APPLICATION OF AUGMENTED REALITY TECHNOLOGY IN TEACHING NATURAL SCIENCE GRADE 7 OF THE TOPIC OF "ATOMS-ELEMENTS-COMPOUNDS" TO DEVELOP STUDENT'S SELF-STUDY COMPETENCE

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Abstract. Science is an intriguing and highly promising research topic. The article presents several theoretical bases, practices, principles, processes, and application orientations in teaching Natural Science subject. In this research, Augmented Reality (AR) products were designed by Adobe Aero software to focus on the topic of "Atoms-Elements-Compounds" to help 7th-grade students improve self-study competence. AR products were used in student's learning activities and have created an engaging learning environment, distinct from using textbooks, and projectors. The research methods involve theoretical, practical, and statistical research. The pedagogical experimental results on 81 students of Newton 5 Primary and Secondary School, Hanoi, Vietnam with three different academic systems have proved that the effectiveness and practicality of this learning method to enhance student's self-study competence in learning Natural Science are obvious and this research can be extended and applied to a larger scale with other secondary schools in the future.

Keywords: augmented reality, Natural Science, Atoms-Elements-Compounds, self-study competence.

1. Introduction

Self-study ability is one of the important general competencies mentioned in the new general education program 2018 in Vietnam. This capacity is formed and developed in all subjects and educational activities in schools [1], including Natural Sciences. However, Natural Science is a new subject that is integrated into the contents of the fields of Physics, Chemistry, Biology, and Earth Science [2, 3]. The teaching and learning content of this subject is still difficult for both teachers and students and the need to improve self-study ability for students is very necessary, especially for difficult, basic, and important topics such as topics of atomic structure, molecule, atom, chemical bonds (Natural Science 7), chemical reactions and energy in chemical reactions, moles (Natural Science 8). The development of secondary schoolers' self-study competence while learning Natural Science in Vietnam still faces numerous difficulties due to the following reasons, such as (1) the lack of student self-study motivation, and learning target purpose; and low autonomy, (2) The large classroom number of students; (3) Unclear learning tasks transferred by the teachers and not enough self-learning material guidelines provided to students before, during and after the lessons; (4) The self-assessment and proposal of measures and adjustments to the

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students' self-study process has not met the requirements [4]. Therefore, to be able to solve this problem, one of the optimal solutions is to provide convenient digital learning materials for students' self-study. In teaching difficult content of chemistry topics belonging to the Natural Science subject, the three triangles model of Chemistry representation is applied with 3 levels: macroscopic, microscopic (molecular), and symbolic levels [5]. The macroscopic level covers the actual phenomena that students can experience in everyday life or laboratory, which can be seen, smelled, touched, or felt. The macroscopic level is where learners can see and handle materials, and describe their properties (e.g., color, odor, density, flammability) or the conversion of one material to another with associated changes in properties. The submicroscopic level involves a particulate level of matter, such as molecules, atoms, ions, electrons, kinetic, structure, particle movement, and a model. Models can be used to describe the structure, composition, and mechanism of chemical systems. It explains why chemical substances behave the way they do. And symbolic level includes symbols, reaction equations, stoichiometry, formulas, mathematical manipulation, and graphs. It represents chemical substances and reactions using formulas and chemical equations. A beginner's approach to a new problem should be in the following order: macroscopic, submicroscopic, and last symbolic; [5]. Many researchers have shown that the most difficult topics of the subject are the mole, chemical formulae, reactions, equations, and organic compounds, and the most challenging for students to understand the content at the submicroscopic level [6]. Therefore, for students to be able to understand abstract concepts at this level, teachers need to use effective visual teaching methods with the use of visual aids like models, videos, tables, graphs, and digital resources.

