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DEVELOPING GRADE 6 STUDENTS' COMPETENCE TO APPLY KNOWLEDGE AND SKILLS THROUGH STEM-BASED INSTRUCTION: A CASE STUDY ON THE TOPIC "ENERGY AND ITS TRANSFORMATION"

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Abstract. The Natural Science curriculum emphasizes the importance of developing students' competence in applying knowledge and skills. This study aimed to propose a framework of competence in applying knowledge and skills through STEM teaching, design the STEM lesson "Energy and its transformation," and evaluate its impact on the competence development of grade 6 students. The framework and assessment tool were developed through a synthesis of literature and iterative expert consultation; the lesson plan was designed to align with the objectives of the curriculum and the proposed framework. A pedagogical experiment was conducted at Trung Vuong Secondary School (Thai Nguyen province) with one experimental class and one control class. Data sources included teachers' assessments of students' competence in applying knowledge and skills (comprising five competence components, nine criteria, and three proficiency levels) and the results of a 45-minute knowledge test administered to both classes after the experiment. Data analysis included descriptive statistics, independent-samples T-tests, and effect size calculation. The findings showed that students demonstrated growth across all competence criteria, with the largest improvements in identifying foundational knowledge and in designing/testing products. The knowledge test results also indicated that the experimental class achieved better learning outcomes than the control class after participating in the STEM lesson. The study concludes that well-designed STEM lessons can significantly enhance grade 6 students' ability to apply knowledge and skills when teachers are supported with practical assessment tools, sufficient instructional time, and training in competence-oriented pedagogy.

Keywords: competence to apply knowledge and skills; STEM-based instruction; natural sciences; grade 6 students.

1. Introduction

In Vietnam, within the roadmap for the renewal of the 2018 General Education Curriculum, the subject of Natural Sciences (NS) at the lower secondary level was developed to cover knowledge domains including matter and its transformations, energy and its transformations, living organisms, the Earth and the Sky, and it has been implemented since the 2021-2022 academic year [1]. In particular, grade 6 marks the beginning of lower secondary education, where developing students' competence to apply knowledge and skills (AKSC) is crucial, laying the foundation for scientific thinking and practical skills from an early stage.

In recent years, several domestic studies have explored the development of students' AKSC. However, these studies have employed varying terminologies or focused on specific aspects of this competence. Trinh Le Hong Phuong and Pham Thi Huong (2019) [2] researched and developed a scale for assessing students' competence to apply chemistry knowledge in real-life contexts at the upper secondary level. This scale consists of three components and ten criteria. Their findings gave teachers valuable insights for evaluating Grade 10 students' ability to apply knowledge in practical situations. Ngo Thu Hang and colleagues (2021) [3] applied WebQuest to teach the chemistry topic "Carbon footprint" in Grade 11. The results of a pedagogical experiment involving 60 Grade 11 students demonstrated initial improvements in both learning outcomes and AKSC. Bach Thi Phuong Thanh and Tran Trung Ninh (2021) [4] investigated how organizing STEM-based lessons could foster AKSC in students. Similarly, the research team of Do Thi Thanh Thu and Pham Thi Bich Dao (2021) [5] used project-based learning and STEM lessons to help students apply integrated knowledge to solve specific real-world problems. Ha Thi Lan Huong (2021) [6] proposed a procedure for organizing integrated chemistry instruction in lower secondary schools to develop AKSC in students. She designed four lesson plans and developed 75 exercises targeting competence development.

From these studies, it can be affirmed that AKSC is one of the essential competencies to be prioritized in teaching NS. Within the scope of this article, we investigate AKSC and propose a framework for its development in students through STEM-based instruction. Accordingly, we design lesson plans and conduct a pedagogical experiment to assess the feasibility of the proposed STEM lessons in enhancing AKSC among Grade 6 students. The research team employed a combination of theoretical research methods, practical research methods, and statistical methods to process data from the pedagogical experiment.

