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Developing natural science capabilities in students through teaching Natural Science 6: A case study in Vinh Phuc Province, Vietnam

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Abstract

The article presents a comprehensive study on the enhancement of natural science competencies in 6th-grade students through STEM education. It outlines the importance of equipping students with scientific knowledge and skills for the 21st century, highlighting the shift from traditional teaching methods to interactive, student-centered approaches. The study, focusing on Vinh Phuc province, evaluates the effectiveness of current teaching methods and proposes improvements for teaching natural sciences in Vietnam. It emphasizes the role of teachers, the impact of the learning environment, and the integration of technology in education. The research employs a mixed-method approach, including document analysis, expert consultation, and mathematical statistical methods, to assess the development of scientific competencies. The findings suggest that STEM education significantly improves students' understanding and application of natural science concepts, advocating for its broader implementation, comprehensive teacher training, and increased investment in educational resources.

Keywords:

Natural science, capabilities, Vietnam, STEM.

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1. Introduction

In the 21st century, equipping students with natural science skills and knowledge is a crucial aspect of comprehensive education. This not onăng lực enhances their understanding of the world around them but also prepares them with necessary skills to adapt to an increasingly developed and integrated society (National Research Council, 2012). In Vietnam, the general education curriculum has been undergoing significant reforms to improve the quality of teaching and learning, especially in natural sciences (Ministry of Education and Training, 2018).

Vinh Phuc province, located in Northern Vietnam, has emerged as a bright spot in applying advanced and modern educational methods. This study focuses on the development of natural science competencies in 6th grade students, a pivotal stage in the development of their scientific thinking and skills. The primary goal of this research is to evaluate the effectiveness of current teaching and learning methods in Vinh Phuc and propose solutions for improvement, thereby contributing to the overall development of natural science education in Vietnam.

Scientific competency involves not only a deep understanding of various scientific fields but also the ability to apply knowledge in practical contexts, critical thinking, and problem-solving skills (Bybee, 2014). In the current educational context, developing these skills in students is not onăng lực a challenge but also an urgent need. However, achieving this requires significant changes in teaching and assessment methods, from traditional approaches to more active and engaging methods, encouraging students' active participation in the learning process (Furtak et al., 2012).

Vinh Phuc, with its efforts in innovating teaching methods and improving educational quality, has become a noteworthy case. Particularly, the application of information technology and advanced educational methods has opened new opportunities for developing natural science competencies in students. This research will focus on analyzing and evaluating these methods, based on data collected from schools in Vinh Phuc, and suggest specific recommendations to enhance the effectiveness of teaching and learning.

In addition to analyzing teaching methods, the study also emphasizes evaluating the impact of the learning environment on the development of students' scientific competencies. The learning environment extends beyond the classroom space and includes factors like resources, curriculum, and support from families and communities (Tobin, 2005). The combination of these elements forms a multi-dimensional support system, significantly contributing to the development of students' scientific competencies.

In conclusion, this study aims not onăng lực to assess and analyze the current status of teaching and learning Natural Science in Vinh Phuc province but also to propose solutions and recommendations to improve the effectiveness of this process. Through this, the research hopes to contribute to the overall development of natural science education in Vietnam, particularly in the context of globalization and international integration.

2. Literature Review

2.1. Current State and Evolution of Natural Science Education

Global Perspective

The landscape of natural science education has undergone significant transformation globally, marked by a shift towards more interactive, student-centered learning approaches. Traditionally, science education was dominated by rote memorization and teacher-centered methodologies. However, with the advent of educational research and a deeper understanding of learning processes, there has been a progressive move toward methodologies that emphasize critical thinking, problem-solving, and hands-on experiences (Anderson, 2002). This shift is encapsulated in the framework proposed by the National Research Council (2012), which advocates for integrating scientific practices with core ideas and crosscutting concepts.

Innovative teaching practices such as inquiry-based learning, where students actively engage with scientific questions and experiments, have become more prevalent. Furtak et al. (2012) highlight the effectiveness of this approach in not onăng lựcy enhancing students' understanding of scientific concepts but also in developing a more profound interest in science. The integration of technology in science education has also been a significant trend. Digital tools and onăng lựcine resources have provided new avenues for interactive learning, enabling students to access a vast array of information and engage in virtual experiments (Scalise, 2018).