Recently, the application of AR technology has been interesting in research by many authors AR in teaching has been updated since the 1990s; especially the application of AR technology in teaching Natural Science, Chemistry, and other subjects. There has recently been an increasing number of publications on the use of AR in education in different countries around the world [7-11], and education in Vietnam is no exception to this current trend [12-14]. The role of using AR in learning processes is to improve or increase reality for students to understand abstract topics; AR allows the learners to be in the real world using visual devices and to combine it with a virtual reality superimposed on it. For that reason, they experienced AR in an easier and more fun way to learn [15]. The researchers also pointed out both obvious benefits, as well as drawbacks of using AR in education. However, with the development of new technology, the limitations of AR technology have been fixed, and the strengths of AR have been further researched and provide more insights into its application and effectiveness in the field of education [16, 17]. As mentioned above, Natural Science education contains several abstract topics such as the Periodic table and properties of the elements, Atom, Element, Molecular, and Chemical bonds, etc. (Chemistry content) which makes not possible for students to interact directly with the learning tasks (such as using sight, touch, hearing, etc.) leading to their challenge and difficulty in learning and configuring new information. However, with AR, students can work with virtual images, giving a self-oriented environment for investigation for learners in the interaction mode closest to the real world. Moreover, it affords students the chance to apply and display multi-dimensional content that is not visible or is difficult to show in a classroom [18]. The use of AR to develop student's self-study competency has been and continues to be researched [12]. Research shows that AR helps students develop self-study competency by enhancing engagement and boosting the confidence of the students. Students also find self-study more enjoyable and easier when using a new type of learning materials. However, the availability of quality AR content and applications is still limited. The lack of AR's content and materials make it challenging for teachers and students to find suitable materials for their lesson. Teachers also need training and support to effectively use AR in their teaching activities. Application of AR in teaching Natural Science education for the topic of "Atom-Elements-Compounds" is the effective solution we propose to

support students and teachers in learning this difficult topic; At the same time, these learning materials are put on an online platform to support students' self-study at home. These materials will also contribute to diversifying the collection of educational resources related to AR. This article investigated and carried out the pedagogical experiment of the application of AR technology in teaching Natural Science Grade 7 with the topic of "Atoms-Elements-Compounds", contributing to the formation and development of self-study capacity for secondary school students.

2. Content

2.1. Survey results on the use of augmented reality technology in teaching Natural Science in secondary schools

2.1.1. Objectives, content, survey participants, and survey methods

Objectives: To clearly understand the current state of self-study competence in secondary schools and the use of AR products in teaching and learning. *Content:* the teachers were surveyed for their opinion about the development of self-study competence of students and teaching experiences using AR products. We also survey the self-study competence of secondary students and their learning experiences using AR products. *Survey methods***:** The survey questions were created with the help of educational experts (Mainly lecturers at Hanoi National University of Education) and then sent the template survey to teachers and students at different schools to answer online in Google Form. *Survey participants***:** We surveyed 28 teachers who are teaching Natural Science in Secondary Schools in the North of Vietnam (Nam Dinh, Thanh Hoa, Bac Ninh, Bac Giang, and Ha Noi). We also surveyed over 90 students in some secondary schools in Ha Noi. Afterward, the data was collected, analyzed, and evaluated the results.

2.1.2. Survey results of teachers on student's self-study competence in learning Natural Science

Twenty-eight Natural Science teachers participating in the survey teach in secondary schools in cities or main provinces where they have better working conditions and access to technology than others. The survey results have shown that most of the teachers responded that they have never used AR technology-related software (over 80%). Around 89.3% of teachers agreed that the use of information technology in teaching is essential. Through a brief introduction to AR in the survey, teachers have developed an understanding of this technology. They believe that the models, images, and information applied to this technology should be highly accurate, have easy instructions, cooperate with different activities, and have a high aesthetic factor. The majority of teachers express a desire and enthusiasm to use AR in teaching (over 90%). Nearly 65% of teachers consider it reasonable to use AR in teaching with a low frequency. A similar survey result of applications of information technology (IT) in high schools was also published in the research of Thai Hoai Minh [20]. Based on this study, although teachers' desire to use information technology in teaching is obvious, actual its implementation in schools still has many difficulties. This can be explained by some limitations such as: not having the opportunity to learn much about IT, time consuming, requirements for facilities, low awareness and abilities of students using IT devices.