2. Content

2.1. Competence in applying knowledge and skills

Competence to apply knowledge and skills (AKSC) refers to the ability to identify problems related to real-life situations and subsequently mobilize relevant knowledge and skills that students have either acquired or independently explored to solve those real-world problems [3], [4]. Another perspective defines AKSC as the learner's ability to flexibly integrate knowledge, skills, and personal attributes such as interest, beliefs, willpower, and attitudes to effectively address problems encountered in learning and everyday contexts [5]. A common theme across these studies is the emphasis on students' ability to apply their knowledge and skills to solve practical problems while acknowledging the influence of personal factors such as interest, beliefs, willpower, and attitudes. Therefore, AKSC can also be approached as "the competence to apply knowledge in real-life situations" or "the skill to apply knowledge in practice" [7], [8]. Applying knowledge to real-life situations represents learners' highest level of cognitive processing. Therefore, in addition to equipping students with knowledge, it is even more critical to develop their ability to apply what they have learned to everyday life [9].

Based on the above definitions and perspectives, we define AKSC as a personal attribute formed and developed through learning, practice, and inherent qualities. It enables learners to flexibly integrate the knowledge and skills they have acquired and individual characteristics such as interest, beliefs, and willpower to identify, analyze, and effectively solve problems and tasks across various contexts. This includes explaining phenomena scientifically and logically, innovating, or adapting to new conditions to achieve desired outcomes.

To determine the structure of AKSC, we analyzed literature addressing AKSC in specific contexts (NS, Chemistry, Biology, STEM, and practical exercises). These studies elaborated on the manifestations of AKSC as outlined in the 2018 General Education Curriculum (CTGDPT 2018) and provided concrete examples of how this competence is expressed. Synthesizing previous research, we identified the core stages of the AKSC process as follows:

- Identify and analyze problem: The 2018 General Education Curriculum refers to "identifying and explaining practical problems". The aforementioned studies include variations such as detecting or recognizing practical or learning problems [3], [4], [10]-[15]. This highlights the starting point of the AKSC process as recognizing a need or challenge in a practical context, which often requires initial interpretation.

- Mobilize knowledge and explain: After identifying the problem, the next consistent step is to retrieve, connect, and apply relevant knowledge. The 2018 General Education Curriculum states: "Apply knowledge and skills in natural sciences to explain common phenomena in nature and everyday life" [16]. Numerous studies also emphasize the role of "explaining" or "mobilizing and using knowledge" in the learning process [4], [10]-[12], [14], [15]; "identifying knowledge in exercises related to practical contexts" and "establishing connections between acquired knowledge and practical problems" [13]. This stage involves establishing the relationship between theoretical understanding and real-world problems, often requiring the synthesis of information.

- Evaluate, critique, and synthesize: Many studies have explicitly highlighted the role of this activity through requirements such as "evaluation of impact" or "critical reflection" [4], [10]-[12], [15]. In particular, some research emphasizes the analysis and synthesis of knowledge and skills to generate critical arguments and sound evaluations [11], [15].

- Propose solutions and make plans: This is an important outcome of AKSC, reflecting the ability to formulate feasible solutions. The 2018 General Education Curriculum identifies the requirement to "propose solutions" as evidence of this competence [16]. Previous studies also consistently affirm the role of proposing methods, measures, or plans to solve problems in the learning process [4], [10]-[12], [14], [15].

- Implement problem-solving: The final stage of application is the implementation of the proposed solutions. The 2018 General Education Curriculum specifies the requirement to "carry out certain solutions" as evidence of this competence [16]. Many studies have directly referred to activities such as "implementing problem-solving" or "executing measures" in practical learning contexts [4], [10]-[15]. This stage closes the cycle of practical application, emphasizing tangible outcomes and the ability to transform plans into reality.

