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TEACHING BASED ON STEM LESSON PROBLEMS FOR THE TOPIC "STATES OF MATTER" IN THE SUBJECT OF GRADE 6 NATURAL SCIENCES

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THE RESEARCHER'S PUBLICATIONS RELATED TO THE DISSERTATION TOPIC

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2. Han Thi Huong Thuy, Do Huong Tra (2023), "Organizing teaching based on the STEM lesson problem "Evaporation and condensation phenomena" (Natural Sciences Grade 6) to develop natural science competence for students, Journal of Education (ISSN 2354-0753), Vol. 23 No. 13 July, pp.29-35.
3. Han Thi Huong Thuy, Do Huong Tra (2023), "The current status of STEM teaching in Vinh Phuc province", Journal of Educational Equipment (ISSN 1859-0810), No. 293, July 2, p. 65-67.
4. Han Thi Huong Thuy, Do Huong Tra (2021), "Organizing teaching based on the STEM topic of magnetism", Journal of Educational Equipment (ISSN 1859-0810), special issue every 2 months 7, pp.28 – 30.

INTRODUCTION

1. Reason for choosing the topic

STEM is an acronym for the words Science, Technology, Engineering and Mathematics, often used when discussing development policies on Science and Technology, Engineering and Mathematics of each country. With different approaches, STEM education will be understood and implemented in different ways. Organizing STEM teaching allows learners to equip themselves with the ability to think rationally and the ability to review and seek confirmation such as learning mathematics and having extensive knowledge in the fields of science and technology.

In the US, since the early 90s, a new educational trend called STEM education has formed. In the STEM education program, science and technology subjects are not taught independently but integrated together into one subject through teaching methods using projects, experiences, practices, etc. In many European and American countries, to maximize the creativity of students at all levels, science fairs are held regularly from school to national level.

Currently, STEM education has been implemented in many countries around the world, especially developed industrial countries such as the US, Australia, Finland, Canada, Japan, Korea. Thus, it can be seen that STEM education around the world has become a trend and is growing strongly in many countries around the world.

STEM education introduced to Vietnam does not originate from scientific educational research or from macro policies on human resources, but from Robot competitions for students from elementary to high school implemented by technology companies in Vietnam together with foreign organizations. Since then, STEM education has begun to spread in many different forms, many different ways of implementation, and many different supporting organizations.

The Government of Vietnam issued Directive No. 16/CT-TTg dated May 4, 2017 of the Prime Minister on strengthening the competence to approach the 4th industrial revolution, which emphasized the need to "promote significant changes in policies, content, and educational methods to create a workforce capable of adapting to emerging trends in production technology. This requires a focus on promoting education in science, technology, engineering, mathematics (STEM), foreign languages, and computer science in the general education curriculum."

Official Dispatch 4325/BĐĐT-ĐĐT-GDTrH dated September 1, 2016, provides guidance for implementing the tasks of secondary education for the academic year 2016-2017 and addresses the adoption of STEM education: "The spirit of integrated education in science, technology, engineering, and mathematics (STEM) must continue to be emphasized in the execution of the general education curriculum, particularly in related subjects. The implementation of STEM education will be piloted in selected schools."

In the 2018 General Education Program, STEM education both means promoting education in the fields of science, technology, engineering and mathematics and represents an interdisciplinary approach, developing competences and qualities of learners. In the 2018 General Education Program, STEM education has been emphasized through the following expressions:

- The general education program includes a complete set of STEM subjects. These subjects, such as mathematics, natural sciences, technology, and computer science, ensure that the majority of students are exposed to STEM education.

- The position and role of computer education and technology education in the 2018 general education program have been significantly enhanced. This not only reflects the clear adoption of STEM education principles but also represents a timely adjustment in response to the Fourth Industrial Revolution.

- There are STEM topics integrated into the curriculum at the primary education level, such as in subjects like Nature and Society, Infomatics and Technology (in elementary school), and Natural Sciences (in lower lower-secondary school).

- Specialized STEM education topics are introduced in grades 10, 11, and 12, including hands-on experiential activities conducted within science research clubs, encompassing STEM research activities.

The program's flexibility allows for the development of certain STEM education content through local curriculum plans and school education plans. STEM programs and activities are implemented and organized through community-oriented educational initiatives.

However, when implementing STEM in actual school settings, teachers and students often encounter various challenges related to lesson duration, teaching procedures, activity organization, learning materials, and student assessment methods. To address some of these difficulties, Official Dispatch 3089 from the Ministry of Education and Training, dated August 14, 2020, emphasizes the following: "The content of STEM-themed lessons should be closely connected to solving a relatively complete problem, allowing students to actively participate and apply the knowledge they have acquired to address the issue. Through this approach, it contributes to the development of competences and qualities in students. Depending on the specific characteristics of each subject and the physical infrastructure of the school, schools can flexibly employ various forms of organizing STEM education, such as teaching science subjects through STEM lessons, conducting STEM experiential activities, and organizing scientific and technical research activities."

According to a study conducted by a group of researchers at the University of Thủ Đô, which was published in March 2023, the current state of STEM education organization has revealed that 72.2% of teachers believe that the most significant challenge is a lack of time to conduct STEM lessons in the classroom. Furthermore, the interdisciplinary nature of STEM topics exceeds

the specialized knowledge of teachers since it requires the integration of various subject areas within STEM education. This has had an impact on the implementation of STEM lessons in lower-secondary schools.

To organize STEM lessons effectively, various active teaching methods can be applied, such as project-based learning, problem-solving instruction, and inquiry-based learning. With outstanding advantages such as enhancing the practicality of the subject, promoting learners' proactiveness, creativity, and interest, improving teamwork skills, analytical problem-solving skills, presentation skills, as well as the ability to defend and argue opinions in front of an audience, the teacher, in the role of a facilitator, can also gain a wealth of experience from the new perspectives and solutions offered by learners to enrich the lessons and adapt research situations. For research topics that are highly theoretical and lack prior research theories, teaching based on problems is an important method in scientific research and teaching. So far, problem-based learning has been introduced in Vietnam and has been researched and implemented in some subjects. However, research and implementation of problem-based learning in STEM lessons are still limited. This is one of the directions for our research topic selection.

