and virus applications while progressively nurturing a profound comprehension of broader biological concepts that govern our complex living world. Therefore, integrating project-based learning not only imparts practical knowledge to students, but also initiates a gradual transformation of their cognitive landscape, instilling a deep appreciation for the intricate web of life that envelopes us.

In light of these compelling findings, a provocative and forward-thinking concept emerges that entails the strategic and rational expansion of research horizons, encompassing a broader spectrum of geographical regions and delving into diverse thematic domains. Implementing this approach in various subjects in the 11th and 12th-grade biology curriculum would be prudent, allowing a more holistic assessment of the efficacy of the 8-step process in improving high school students' grasp of the natural world. Additionally, exploring alternative pedagogical strategies instead of the project-based method in step 2 merits consideration, as this may yield more comprehensive insights into the effectiveness of the 8-step process.

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Conflict of Interest

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

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