Vietnam's Educational Landscape

In Vietnam, the education system has been undergoing substantial reforms, especially in the field of natural sciences. The Ministry of Education and Training (MOET) of Vietnam has been instrumental in these reforms, aiming to align the country's science education with international standards. The revised curriculum introduced by MOET focuses on developing critical thinking, creativity, and practical skills in students, moving away from the traditional emphasis on memorization and theoretical knowledge (Ministry of Education and Training, 2018).

However, the implementation of these reforms faces unique challenges. Vietnam's diverse socio-economic landscape means that resource allocation and teacher training vary significantly between urban and rural areas. Nguyen and Nguyen (2016) note that while urban schools are often at the forefront of adopting new teaching methodologies, rural schools struggle with a lack of resources and trained personnel. This disparity poses a significant challenge in ensuring a uniform quality of science education across the country.

Furthermore, the incorporation of technology in education, a global trend, is still in its nascent stage in many parts of Vietnam. While some urban schools have started integrating digital tools in their science curriculum, a large segment of the student population in rural areas does not have access to these technologies (Le, 2019). This digital divide is a critical factor in the evolution of science education in Vietnam.

Research and Theory Foundations

The evolution of natural science education globally and in Vietnam is underpinned by several key research findings and theoretical frameworks. Constructivism, a theory posited by Piaget and later expanded by Vygotsky, suggests that learning is an active process where students construct new knowledge based on their experiences (Vygotsky, 1978). This theory has greatly influenced the shift towards student-centered learning in science education.

Further, Bloom's Taxonomy, revised by Anderson and Krathwohl (2001), emphasizes the need to move beyond mere knowledge recall to higher-order thinking skills like analyzing, evaluating, and creating. This framework has been fundamental in guiding curriculum development and assessment methods in science education, promoting a deeper, more conceptual understanding of science.

In summary, the evolution of natural science education reflects a global trend towards more interactive and student-centered learning, underpinned by significant educational research and theories. In Vietnam, while strides have been made towards modernizing science education, challenges such as resource disparity and technology integration remain. Addressing these challenges is crucial for the continued development and effectiveness of science education in the country.

2.2. Effective Teaching Methodologies and Learning Outcomes in Natural Sciences

Teaching Approaches

The effectiveness of natural science education greatly depends on the methodologies employed. Inquiry-based learning (IBL) has emerged as a particularly impactful approach, encouraging students to explore scientific concepts through questioning, experimentation, and reflection. According to Minner et al. (2010), IBL not onăng lực enhances students' understanding of scientific concepts but also fosters a deeper engagement with the subject matter. This approach aligns well with the constructivist theory, which posits that knowledge is actively constructed by the learner, rather than passively received (Piaget, 1964).

Project-based learning (PBL), another progressive teaching methodology, involves students in complex, real-world projects, offering a contextual framework for learning. Bell (2010) suggests that PBL aids in the development of critical thinking, problem-solving, and collaborative skills, which are essential in the study of natural sciences. Furthermore, the integration of technology, through digital simulations, interactive software, and onăng lựcine resources, has been shown to significantly enrich science education. Scalise (2018) notes that technology not onăng lực provides diverse learning materials but also facilitates an interactive and engaging learning environment.

Role of Teachers and Educational Tools

The role of teachers in implementing these methodologies is pivotal. Teacher preparedness and attitudes towards innovative teaching practices significantly influence their effectiveness. Ertmer and Ottenbreit-Leftwich (2010) highlight the importance of teacher training in adopting new methodologies and integrating technology into the curriculum.

Furthermore, the availability and use of educational tools such as laboratory equipment, digital devices, and scientific kits are crucial in facilitating hands-on experiences and practical application of theoretical knowledge.

Student Learning Outcomes

The application of these teaching methodologies has a profound impact on student learning outcomes. Students engaged in IBL and PBL have been found to demonstrate improved scientific literacy, exhibiting a better understanding of scientific concepts and processes (Singer et al., 2000). These approaches also contribute to the development of higher-order thinking skills, as defined in Bloom's revised taxonomy, including analysis, evaluation, and creation (Anderson et al., 2001).

Moreover, the involvement in inquiry and project-based activities enhances students' abilities in scientific inquiry and research. As argued by Linn et al. (2004), such experiences encourage students to think like scientists, engaging in hypothesis formation, experimentation, and data interpretation. This not onăng lựcy builds their scientific knowledge base but also fosters a scientific mindset, crucial for lifelong learning and engagement with science.