In teaching the natural sciences, in addition to general skills, specific skills of the subject are also addressed: Natural Science Competencies. Natural Science Competencies are reflected in three components: Perceiving natural sciences, Exploring the Natural World, and Applying the knowledge and skills acquired.

Developing Natural Science Competencies through STEM lessons with content linked to practical applications is not only in line with the educational development direction but also helps students become more interested and proactive in their learning. It transforms academic knowledge into practical life knowledge, strengthens students' confidence in science, and makes it easier for them to adapt to real-life situations. Organizing STEM lessons based on problem-based learning, the following 21st-century skills will gradually be enhanced:

- Critical thinking and problem-solving skills.
- Communication and collaboration skills.
- Creativity and innovation skills.
- Technology and information communication literacy.
- Project management skills.
- Presentation skills.

Therefore, it meets the requirements of the Natural Sciences competency. Assessing the Natural science competence as required in the 2018 program is difficult for teachers and students, so it is necessary to restructure and clearly demonstrate the levels of behavioral quality criteria.

For the above reasons, the research chose the topic: **Teaching based on STEM lesson problems for the topic "States of Matter" in the subject of Grade 6 Natural Sciences.**

2. Research objectives

Proposing the procedure of building and organizing teaching based on STEM lesson problems for the topic “States of Matter” ” in the subject of Grade 6 Natural Sciences to foster students' natural science competence.

3. Research subjects and scope

3.1. Research subjects

- Knowledge content of the topic “States of matter” in Natural Sciences Grade 6.
- Procedure of building and organizing teaching based on STEM lesson problems
- Natural science competence of students

3.2. Research scope

Content of knowledge: transformation of substances, focusing on the following knowledge:

+ Diversity of substances
+ Three fundamental states of matter
+ The change of forms (states) of a substance

4. Research objects

The research was conducted experimentally with 6th-grade students within the Vinh Phuc province.

5. Scientific hypothesis

If the proposed structure of natural science competencies is developed, and if a procedure for creating and organizing STEM problem-based lessons that meet the requirements for nurturing natural science competencies, along with an analysis of the content of the "States of Matter" topic in 6th-grade Natural Science, is presented, then it will contribute to enhancing students' natural science competencies to meet the objectives of the subject.

6. Research tasks

- Investigate the theoretical foundation of competency development, with a special focus on the natural science competencies of students in the teaching of the subject of Natural sciences .
- Research the procedure of creating and organizing STEM problem-based lessons.
- Develop a procedure of teaching based on STEM lesson problems for the "States of Matter" topic.
- Examine the current state of teaching, both in terms of organizing STEM problem-based lessons and nurturing natural science competencies of students.
- Propose teaching methods to enhance students' natural science competencies.
- Analyze certain content related to the "States of Matter" topic and the ability to apply it in teaching based on STEM problem-based lessons.
- Design a procedure of teaching based on STEM lesson problems to nurture students' natural science competencies.
- Develop an assessment tool for natural science competencies in teaching the "States of Matter" topic in the 6th-grade natural science subject.

- Conduct the pedagogical experiment.

- Collect experimental data and compare it with the objective of nurturing natural science competencies to analyze student behavior.

- Evaluate the feasibility and effectiveness of the proposed teaching procedure in nurturing students' natural science competencies.

7. Research methods

7.1. Theoretical research methods

- Study documents from the Party, the State, and the Ministry of Education & Training related to the development of students' qualities and competencies, with a specific focus on natural science competencies.

- Review books, journals, specialized publications, dissertations, and theses related to the research topic.

- Explore educational and psychological literature, theoretical foundations of problem-based learning, and STEM education.

- Analyze curricula and teaching materials for the natural science subject.

7.2. Practical Research Methods

- Conduct surveys and investigations to assess the current application of active teaching methods, including problem-based learning.

- Investigate the current implementation of STEM in education.

- Examine the current state of nurturing natural science competencies in lower-secondary schools.

7.3. Expert Consultation

Engage in discussions with experts regarding the procedure of developing and organizing problem-based STEM lessons and the tools for assessing natural science competencies.

7.4. Experimental Method

Conduct the pedagogical experiment to test the scientific hypothesis of the research topic and assess the feasibility and effectiveness of the designed teaching procedures for nurturing students' natural science competencies.

7.5. Mathematical Statistical Method

Utilize mathematical statistical methods to analyze the results of the pedagogical experiment when evaluating the effectiveness of the teaching procedures in nurturing students' natural science competencies.

8. New Contributions of the Thesis

Theoretical contributions: The thesis has:

- Proposed the structure of natural science competencies.

- Suggested a procedure for developing and organizing problem-based STEM lessons to nurture students' natural science competencies.

Practical contributions:

- Designed four teaching procedures for problem-based STEM lessons to nurture students' natural science competencies.

- Developed assessment tools for natural science competencies in teaching the "States of Matter" topic in the 6th-grade natural science subject.

The research results provide scientific data and information that enrich the reference materials for teaching based on STEM lesson problems in the natural science subject.

9. Thesis Structure

In addition to the introduction, conclusion, references, and appendices, the thesis consists of four chapters:

Chapter 1: Literature Review

Chapter 2: Theoretical and practical foundations of teaching based on STEM lesson problems for nurturing students' natural science competencies.

Chapter 3: Designing procedures of teaching based on STEM lesson problems for the "States of Matter" topic.

Chapter 4: Pedagogical experiment

Chapter 1
LITERATURE REVIEW

1.1. Research on Problem-Based Learning

One of the key objectives of the teaching and learning process is to nurture students' competencies, as these competencies play a crucial role in their daily lives and work. Therefore, it is essential to develop these competencies in students throughout their learning journey. In response to this goal, advanced education systems have been actively shifting from content-focused education to competency-based teaching and learning. Competency-based education has become a hot topic in today's educational landscape and has evolved into an international educational trend. The benefits of competency-based learning have been acknowledged by policymakers and educational influencers worldwide.

In the most advanced education systems globally, the emphasis on nurturing students' competencies is particularly pronounced. Education is centered around the learner, facilitating flexible understanding and lifelong learning skills development. Educators highly value active teaching methods, including Problem-Based Learning (PBL). PBL originated at McMaster University's medical school in Hamilton in the 1960s. Since then, PBL has evolved and expanded into various fields of education, including health sciences, mathematics, law, education, economics, business, social research, and engineering.