Based on the above analysis, we identified the structure of AKSC as consisting of five components: identifying and analysing the problem; mobilizing knowledge and explaining the problem; applying knowledge and skills to propose and select solutions; implementing the plan/solution; Reporting and evaluating the process of applying knowledge and skills.

2.2. STEM lessons

STEM education in schools is currently implemented in three forms: (1) teaching science subjects through STEM lessons; (2) organizing STEM experiential activities; and (3) organizing scientific and technological research activities [17]. Among these, teaching science subjects through STEM lessons is the most widely applied form, as it occurs directly within the formal curriculum, ensuring consistency and systematic instruction. This form can be easily integrated into existing teaching content, does not require significant additional resources such as specialized facilities or equipment, and can be implemented on a large scale.

Within the scope of this article, the author chooses the format of "teaching science subjects through STEM lessons" to design and organize instructional activities in Natural Sciences (NS). For simplicity and clarity, the author will use the term "STEM lessons" to refer to the entire phrase above.

2.3. Designing the assessment tool for students' competence to apply knowledge and skills through STEM lessons

In developing the framework for students' AKSC through STEM lessons in NS, we followed a systematic seven-step process. First, the concepts of competence and AKSC were clarified, and the design process for STEM lessons was reviewed in relation to the development of students' AKSC. Relevant international and domestic literature was then synthesized, including existing AKSC frameworks [2]-[5], established research procedures [18], [19], and international studies on factors influencing competence development [20]-[22]. Expert consultation and classroom observations in NS further informed the framework. Based on these foundations, a preliminary draft (five competence components, nine criteria, and three proficiency levels) was produced, subjected to expert review, revised iteratively, and finalized. The AKSC assessment system uses three levels of 1, 2, and 3 (points) reflecting S's development in STEM activities. Detailed descriptors for each criterion at each level are shown in Table 1.

Table 1. Performance levels for each criterion of the AKSC in STEM-based teaching

Competence components	Criterion	Level of expression			Evidence/ Observable indicators
		Level 1 (1 point)	*Level 2 (2 points)*	*Level 3 (3 points)*	
1. Identifying and analysing the problem *(CC1)*	1.1. Identify and clarify the STEM problem, recognizing relevant foundational knowledge and skills. *(C1.1)*	Identify some isolated pieces of knowledge related to the STEM problem.	Identify multiple foundational knowledge and skills that are directly related.	Identify and categorize interdisciplinary knowledge and practical experience.	Worksheet for identifying related knowledge; learning diary; oral responses
2. Mobilizing knowledge and explaining the problem. *(CC2)*	2.1. Analyze and establish the relationship between foundational knowledge and skills with the STEM problem. *(C2.1)*	State basic but fragmented relationships between knowledge and the problem.	Analyze relationships between knowledge and the problem relatively clearly.	Analyze relationships deeply and logically, clarifying the scientific basis of the problem.	Mind map of knowledge relationships; analytical presentation
	2.2. Explain the nature, mechanism, or phenomenon of the STEM problem based on foundational knowledge and skills. *(C2.2)*	Provide explanations, but they are incomplete or inaccurate.	Provide relatively complete and reasonable explanations of the problem's nature.	Provide accurate, comprehensive explanations with clear evidence.	Oral responses, written explanations, group presentations, project reports
3. Applying knowledge and skills to	3.1. Propose feasible solutions/design	Propose one solution or a	Propose at least two solutions	Propose diverse, creative	Design drawings; description