In addition, the integration of technology in science education has shown to improve student engagement and motivation. Interactive and multimedia-rich resources make learning more appealing and can cater to diverse learning styles (Mayer, 2009). This technological integration also prepares students for the digital world, equipping them with the necessary skills to navigate and utilize digital tools effectively.

In conclusion, the effectiveness of natural science education is greatly enhanced by employing methodologies like inquiry-based learning, project-based learning, and the integration of technology. These approaches not onăng lựcy facilitate a deeper understanding of scientific concepts but also foster critical thinking, problem-solving, and a scientific mindset in students. The role of teachers in effectively implementing these methodologies and the provision of appropriate educational tools are crucial components in achieving these learning outcomes.

References:

2.3. Challenges and Opportunities in Natural Science Education in Vietnam

The journey of reforming and enhancing natural science education in Vietnam, particularly at the middle school level, presents both unique challenges and promising opportunities.

Challenges in the Vietnamese Context

Vietnam's education system, while striving for improvement, faces several significant challenges. One of the primary issues is the disparity in educational resources and quality between urban and rural areas. Urban schools often benefit from better infrastructure, more qualified teachers, and greater access to technology, whereas rural schools struggle with

limited resources and less exposure to modern teaching methodologies (Pham & Fry, 2004). This urban-rural divide results in unequal opportunities for students and affects the overall effectiveness of science education reforms.

Additionally, the traditional Vietnamese education system, known for its emphasis on rote memorization and theoretical knowledge, has been slow to adopt more hands-on, inquiry-based approaches. Changing this deeply ingrained educational culture requires not onăng lựcy curricular reforms but also a shift in the mindset of educators and parents (Tran, 2013).

Opportunities and Innovative Solutions

Despite these challenges, there are significant opportunities for growth and innovation in Vietnam's science education. The Vietnamese government's commitment to educational reform, as evidenced by the recent curriculum overhaul, sets a positive trajectory for future developments (Ministry of Education and Training, 2018).

Innovative teaching methodologies, such as blended learning, which combines traditional classroom methods with onăng lựcine digital media, are gaining traction. This approach can be particularly effective in resource-limited settings, offering a cost-effective solution to the challenge of delivering high-quality science education (Nguyen, 2015).

Moreover, there is an increasing recognition of the importance of teacher training and professional development in Vietnam. Initiatives aimed at improving teacher competency in active learning strategies and technology integration are crucial for the successful implementation of the new science curriculum. Partnerships with international educational organizations also offer valuable opportunities for knowledge exchange and capacity building (Le, 2019).

In conclusion, while the path to enhancing natural science education in Vietnam is fraught with challenges, it is also lined with opportunities for innovation and improvement. Leveraging these opportunities requires a concerted effort from government bodies, educational institutions, and the community at large. By addressing these challenges head-on and embracing new methodologies, Vietnam can make significant strides in advancing its science education to meet the demands of a rapidly changing world.

3. Material and Methods

This study employed a mixed-methods approach, integrating document analysis, expert consultation, and mathematical statistical methods to explore the development of natural science competencies in students through the teaching of Natural Science 6 in Vinh Phuc Province, Vietnam.

3.1. Document Analysis

The initial phase of the research involved an extensive review of relevant documents. This included academic journals, policy documents, curriculum guidelines, and previous research studies pertinent to natural science education both globally and within Vietnam. The

aim was to gather comprehensive background information and identify prevailing trends, challenges, and opportunities in the field. This document analysis provided a foundational understanding necessary for framing the subsequent stages of the study.

3.2. Expert Consultation

Following the document analysis, expert consultations were conducted to gain deeper insights into the practical aspects of teaching natural sciences in the Vietnamese context. A select group of experts, including experienced educators, curriculum developers, and academic researchers specializing in science education, were engaged in semi-structured interviews. These interviews sought to capture their perspectives on effective teaching methodologies, curriculum development, and the challenges faced in the current educational landscape. The insights gained from these experts were instrumental in validating the findings from the document analysis and refining the research focus.