Research on PBL has been focused on primarily in higher education institutions. PBL was introduced and widely adopted in many universities worldwide. Currently, numerous universities have established research centers and implemented PBL or created problem banks for their specific training programs. Some examples include universities in the United States, such as Delaware and Colorado, in the United Kingdom, such as Samford, in Canada, like McMaster and Queen, and in Australia, such as Sydney.

Research studies have also reported the achievements of PBL in secondary education in some countries around the world. In 2011, the "Former les

enseignants au changement" program in Europe addressed the competencies necessary for bringing about teacher changes, including the organization of active learning activities for students.

In Vietnam, prior to the 1980s, there were few research works on PBL. Research on PBL in Vietnam has used different terminology, including "teaching based on problems," "problem-based learning," and "teaching according to problems." Despite variations in terminology, the essence of these approaches is quite similar. In her book titled "Modern Teaching Organizational Styles in High School Physics Education" [26], Do Huong Tra provided essential theoretical foundations for various modern teaching styles being applied today, including the PBL model. This work also enables teachers to distinguish, compare, and evaluate different teaching models, allowing them to proactively and creatively select an appropriate teaching model or method for a specific topic under specific educational conditions.

In secondary education in Vietnam, teaching based on problems is still relatively new and has not been widely explored or utilized. Given the distinct characteristics of problem-based learning, the challenge for students is to connect the real-world context to the subjects. Consequently, subjects closely related to practical experiences offer more opportunities for developing problem scenarios; hence, the applicability of problem-based learning in these subjects is higher.

1.2. Research on STEM education

STEM stands for Science, Technology, Engineering, and Mathematics. STEM education essentially involves providing learners with the knowledge and skills related to the fields of science, technology, engineering, and mathematics. These knowledge and skills need to be integrated, intertwined, and mutually supportive to enable students not only to understand the principles but also to apply them in practice and create products in their daily lives.

STEM education has garnered the attention of many organizations and educators who are conducting research on it. In the context of education worldwide, STEM is understood as STEM education. STEM education has different interpretations.

Currently, in our country, research on STEM education at the lower-secondary school level mainly revolves around STEM experiential activities and scientific research, with less emphasis on the application of STEM lessons. STEM lessons can utilize active teaching methods and techniques to enhance educational effectiveness, with the goal of nurturing natural science competence.

Therefore, there is a need for specific research on teaching STEM lessons with the knowledge defined in the 2018 educational program, as well as research directions for designing specific STEM teaching procedures to meet the goal of nurturing competences in learners.

1.3. Research on teaching, fostering and developing scientific competence

According to the Philosophy Dictionary (M.Rôdentan and P.IUĐin, 1976), competence is understood in a broad sense as the psychological characteristics

of an individual that regulate their behavior and are the conditions for an individual's life activities. At the same time, the philosophical perspective states that human competence is a product of social development. According to P.A.Rudich, competence is the psychophysical quality of an individual that governs the process of assimilating knowledge, skills, and abilities, as well as the effectiveness of performing specific activities.

Various studies have recognized the necessity of nurturing competence, including scientific competence, for students, and have focused on the elements of scientific competence. These elements include: generating knowledge through productive activities, conducting research according to a specific process to gather data and arrive at objective conclusions about nature and interpreting this data, and using known theoretical knowledge to explain natural and social phenomena. However, there is a lack of research addressing the process of nurturing scientific competence.

From the studies on methods and processes for nurturing scientific competence, it is evident that these studies have discussed the concept of competence. Concepts such as scientific competence and experimental competence have been highlighted, and the corresponding structures of competence have been elucidated. These studies have also clarified the roles of these competences in implementing natural science programs, aiming to develop students' competence according to the 2018 curriculum. However, there is a need for specific research on natural science competence and the structure and nurturing of natural science competence for lower-secondary school students.

It can be seen that in order to organize problem-based learning, it is necessary to overcome the existing issues in current teaching, such as the fact that situations, experiments, or research questions all originate from the teacher. In this way, students are passive in the learning process, and the conclusions drawn from a single hypothesis are less objective, while a hypothesis can have multiple conclusions that need to be demonstrated. The core question of the observed phenomenon research has not been emphasized.

From the literature review, it is evident that applying problem-based learning in STEM lessons to nurture natural science competence is necessary. To nurture natural science competence in lower-secondary school STEM lessons, the following questions need to be addressed:

- How to organize teaching and learning activities in problem-based STEM lessons in the first year of lower-secondary school to help students grasp scientific knowledge while developing their natural science competence?

- How to propose a process for organizing problem-based STEM lessons suitable for the students' level and the practical conditions in Vietnam?

- Based on the requirements stated in the natural science curriculum, how to propose the structure of natural science competence in STEM teaching, which can serve as a basis for designing teaching activities and assessment methods?

- What are the content and methods for nurturing natural science competence that can serve as a foundation for designing problem-based STEM lessons?

Based on these research questions, we have identified the title of our research: **"Teaching based on STEM lesson problems for the topic "States of Matter" in the subject of Grade 6 Natural Sciences".**

Chapter 2
THEORETICAL AND PRACTICAL BASIS OF TEACHING BASED ON STEM LESSON PROBLEM TO FOSTER NATURAL SCIENCE COMPETENCE FOR STUDENTS

2.1. Problem-based learning

2.1.1. Concept

According to H.S. Barrows, problem-based learning is an example of a teaching model in which the learner is the center of learning and teaching. It is a learning method based on the principle of using problems as a starting point for acquiring and integrating new knowledge.

2.1.2. The goal of problem-based learning

One of the important goals of problem-based learning is the development of self-directed learning and skills training, and competence building for learners.

In addition to course content, problem-based learning can promote the development of critical thinking skills, problem-solving skills, and communication skills. It can also provide opportunities for group work, searching and evaluating research literature, and lifelong learning.

2.1.3. Features of problem-based learning

- Student centered approach and practical experience is important.
- Group collaboration is a core issue
- Teachers play a supporting role.
- Knowledge is multi-disciplinary and related to the practical environment.
- Promotes a deeper approach to learning.
- Encourage flexible learning methods and students are more likely to use library resources for research. From there, providing a model for lifelong learning
- Develop greater knowledge retention and recall skills; develop important thinking, writing and communication skills.
- Students tend to demonstrate stronger knowledge application skills.
- Provide a model for lifelong learning.