propose and select solutions. *(CC3)*	models to address the STEM problem (can be represented by diagrams /sketches). *(C3.1)*	superficial sketch	with clear sketches.	solutions with clear and reasonable sketches.	of group ideas.
	3.2. Select the most optimal solution/model and explain its scientific basis. *(C3.2)*	Select a model without clear criteria or justification.	Select an appropriate model and justify based on some criteria.	Select the optimal model with detailed analysis and comparison of strengths and weaknesses.	Analysis and comparison sheets of design models; argumentative presentation
4. Implementing the plan/solution. *(CC4)*	4.1. Discuss and adjust the process of implementing/manufacturing the STEM product. *(C4.1)*	Participate in discussions but contribute little or do not accept feedback.	Engage actively in discussions and adjust the process after receiving feedback.	Discuss effectively, defend opinions, and make reasonable adjustments.	Group discussion notes/videos; direct observation of group activities
	4.2. Implement/ manufacture, test, evaluate, and adjust to complete the product/solution. *(C4.2)*	Produce a simple product, with little testing and no adjustments.	Produce a product that meets objectives, with basic testing and adjustments	Produce a complete, well-functioning product, with clear improvements after testing.	Product photos/videos, testing and adjustment diaries; completed products
5. Reporting and evaluating the process of applying knowledge and skills. *(CC5)*	5.1. Report clearly on the product and the process of solving the STEM problem. *(C5.1)*	Present a brief report with poor structure.	Present a sufficient report with images or supporting evidence.	Present a logical, comprehensive report with rigorous analysis and evidence.	Written report; oral presentation; supporting videos/photos
	5.2. Self-assess, incorporate feedback, and adjust the design/solution for improvement. *(C5.2)*	Receive feedback but show no clear adjustment.	Assess the product, accept feedback, and make appropriate adjustments	Provide in-depth feedback, with clear adjustments that enhance product quality.	Feedback sheets, description of adjustments after suggestions, and an improvement diary

2.4. Designing the assessment tool for students' competence to apply knowledge and skills through STEM lessons

This topic is part of the "Energy transformation" content strand within the thematic area "Energy and its transformation." The lesson is designed to be implemented after students have been introduced to the theoretical concepts of energy transformation and renewable energy in prior lessons. Lesson title: *Constructing a model house using solar energy.* Subject: Natural Sciences (NS) - Grade 6. Duration: 3 class periods.

Practical situation: In this STEM lesson, students are introduced to the real-world issue of energy sustainability. Traditional energy sources such as coal, gas, and petroleum are limited, and their use poses significant risks to the environment, human health, and ecosystems. To address this challenge, students are tasked with designing and constructing a solar-powered house model capable of lighting an electric bulb.

Activity 1. Problem identification

Objectives: Students name several types of renewable energy currently applied in various regions of Vietnam. Students identify how energy transforms from one form to another in each example; they agree on the criteria for evaluating their reports and the final product.

Implementation: The teacher shows a short video and asks students to list renewable energy sources that are being used in Vietnam based on their prior home study. Students answer the questions and contribute to their classmates' responses. The teacher facilitates student discussions to establish and agree on the product evaluation criteria as follows: (1) the model must have all components assembled securely and neatly; (2) the electric bulb must light up under sunlight conditions; and (3) the product should be decorated in a creative and visually appealing way. Evaluation criteria for product reports include: (1) demonstrating a process with detailed, scientific steps (with explanations); (2) a beautiful product decoration plan; (3) a complete, clear report. The teacher assigns the project: "Designing and constructing a model house using solar energy".

Activity 2. Research background knowledge and propose solutions

Objectives: Students calculate the required materials needed to design a model house using solar energy. Students determine the procedure for constructing the model house and identify its basic operating mechanism related to energy transformation.

Implementation: The teacher provides knowledge about energy transformation in solar panels and guides students in identifying the materials required to construct the solar-powered house model. These include solar panels, electrical wires, a light bulb, cardboard, colored paper, double-sided tape, pens, rulers, scissors, a paper cutter, and additional decorative materials. The steps of implementation were as follows: (1) cut the prepared cardboard to assemble the house model; (2) fix the solar panel on the roof and install the LED bulb inside the house; (3) connect the solar panel and the bulb using wires according to the correct positive (+) and negative (–) poles; (4) place the house model under sunlight to observe the results. Students brainstorm ideas for decorating the product. The teacher assigned homework: to create a design plan for a model house using solar energy.