3.3. Mathematical Statistical Methods

The final phase of the study involved the application of mathematical statistical methods to analyze the data collected. Quantitative data obtained from surveys distributed to teachers and students in various schools across Vinh Phuc Province were subjected to statistical analysis. Techniques such as descriptive statistics, correlation analysis, and regression analysis were employed to identify patterns, relationships, and trends in the data. This quantitative analysis was crucial in quantifying the impact of different teaching methodologies on student learning outcomes and in providing empirical evidence to support the study's findings.

In summary, the combination of document analysis, expert consultation, and mathematical statistical methods provided a comprehensive approach to exploring the development of natural science competencies in middle school students. This triangulation of methods ensured a robust and multifaceted understanding of the subject, allowing for a more nuanced and accurate representation of the natural science education landscape in Vinh Phuc Province.

4. Results and Discussion

To assess whether students' natural science abilities improve when taught using STEM education, we conducted lessons on three topics from the grade 6 natural science curriculum: Melting and Freezing Phenomena, Evaporation and Condensation, and the Properties of Matter and its State Changes across four different classes.

4.1. The Teaching Process in STEM Education

`Each lesson was designed to follow a seven-stage teaching process. For example, the lesson on "Evaporation and Condensation" is described as follows:

Stage 1: Real-world Problem Situation

Introduction: Students observe images of coastal residents facing drought and freshwater scarcity, sparking their awareness and posing a challenging problem.

Stage 2: Problem to be Solved

The problem for students to solve is: How to obtain fresh water for coastal residents? Can a model for desalinating seawater be designed using simple items like plastic bottles, straws, cling film, ceramic bowls, cups, and tape?

Stage 3: Proposing Actionable Solutions

To propose solutions for turning seawater into fresh water, groups complete a study sheet. Possible solutions include:

- Solution 1: Placing seawater in a bowl with a small cup inside, covering it with a thin plastic film, and placing a weight on top to easily collect fresh water after evaporation and condensation.

- Solution 2: Using a two-bottle system connected at the neck. Seawater is put in the lower bottle, and the bottles are tilted at an angle so that the fresh water collected in the upper bottle after evaporation and condensation doesn't flow back.

- Solution 3: Using a two-bottle system, with seawater in the first bottle and a small straw at the top of the second bottle. Fresh water is collected outside the straw and in the second bottle after evaporation and condensation.



Stage 4: Evaluation, Theoretical Foundation, and Feasible Solution Selection

Groups evaluate and choose feasible solutions. They need to compare how the process of turning seawater into fresh water will occur under different conditions of the proposed solutions:

- Increasing the rate of evaporation (increasing surface area or providing heat).

- Increasing the rate of condensation by reducing the temperature.

Stage 5: Implementing the Solution

During experiments, students describe their processes and record results for comparison.

Stage 6: Evaluating the Problem-Solving Process and Product

Comparing results helps students determine which experience best meets the challenge:

- Solution 1 yields little fresh water.

- Solution 2 is simple but also yields little fresh water.

- Solution 3 is simple and produces more fresh water.

Students adjust their model designs to collect more fresh water after evaporation and condensation.

Stage 7: Conclusion and Explanation. Legitimizing Knowledge.

Analyzing results, students answer: What conclusions can be drawn?

- Seawater can be turned into fresh water using simple systems after evaporation and condensation.

Teachers guide students to explain using terms like "liquid state," "gaseous state," "evaporation," and "condensation."

- Water can change from liquid to gas (water vapor) due to temperature, a process called evaporation.

- Water vapor can change back to liquid due to temperature, a process called condensation.

Students assess if their experimental results match their initial assumptions.

- At the end of Stage 7, teachers guide students to apply knowledge of evaporation and condensation to explain natural phenomena and solve real-life situations: Desalinating seawater using solar energy and designing models to turn seawater into fresh water for coastal residents, aiming for sustainable development in learning.

4.2. Assessing students' natural science abilities

Students' natural science capacity is assessed through table 1

Table 1. Rubric for assessing NATURAL SCIENCE COMPETENCESTEM lesson "Evaporation and condensation phenomena"

Component capacity	**Behavioral expression**
NT. Ability to perceive knowledge	NT1 Awareness of knowledge of science natural science

Component capacity	**Behavioral expression**
of natural science	
KP. the capacity of scientific discovery	KP1 Identify the problem: Raise questions that need to be solved: How can seawater be converted into fresh water?
	KP2 Apply knowledge about evaporation and condensation of water to make predictions and hypotheses
	KP3 Planning: Follow the steps to design an experiment and a device model Analyze, compare, and improve to choose a feasible scientific plan
	KP4 Implement the plan
	KP5 Present and report the results of scientific discovery activities
VD. capacity to apply scientific knowledge towards sustainable development	VD1 Explain and solve practical problems based on learned knowledge
	VD2 Adjust knowledge, change attitudes and behaviors in accordance with the requirements of sustainable development