2.1.4. Problem-based learning with other types of teaching organization

When doing research on problem-based learning, the researcher realized that there are many similarities with problem-solving learning. So what is the difference between these two types of teaching organizations?

According to Do Huong Tra, problem solving teaching is a type of teaching organization in which teachers create problematic situations, control students to detect problems, and act voluntarily, actively and creatively to solve problems

and thereby gain knowledge, practice skills and achieve learning goals. Thus, problem-based learning is quite similar to problem-solving learning [26]. Both types of teaching organizations are concerned with the problem and put students at the center of the teaching procedure. However, the biggest difference in these two types of teaching organizations is the characteristics of the problem to be solved. For problem-based learning, the characteristics of the problem must be related to the curriculum but practical for learners, requiring students to have the skills to synthesize knowledge and structure knowledge to solve problems. According to the data of practical conditions and with that characteristic, problem-based learning will be one of the suitable options for STEM lessons.

2.1.5. Situations in problem-based learning

In problem-based learning, situations are often written in two ways: interrupted situations and consecutive situations [15].

Interrupted situations, meaning the result of this problem leads to another problem, and the process continues until the issues are clarified.

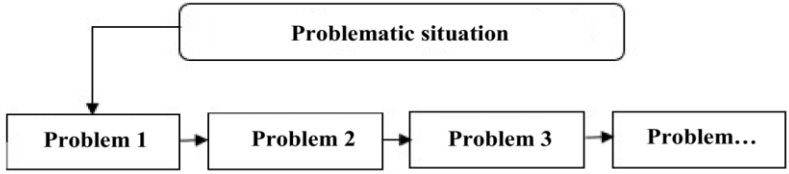

Figure 2.3. The diagram illustrating interrupted situations

Consecutive situations can arise from a complex initial problem, giving rise to multiple secondary problems simultaneously.

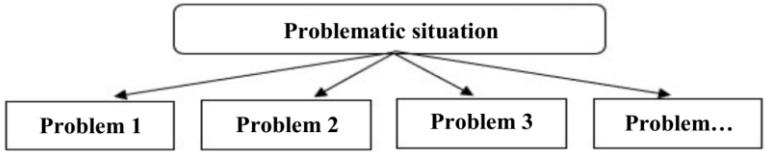

Figure 2.4. Diagram illustrating consecutive situations

Interrupted situations are often suitable for students because the arising problems to be solved at this level are usually simple and focused on building knowledge in the lesson. Consecutive situations are suitable for university students as these problems are usually complex, and within the situation, many issues emerge. From one problem, it can be broken down into several small problems, small tasks with problem-solving aspects, and the learner must identify the problems that need to be addressed. Therefore, in the thesis, interrupted situation writing is used when organizing problem-based learning.

2.1.6. Organization of problem-based learning: Problem-based learning can be organized into 7 stages as shown in Figure 2.:

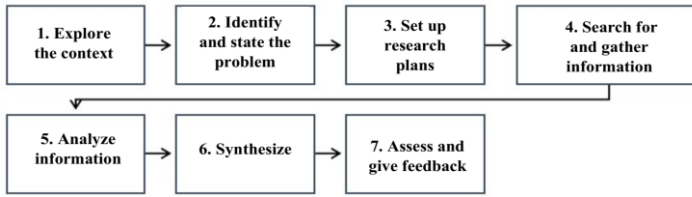

Figure 2.6. Steps in organizing problem-based learning

2.2. STEM-based teaching in Lower-secondary school

2.2.1. Concept

STEM is an acronym for the words Science, Technology, Engineering and Mathematics, often used when discussing development policies on Science and Technology. Technology, Engineering and Mathematics of each country. STEM also represents the relationship between science, technology, engineering, and mathematics in the development of science and engineering and in STEM education. Knowledge and skills must be integrated, and supplemented. Supporting each other helps students not only understand principles but also apply them to practice and create products in everyday life.

2.2.2. Goals of STEM-based teaching

The goals of STEM-based teaching in different countries are different. In the UK, the goal of STEM teaching is to create high-quality scientific research human resources. In the US, there are three basic goals for STEM teaching: equipping all citizens with STEM skills, expanding the workforce in the STEM field to include women and underrepresented minorities to maximize the country's human potential, increasing the number of students who will pursue and study in-depth STEM fields. In Australia, the goal of STEM teaching is to build the nation's knowledge base to meet the emerging challenges of developing a 21st century economy.

2.2.3. Physiological and cognitive characteristics of early lower-secondary school students

After a period of adapting to the school environment and learning activities at the elementary level, students at the beginning of lower-secondary school have accumulated many psychological and cognitive achievements to be ready to enter a new developmental stage (lower-secondary school stage). In the early stages of lower-secondary school, the physiological and cognitive characteristics of students are shown:

- Characteristics of cognitive activities
- Characteristics of emotional life and personality

2.2.4. Products of STEM teaching in lower-secondary school

Lower-secondary school students are aged 11-15, however the thesis is concerned with early lower-secondary school students (Grade 6), so the products of STEM teaching for these students also have different requirements

than with students in the upper grades of lower-secondary school. For early lower-secondary school students, STEM teaching products can be:

- Scientific experiments
- Technical projects and products
- Applications and software
- Laboratory kit and equipment
- Research products and problem solutions

2.3. Procedures of teaching based on STEM lesson problems

From comparing the teaching procedures, we propose a procedure of teaching based on STEM lesson problems (Figure 2.9).