Activity 3. Solution selection

Objectives: Students present their design plan for a model house using solar energy, analyze its basis, and clarify how knowledge of energy transformation is applied in the product. Students collaborate to defend, review, and finalize their prototype construction and evaluation plans.

Implementation: Teachers use gallery techniques to let students observe and evaluate other groups' designs. Each group evaluates another's plan using the criteria and notes comments on a feedback sheet. Students provide feedback as assigned by the teacher. Groups discuss and revise their plans based on feedback from peers and the teacher. The teacher summarizes key points, connects the discussion to the lesson content, validates final plans, and highlights strengths and areas for improvement in each plan.

Activity 4. Construction, testing, and evaluation (conducted at home)

Objectives: Students construct a model house according to their revised plan from Activity 3. Students test, evaluate, and modify the product as necessary.

Implementation: The teacher provides printed design templates, solar panels, LED lights, electrical wires, and double-sided tape. Students prepare decorative materials themselves (e.g., colored pens, paper). Students record testing results and optimal conditions on the Worksheet provided by the teacher. The worksheet is designed for students to document key observations during the product construction process, evaluate the quality of the product, and analyze the factors contributing to success or failure in each attempt.

Activity 5. Sharing, discussion, and revision

Objectives: Students learn from others' experiences and problem-solving techniques, and explore creative approaches that different groups use.

Implementation: Students display their group's model houses. The teacher facilitates group presentations. One member from each group presents their product. Other groups observe, give feedback, and ask questions. The teacher summarizes the key points, highlights the best results, links them to relevant scientific concepts, and analyzes the construction techniques for producing a complete and functional solar-powered model house.

2.5. Results of the pedagogical experiment

We conducted a pedagogical experiment in two Grade 6 classes at Trung Vuong Secondary School, Thai Nguyen Province. The experimental class was Class 6B with 40 students, while the control class was Class 6E with 37 students. The academic levels of students in both classes were equivalent. During the pedagogical experiment, we assessed the development of students' AKSC in the experimental class using teacher evaluation forms based on the AKSC criteria through STEM lessons. It should be noted that in this experiment, the experimental class (6B) had already participated in two STEM lessons, namely "Handmade chocolate making" and "Designing an air quality measuring device". Therefore, the pre-experiment scores of AKSC criteria for class 6B actually reflect the teacher evaluations conducted after students had completed these two STEM lessons, which served as a valid baseline for comparison with the post-experiment results.

In addition, after the experiment, both the experimental and control classes completed a 45-minute knowledge test under the following conditions: both were given the same test and grading rubric, and both classes were taught by the same teacher. Because the experimental class received STEM instruction while the control class did not, the test included only questions related to the core subject knowledge that all students in both classes had been taught. No questions that were specific to the STEM lessons were included to ensure fairness and comparability between the two groups.

Figure 1 illustrates the average scores of the criteria achieved by students in the experimental class before and after the pedagogical experiment.

From Figure 1, it can be observed that the average scores for the assessment criteria achieved by students before and after the pedagogical experiment (PE) show a significant change. Specifically, criterion 1.1 (representing CC1) exhibited the most noticeable improvement after the implementation of the PE, followed by criterion 4.1 and criterion 4.2 (representing CC4); criterion 3.1 and criterion 3.2 (representing CC3); and criterion 5.1 and criterion 5.2 (representing CC5). The smallest difference was seen in criterion 2.1 and criterion 2.2 (representing CC2).

These results can be explained by the nature of each competence component. CC1, CC3, CC4, and CC5 are closely connected to hands-on activities in STEM lessons—such as identifying and clarifying problems, proposing and defending solutions, experimenting with models, and improving products. These activities gave students multiple opportunities to practice, which led to strong development. Meanwhile, CC2 emphasizes the ability to analyze and explain STEM problems based on students' existing background knowledge. This requires not only recalling prior knowledge but also using it to interpret real-world contexts. Because this cognitive process is more demanding and develops gradually, progress in C2.1 and C2.2 was less pronounced compared to other criteria.