Assessment results will be recorded for each lesson and each class. Table 2 is an example

Table 2. Results of students' natural science science competence in the lesson "evaporation and condensation phenomena"

Student	**Expression level**	**NT**	**KP**					**VD**	
		NT 1	**KP 1**	**KP 2**	**KP 3**	**KP 4**	**KP 5**	**VD 1**	**VD 2**
1. N1.6A3- XH	**M3**		√		√	√		√	
	M2	√		√			√		√
	M1								
score		**2**	**13**					**5**	
2. N2.6A3- XH	**M3**				√	√		√	
	M2	√	√	√			√		√
	M1								
score		**2**	**12**					**5**	
3. N3.6A3- XH	**M3**		√		√	√		√	
	M2	√		√			√		√

	M1								
score		**2**	**12**					**5**	
4. N4.6A3- XH	**M3**		√		√	√			
	M2	√		√			√	√	√
	M1								
score		**2**	**13**					**4**	
5. N1.6A- ĐX	**M3**		√		√	√			
	M2	√		√			√	√	√
	M1								
score		**2**	**13**					**4**	
6. N2.6A- ĐX	**M3**				√	√		√	
	M2	√	√	√			√		√
	M1								
score		**2**	**12**					**5**	
7. N3.6A- ĐX	**M3**		√		√	√		√	
	M2	√		√			√		√
	M1								
score		**2**	**13**					**5**	
8. N4.6A- ĐX	**M3**								
	M2	√	√	√	√	√	√	√	
	M1								√
score		**2**	**10**					**5**	

- From the results of assessing the natural science competence of a group in one lesson, the group's competence score is determined (reduced to a 10-point scale).

4.3. General results and discussion

The final results of 3 lessons of 4 classes are shown in table 3

Table 3. Comparison of average scores of the first test in two pairs of classes at the same school

School/Class	Average Score	Median	Standard Deviation	T- Test
Đồng Xuân 6A	7,28	7,75	0,58	p = 0,44 (p > 0,05)
Đồng Xuân 6B	7,58	7,5	0,28	
Xuân Hòa 6A2	7,48	7,5	0,45	p = 0,40 (p > 0,05)
Xuân Hòa 6A3	7,39	7,5	0,58	

After we have developed the competency assessment test, we conduct the first test after teaching 2 lessons: Melting and freezing phenomena, evaporation and condensation phenomena and the second test after the lesson. teach lesson 3: Properties of substances and transformations of substances, for 2 pairs of selected classes in 2 schools (2 pairs of the same school and 2 pairs of different schools) as shown in Figure 1 and Figure 2

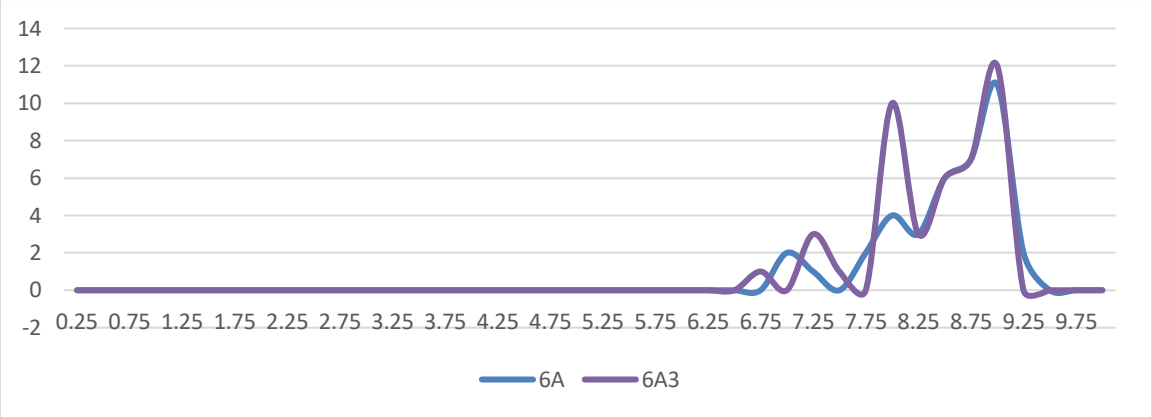

Figure 1. Normal distribution curve of first test score results (Grades 6A and 6A3)