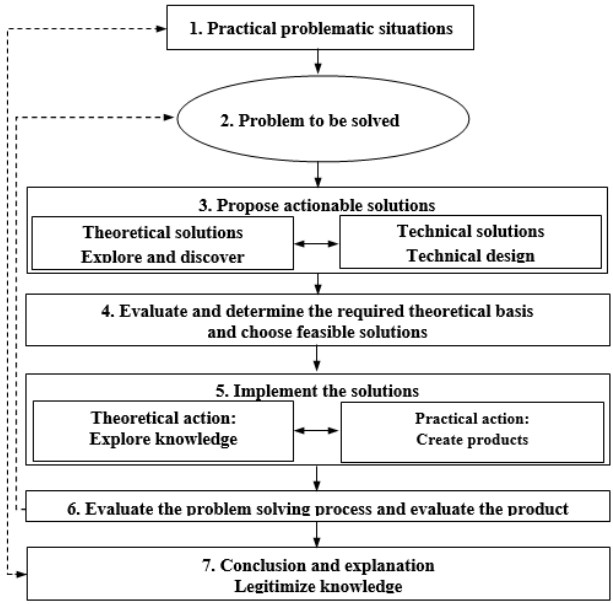

Figure 2. 9. Teaching based on STEM lesson problems

2.4. Fostering natural science competence in teaching based on STEM lesson problems

2.4.1. Concept of natural science competence

Competence is one of the concepts that began to be researched from the foundation of psychology, and to date, there have been numerous studies addressing the concept of competence. The common point of these concepts is that competence is related to the activities of using knowledge (perception), skills (behavior), and attitudes (values, perspectives) to solve problems in specific practical contexts. However, it is not the mechanical combination of these three factors but the flexible application of these factors to solve problems, and its outcomes can be observed and measured.

2.4.2. Framework of Natural Science Competence in STEM Education

Table 2.5. Framework of Natural Science Competence

Elemental competences	**Behavioral expressions**	**Quality criteria of behaviors**		
		Level 1	Level 2	Level 3
NT. Recognizing the natural sciences.	NT1. Perceive knowledge in the field of natural sciences.	NT1. M1 Name phenomena, concepts, and laws of natural procedures.	NT1. M2 Describe, present, and explain scientific phenomena and laws.	NT1. M3 Apply knowledge in familiar and unfamiliar situations to analyze, synthesize, and evaluate.
KP. Discover about sciences	KP1. Identify the problem: Raise questions that need to be solved.	KP1.M1 Realize there is a problem but not yet clearly identify the problem that needs to be solved.	KP1.M2 Recognize and ask questions that address the problem that needs to be solved.	KP1.M3 Recognize and ask questions that address the problem that needs to be solved by connecting existing knowledge and experience and using their own language to stae the problem.
	KP2 Apply known knowledge to make predictions and hypotheses.	KP2.M1 Make judgments but have no reasoning.	KP2.M2 Make well-founded judgments but have not yet formulated a hypothesis.	KP3.M3 Make well-founded judgments and build hypotheses that need to be investigated.
	KP3. Plan: Follow the steps to design an experiment, an equipment model to	KP3. M1 Make plans to design an experiment, a device model, but it's not yet complete.	KP3. M2 Make plans to design an experiment and a complete device model, but a feasible	KP3. M3 Make plans to design an experiment and a complete device model. Analyze and

Elemental competences	Behavioral expressions	Quality criteria of behaviors		
		Level 1	Level 2	Level 3
	analyze, compare, and improve to choose a feasible solution.		solution has not been selected.	compare to choose a feasible solution.
	KP4. Implement the plan.	KP4. M1 Create the product as planned but the results have not been evaluated.	KP4. M2 Create the product according to plan and test the product to evaluate the results but can not draw conclusions and make adjustments when necessary.	KP4. M3 Create the product according to plan and draw conclusions, adjust the product when necessary after evaluation and explanation.
	KP5. Present and report the results of discovery activities.	KP5. M1 Report but unable to explain or criticize.	KP5. M2 Reporting and criticism are possible but not convincing.	KP5. M3 Report and defend results convincingly.
VD. Apply scientific knowledge towards sustainable development.	VD1. Explain and solve practical problems based on learned knowledge.	VD1.M1 Identify practical problems based on knowledge learned but not yet explained.	VD1.M2 Identify practical problems and explain them based on learned knowledge.	VD1.M3 Identify practical problems, explain and solve them based on learned knowledge.
	VD2. Adjust	VD2.M1 Adjust	VD2.M2 Adjust	VD2.M3 Adjust knowledge,

Elemental competences	Behavioral expressions	Quality criteria of behaviors		
		Level 1	Level 2	Level 3
	knowledge, change attitudes and behaviors in accordance with the requirements of sustainable development.	knowledge based on practice.	knowledge, change attitudes and behavior.	change attitudes and behaviors and change the attitudes and behaviors of those around in accordance with the requirements of sustainable development.

SUMMARY OF CHAPTER 2

Natural science competence is one of the important human capacities that many advanced educational systems in the world care about fostering for students in teaching. This is one of the group of specialized competencies that need to be formed and developed for students that our country's Ministry of Education and Training identified in the new general education program. According to the theory of many researchers, students' natural science competence consists of 3 elements, each element includes a number of behavioral indicators, each behavioral index can be expressed at different levels. Therefore, fostering natural science competencies for students means fostering component competencies and is specified according to behavioral indicators. Accordingly, assessing students' natural science competence is also assessing the development of component competencies through the level of expression of behavioral indicators.

To foster natural science competence for students, problem-based learning is a type of active teaching organization. Proposing procedures of teaching based on STEM lesson problems and the structure of natural science competencies will help in teaching the content of knowledge of Grade 6 Natural Sciences as well as assessing students' natural science competence effectively. However, through practical investigation, it has been shown that the application of active teaching methods as well as the introduction of STEM education in schools currently has many shortcomings: lack of theoretical basis, inadequate facilities, and insufficient class time. Therefore, based on research findings, proposing a problem-based STEM teaching approach and a structured framework for natural science competence aims to support the effective education and cultivation of natural science competence in students.

Chapter 3
DESIGNING A PROBLEM-BASED LEARNING PROCEDURE FOR STEM LESSON TOPIC “STATES OF MATTER”

3.1. Analyze the content of knowledge on the topic "States of matter"

In the general curriculum, three states (forms) of matter are mentioned: solid, liquid and gas. Transmutations of matter are known as physical phenomena. Those are also phenomena that happen frequently in life.