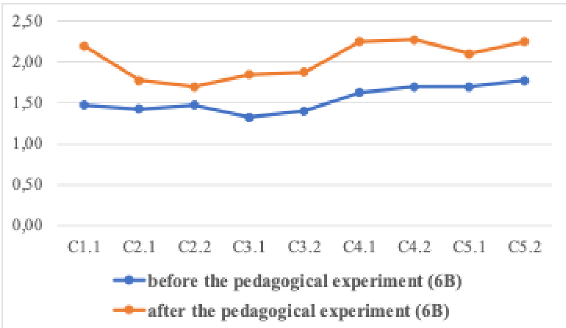

Figure 1. Evaluation results by criterion for class 6B at Trung Vuong secondary school after the pedagogical experiment

The cumulative test score curve and the summary table of the main statistical parameters for the experimental class and the control class after the pedagogical experiment are presented as follows:

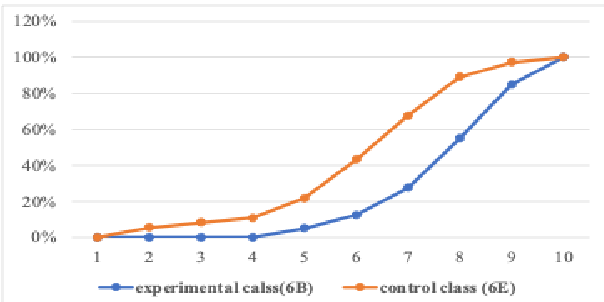

Figure 2. Cumulative test score curve for the experimental class (6B) and the control class (6E) after the pedagogical experiment

The results in Figure 2 show that the cumulative test score curve of the experimental class is positioned to the right and above that of the control class, indicating that the post-experiment test scores of the experimental group were higher than those of the control group. We analyzed the mean scores, standard deviations, analysis of variance, and T-test. The results are presented in Table 2.

Table 2. Descriptive statistics and t-test results after the pedagogical experiment

Class	Sample Size	Mean Score	Standard Deviation	Variance	p-value (T-Test Result)	Effect Size (ES)
Experimental (6B)	40	8.15	1.350	1.823	0.000	0.92
Control (6E)	37	6.68	1.600	2.559	0.000	

From the results presented in Table 2, the experimental class achieved a higher mean score (8.15) than the control class (6.68), with a greater proportion of high scores and fewer low scores. The smaller standard deviation and variance indicate that the results of the experimental class were more concentrated around the mean. The p-value (< 0.05) confirms a statistically significant difference between the two groups, and the effect size (0.92) reflects a large impact. These findings demonstrate that the implementation of STEM lessons significantly improved students' learning outcomes.

3. Conclusions

This study proposed a framework of the AKSC through STEM lessons, including five competence components and nine criteria across three levels. A STEM lesson plan on "Energy and its transformation" was designed and tested in a pedagogical experiment. Results showed clear improvements, particularly in competencies related to identifying foundational knowledge and designing/testing products. The findings confirm that STEM lessons can effectively enhance students' AKSC, provided that teachers receive practical tools, adequate instructional time, and competence-oriented training.

Nevertheless, the study has some limitations. The experiment was conducted with a relatively small sample from a single school, which may restrict generalizability. The framework has not been validated through confirmatory factor analysis (CFA), and no longitudinal data were collected to examine sustainability.

Future research should expand the application to other STEM topics and grade levels, conduct CFA to confirm the framework's structural reliability, and carry out longitudinal studies to assess long-term effects. Integrating digital technologies and blended teaching models also represents a promising direction for further strengthening students' AKSC within the context of educational reform.

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