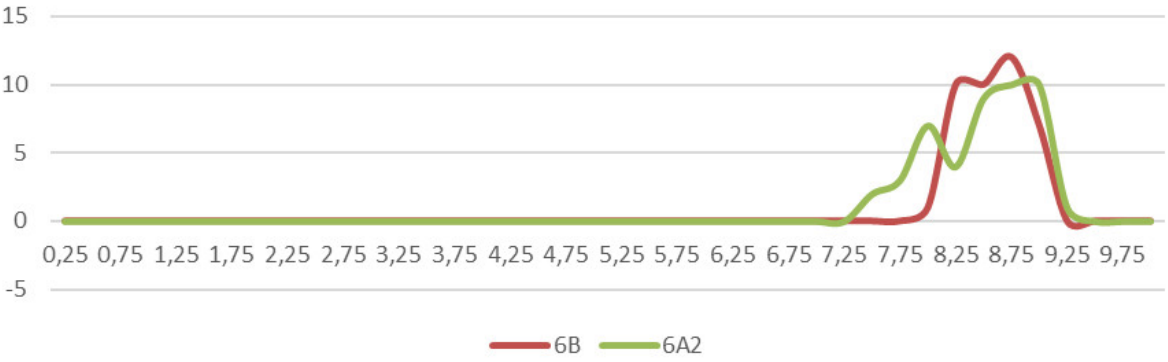

Figure 2. Normal distribution curve of first test score results (Grades 6B and 6A2)

Comparing the first test scores shows that: In all 4 experimental classes, the majority of students achieved the science category, leading to 01 student achieving the average category). Thus, it can be concluded that the natural science competence of students in all 4 experimental classes is higher than the input survey science score. That also shows the scientific feasibility and effectiveness of the conducted STEM lessons.

5. Recommendations

Given the findings of this study on the impact of STEM education on developing natural science competencies in grade 6 students, the following recommendations are proposed: Encourage the broader implementation of STEM methodologies across the entire natural science curriculum. This should involve not only theoretical knowledge but also practical applications, ensuring a holistic learning experience that fosters scientific inquiry and critical thinking. Prioritize comprehensive training programs for teachers in STEM education techniques. This includes workshops and continuous professional development courses that focus on innovative teaching methods, effective use of technology, and the integration of real-world science problems into the curriculum. Increase investment in educational resources, particularly in under-resourced areas. Ensure that all schools have adequate access to laboratory equipment, technological tools, and materials necessary for conducting scientific experiments and research projects. Establish partnerships with local scientific institutions, technology companies, and universities. These collaborations can

provide valuable resources, expertise, and real-world insights, enriching the STEM education experience for students.

By adopting these recommendations, natural science education can be significantly enhanced, preparing students to meet the challenges of a rapidly evolving scientific landscape and equipping them with the skills necessary for future success.

6. Conclusion

This study has explored the implementation and effectiveness of STEM education methodologies in enhancing natural science competencies among 6th-grade students in Vinh Phuc Province, Vietnam. The findings clearly indicate that the adoption of STEM approaches, characterized by hands-on activities, real-world problem-solving, and integrated learning, has significantly improved students' understanding and application of natural science concepts.

The structured, seven-stage teaching process has proven effective in not only engaging students in the scientific process but also in fostering critical thinking and creative problem-solving skills. The positive outcomes observed through the assessment of students' competencies in various STEM activities underscore the value of this approach in contemporary science education.

Furthermore, the study highlights the importance of teacher training, resource allocation, and curriculum development in achieving successful STEM education. The integration of real-world scientific challenges into the classroom has been particularly impactful, connecting theoretical learning with practical application.

7. Conflicts of Interest

The authors declare no conflicts of interest.

8. About the Author(s)

Nguyen Quang Linh is an Doctor of Education, and a senior lecturer at the Thai Nguyen University of Education, Vietnam. Dr Nguyen Quang Linh has published many articles in prestigious scientific journals in the list of Scopus. The main research interests of Dr Nguyen Quang Linh include: integrated teaching, teaching according to STEM education, developing student capacity and experimenting in teaching.

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