3.2. Content of the topic "States of matter" in the general education program

3.2.1. Objectives of natural sciences

Along with other subjects, Natural Sciences contributes to realizing the general goal of the general education program towards developing the qualities and competencies of learners. The subject of Natural sciences develop natural science competence in students, including the following components: understand natural science, explore the nature, apply learned knowledge and skills. Simultaneously, it contributes to shaping and developing essential qualities and general competences, depicting the "portrait" of new learners in the general education program. This especially includes fostering a love for nature, a scientific worldview, confidence, honesty, objectivity, and an appropriate attitude towards the natural world. This is aligned with the requirements for sustainable development to become responsible citizens and cultured, diligent, creative workers, meeting the personal development needs and the demands of a career in construction and protecting the country in the era of globalization and the new industrial revolution.

3.2.2. Requirements for Qualities and Competencies

- Regarding the requirements for qualities in the Natural Science subject, it plays a crucial role in shaping and developing students' scientific worldview. It is essential in educating students to possess qualities such as confidence, honesty, objectivity, love for nature, and respect for the laws of nature. This helps them adapt appropriately to nature in line with the demands of sustainable social development and environmental protection.

- Concerning the requirements for competencies in the Natural Science subject, the focus is on forming and developing students' professonal skills: (1) understanding natural science knowledge, (2) exploring and discovering the natural world, and (3) applying knowledge in practice, interacting with nature in accordance with the requirements of sustainable social development and environmental protection.

3.3. Teaching Procedure for the Theme "States of Matter"

3.3.1. Analysis of the Content of the Theme

In the 6th-grade Natural Science curriculum, Thermodynamics knowledge is learned in the theme "States of Matter." This knowledge enables students to explain various phenomena in practical situations, such as casting copper, weather phenomena (rain, mist, ice, snow), boiling, the melting of ice affecting

rising sea levels, etc. Additionally, there are practical applications of thermodynamics knowledge suitable for 6th-grade students, such as making ice cream, yogurt, scented candles, etc. To facilitate 6th-grade students, we chose water as the matter for studying changes of states of matter, later expanding to other substances.

3.3.2. Supplementary Scientific Knowledge for Teachers

3.3.3. Organization of STEM Lessons

For the theme "States of Matter" we have designed 04 STEM lesson procedures: Melting phenomenon; Solidification phenomenon; Evaporation and condensation phenomena, Properties of matter, and Changes of states of matter. The specific procedures for STEM lessons are as follows:

Lesson 1: Melting phenomenon

1. Objectives: develop natural science competencies for the STEM lesson "Melting phenomenon":

- The competence to understand natural science knowledge:

+ Recognize the diversity of matter (NT1. M1).

+ Present the basic characteristics of solid, liquid, and gas states (NT1. M2).

+ Define the concepts of melting, evaporation, and condensation (NT1. M1).

+ Describe the processes of melting, evaporation, and condensation of matter (changes of states of matter) (NT1. M2) (NT1. M3).

- The competence to explore scientific phenomena:

+ Identify the problem: ice cubes can melt fastest under different conditions (KP1.M3).

+ Apply known knowledge to make predictions and hypotheses: In addition to temperature, the melting speed of ice cubes depends on specific conditions (KP2.M3)

+ Make a plan: propose many solutions to melt the ice cubes fastest (KP3.M3)

+ Implement the plan: implement the proposed solutions and draw conclusions (KP4.M3)

+ Present and report the results of discovery activities: report results convincingly (KP5.M3)

- The competence to apply scientific knowledge towards sustainable development

+ Give some examples in which the procedures of melting, evaporation and condensation take place (Example 1.M3).

+ Explain a number of natural phenomena and solve real situations related to the knowledge acquired to aim for sustainable development for learners (Example 2.M3).

2. Flow chart of teaching STEM lesson "Melting phenomenon"

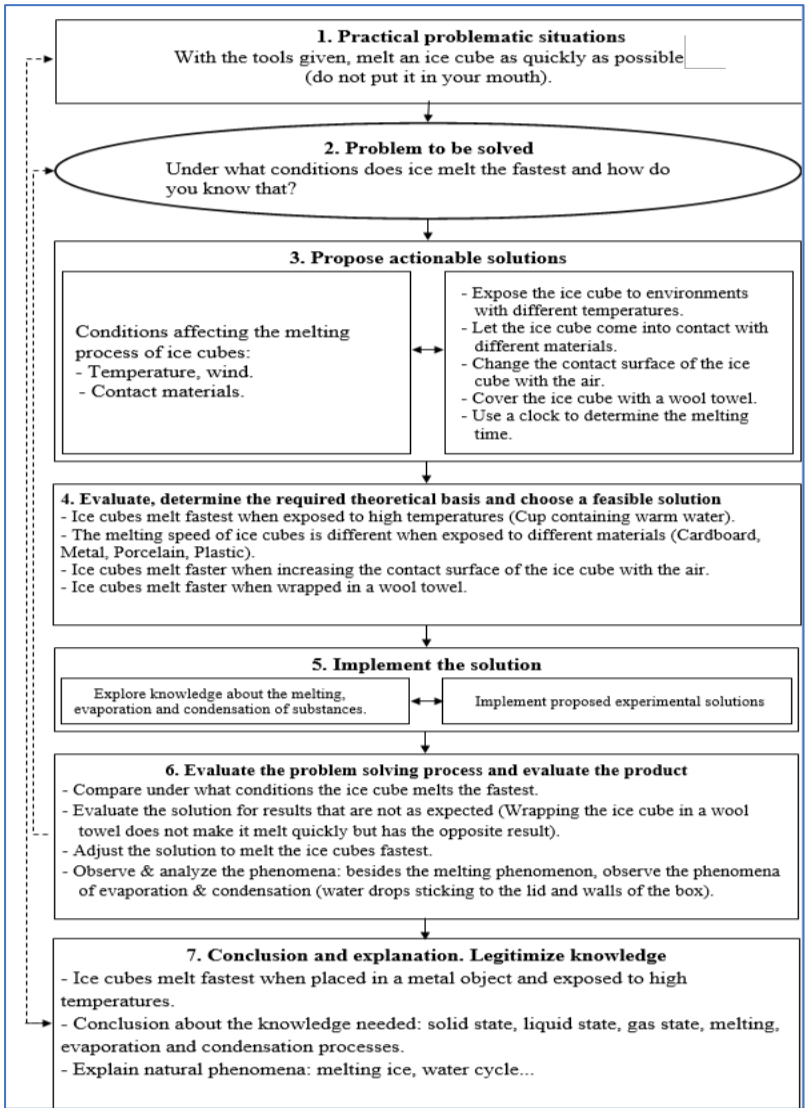

Figure 3.3. Teaching procedure of the STEM lesson "Melting phenomenon"

The procedure is the same for other STEM lessons:

Lesson 2: Freezing phenomenon

Lesson 3: Evaporation and condensation phenomena

Lesson 4: Properties of substances and transformations of substances

SUMMARY OF CHAPTER 3

1. In this chapter, applying the theory of nurturing and developing natural science competences for students, we have designed four teaching procedures for the STEM lesson topic "Changes of states of matter" in the 6th-grade natural science subject. The teaching procedures are presented in a uniform structure, creating favorable conditions for organizing experimental teaching and assessing students' natural science competences. The results obtained in Chapter 3 allow us to draw the conclusion: Analyzing the knowledge of the theme "States of Matter" - natural science 6 reveals significant opportunities for using STEM-based teaching, as the knowledge of the theme can be closely related to practical issues. The use of STEM-based teaching will support teachers in the teaching process, help students connect classroom knowledge with real-life situations, and create favorable conditions for nurturing students' natural science competences.

2. Identifying the knowledge of each lesson and the conditions for conducting STEM lesson topics is particularly important. From there, teachers will have sufficient basis to combine with their own experience to build and select STEM lesson topics that meet the requirements of nurturing and developing students' skills.

3) STEM lesson problem-based teaching can be used in lessons on the topic “States of matter”. This shows the potential to exploit teaching based on STEM lesson problems in the procedure of teaching and fostering natural science competence for students.

In the procedure of STEM lesson problem-based teaching, it is necessry to constantly evaluate and innovate teaching methods to suit student psychology and lesson content. The assessment needs to be through rubrics of component competencies of natural science competencies, from which to accurately determine the direction that needs to be revised in teaching methods as well as the content of the STEM lessons.

Chapter 4
PEDAGOGICAL EXPERIMENT

4.1. Purpose and tasks of the pedagogical experiment

4.1.1. The purpose of the pedagogical experiment

A pedagogical experiment was conducted to verify the accuracy of the scientific hypotheses posed by the research topic. Simultaneously, they assess the feasibility and effectiveness of the teaching procedures designed in Chapter 3, employing the approach of problem-based learning in STEM lessons to nurture students' natural science competences. Based on the results of the the pedagogical experiment adjustments are made to align with the organization of teaching methods and the designed teaching procedures, aiming to enhance students' natural science competences.

4.1.2. Pedagogical experiment tasks

To achieve the set goals, when conducting the pedagogical experiment, the thesis performed the following tasks:

- Prepare adequate facilities: Design teaching procedures to meet the research goals of the thesis, experimental tools, other audio-visual equipment (screen, projector...)

- Organize lessons designed in chapter 3.

- Collect information about students' natural science competence during the teaching procedure through direct observation, video analysis, worksheets and other learning products such as tests,... ; In addition, in the second round of the pedagogical experiment, to evaluate students' progress through lessons, the research focused on monitoring the manifestions of natural science competencies in 8 students.

- Analyze and evaluate the results of the pedagogical experiment obtained.

4.2. Participants and content of the pedagogical experiment

4.2.1. Participants of the pedagogical experiment: The pedagogical experiment was conducted in 2 rounds with 6th grade students of Xuan Hoa Lower-secondary School and Dong Xuan Lower-secondary School - Vinh Phuc province in the lessons designed in chapter 3.

4.2.2. Time and content of the pedagogical experiment

The time to conduct Round 1 of the pedagogical experiment was from October 12, 2021 to October 26, 2021.

Pedagogical experiment round 2 was conducted on October 13, 2022 to October 27, 2022

In the experimental classes, teachers conducted teaching according to the teaching procedures designed according to the procedure of fostering natural science competence for students.

4.3. Pedagogical experiment method and design

4.3.1. Pedagogical experiment method

4.3.1.1. Observation method

4.3.1.2. Mathematical statistical methods

4.3.2. Pedagogical experiment design

As stated, the study chose a design without a control group.

To organize the pedagogical experiment well, we organized training for teachers of the experimental classes on:

- Teaching and fostering natural science competence.

- Teaching based on STEM topics, especially paying attention to creating opportunities for students to ask questions, discover problems that need to be solved, propose solutions, select and evaluate solutions; implement solutions and present and evaluate completed products.

- Use active teaching techniques such as Mind maps, tablecloth technique, KWL technique.

After round 2, we organized a test for students in the experimental classes to evaluate their natural science competence.

4.4. Developments and results of the pedagogical experiment

4.4.1. Results of the pedagogical experiment round 1

4.4.1.1. Evaluation criteria:

The results of the pedagogical experiment were evaluated according to the following criteria:

- The reasonableness of the procedure of fostering natural science competence
- The appropriateness of teaching procedures designed for students' cognitive levels.
- The feasibility of implementing products in the actual conditions of the schools.
- The spirit and cooperative attitude of students
- Demonstrations of students' natural science competence (qualitative assessment).

4.4.1.2. Evaluate the results of round 1 of the pedagogical experiment

According to the set criteria, the 1st round of the pedagogical experiment showed that:

- STEM lesson problem-based teaching is effective in fostering natural science competence for students. Through the use of problem-based learning in STEM lessons, students are excited to carry out activities of designing experiments and models, etc., thereby stimulating creative thinking to develop components of natural science competence. Problem-based learning can include different lessons in the teaching procedure. Use problem-based learning in STEM lessons to present realistic and authentic situations, helping students feel closer and increase their inspiration to propose solutions to the problems posed. Students applying existing knowledge to solve the given situations is also a way to help form new knowledge more vividly and gently. Students exhibit a positive cooperative attitude and enthusiasm in each class.
- The steps to build a procedure of teaching based on STEM lesson problems to foster natural science competence initially show their suitability when experimenting. For different goals, the content based on STEM lesson problems is also different, thereby the teaching procedure is also different, but still follows the 6 stages as researched in chapter 2.
- The procedure of using problem-based learning in STEM lessons has met the goal of fostering students' natural science competence. During the first round of the pedagogical experiment, the lessons were designed according to the researched procedure. The results showed that students were excited and initially achieved the goals of each lesson.
- According to the assessment of teachers directly teaching in the experimental classes, the problem-based learning procedures were quite appropriate, easy to implement and can be well applied to current teaching conditions in lower-secondary schools.

4.4.1.3. Necessary adjustments to prepare for the second round of the pedagogical experiment

From the results of the first round of the pedagogical experiment, it can be seen that the procedure of teaching based on STEM lesson problems is quite suitable for fostering natural science competence.

4.5. Evaluate the results of the pedagogical experiment

4.5.1. Develop criteria to evaluate the achieved levels of problem-solving competence

For the convenience of assessing the level of achievement of natural science competence, the quality criteria of behaviors need to be scored.

4.5.2 Case study: evaluating the development of students' natural science competence

4.5.2.1. Evaluation of each element of the natural science competence

4.5.2.2. Overall assessment of natural science competence

4.5.3. Evaluation through the post-test of the pedagogical experiment

Table 4.1: Summary of results of the first competence assessment round

School/Class		Average Score	Median	Standard Deviation	T- Test
Bac Son	10A6 (Experimental)	6,88	7,0	1,48	p = 0,028 (p < 0,05)
	10A7 (Control)	6,19	6.0	1,30	
Luu Nhan Chu	10A6 (Experimental)	6,77	7,0	1,40	p = 0,029 (p < 0,05)
	10A8 (Control)	6,08	6.0	1,31	

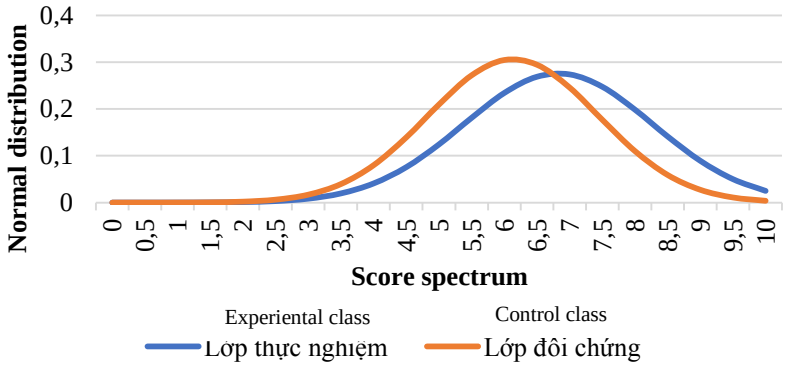

Figure 4.1. Normal distribution curve of the first competence assessment round

Comparing the average score of the first test, it can be seen that in both schools, the average score of the experimental class was higher than the control

class. Using the T-test with 2 independent groups results in p<0.05. Thus, it can be concluded that the difference in the average score of the first test in the control and experimental classes in both schools is significant.

Table 4.2: Summary of results of the second competence assessment round

School/Class		Average Score	Median	Standard Deviation	T- Test
Bac Son	10A6 (Experimental)	7,14	7,0	1,32	p = 0,004 (p < 0,05)
	10A7 (Control)	6,31	6,0	1,24	
Luu Nhan Chu	10A6 (Experimental)	6,92	7,0	1,35	p = 0,043 (p < 0,05)
	10A8 (Control)	6,31	6,0	1,26	

From the results obtained in the second test, similar conclusions can be drawn: In both schools, the average score of the experimental class was higher than the control class. Using the T-test with 2 independent groups gives the result p ≤0.05. Thus, it can be concluded that the difference in the average score of the second test in the control and experimental classes in both schools is significant.

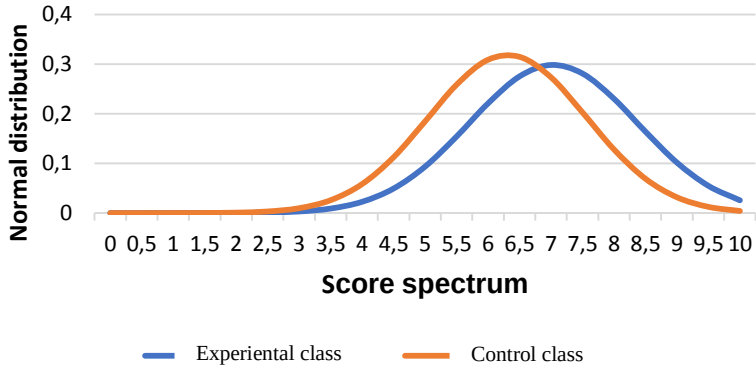

Figure 4.2. Normal distribution curve of the second competence assessment round

The results indicate that educational film content and the teaching process using educational films have been effective in cultivating students' problem-solving competence.

SUMMARY OF CHAPTER 4

The assessment of students' natural science competencies includes qualitative assessment of 167 students' natural science competencies through 2 competency tests; evaluation of the progress of 8 students in natural science competencies through criteria-based assessments with a behavior checklist;

quantitative assessment of the development of each competency element for 8 students. The assessment results allow us to draw some basic conclusions:

1. The procedure of teaching based on STEM lesson problems is suitable for application to 6th-grade students to cultivate their natural science competencies. Utilizing STEM lesson problem-based teaching also provides teachers with additional tools to implement new teaching ideas, focusing on students as the center and encouraging them to be more innovative in the learning process.

2. The proposed procedures of problem-based teaching in Chapter 3 show some reasonableness after the first experiment. With adjustments and additions to the procedures for the second experiment, they have proven to be effective in enhancing natural science competencies in learning activities.

3. Results of assessing students' natural science competence will help:

- Identify students' difficulties for timely intervention and assistance. Recognizing the strengths and weaknesses of students in problem-solving stages also helps teachers provide clear guidance in supporting students.

- Distinguish among student groups and understand the specific strengths and weaknesses of each student's competencies to assign tasks tailored to each student's abilities without exceeding their learning capacity. This approach also ensures a more appropriate evaluation of students' efforts, avoiding overload in teaching and reducing academic pressure.

- Identify students with natural science competence to nurture and orient them toward future careers and occupations.

4. The assessment tools demonstrate reliability in evaluating the development of students' natural science competencies and the appropriateness of behavioral indicators for 6th-grade students.

5. The selected teaching materials for guiding students' activities align with the developmental process of natural science competencies in the learning process, aiming to form knowledge about "States of Matter" for 6th-grade students in middle school.