Figure 1. Survey results of teachers on students' self-study competence

2.1.3. Survey results of students on their self-study competence in learning Natural Science

Related to the survey of students, the results have shown that more than 90% of students think that self-study is essential. More than 90% of students responded that they have electronic devices with internet access to support their learning activities at home. Over 80% of students expressed a desire for interactive videos (listening to the content and answering interspersed questions) when given new learning tasks by teachers. More than 75% of students reported lacking motivation to sustain self-study. Most students acknowledged that self-study is a necessary and important process for excelling in the subject. Many students expressed a desire for support from their families and teachers during the self-study process, along with a variety of learning methods and study materials.

Figure 2. Survey results of students on their self-study competence

2.2. Develop a toolkit to assess self-study competence for secondary students

Assessing self-study competence is a key point in learning. It helps students assess their abilities to orientate learning and improve their self-study competence. Based on the research on self-study of research [12], we have developed a tool to assess self-study competence for secondary students learning. We also added the criteria to evaluate the use of AR materials in student's self-study activities. It has 8 criteria with three levels as shown in Table 1.

Table 1. The table describes the 8 criteria with three levels of assessment for the development of self-study competence

Elemental capacity	Criteria evaluate	Level		
		1	*2*	*3*
Identify the objectives and self-study plan	1. Define learning goals.	Identify learning goals but not clear and not specific.	Indicate parts of learning goals, and identify the objectives but not clearly.	Indicate fully parts of learning goals, and identify the objectives clearly and fully.
	2. Self-study follows the AR materials that have been given.	Identify how to self-study with other study materials but haven't identified how to self-study.	Identify how to self-study with the AR materials that have been given but are not suitable with	Identify how to self-study with the AR materials that have been given and suitable with

		with the AR materials.	self-study contents.	self-study contents.
	3. Expect the time and the results achieved.	Haven't identified the time, and haven't expected the results of self-study activities.	Haven't identified the time and haven't expected the results of self-study activities reasonably and correctly.	Identify the time and expect the results of self-study activities reasonable and correct.
Competence in the implementation of the Self-study Process	4. Document search and information gathering.	Collected very little information about references, only use the study materials which are given by teachers.	Collected a lot of information sources but the reliability is not high, not paying attention to learning goals and tasks.	Collected a full range of information to be found with a highly active attitude, highly selective in different forms, suitable for the objectives and learning goals.
	5. Selective filtering and information processing.	Understand the information but do not know how to analyze, and process information sources to give out the conclusion.	Understand the information, know how to analyze, and process information sources but do not know how to give out the correct conclusion.	Understand the information, know how to analyze, process information sources, and give the correct conclusion.
	6. using given learning materials to solve learning tasks.	Don't know yet or know how to record the content of the topic but don't know how to explain and present learning results clearly and completely.	Know how to record the content of the topic and know how to explain the topic but not accurately and not completely.	Know how to record the content of the topic and how to explain the topic accurately and completely.
Testing and Evaluation	7. Evaluate the self-study results.	Only assess the learning results through the test and haven't	Know how to self-assess and comment follow the standards of	Know how to self-assess, comment follow the standards of

		self-assessment and comment through the assessment scale of self-study competence and standards of knowledge and skills.	knowledge and skills but haven't followed the assessment scale of self-study competence.	knowledge, and skills, and know how to self-assess the assessment scale of self-study competence clearly, and correctly.
	8. Self-regulation.	Overcome and adjusted some errors and limitations but not yet know how to self-adjust the way of learning.	Overcome and adjusted some errors, limiting, and self-adjusting the way of learning but still have some points that are not suitable with objectives and learning goals.	Overcome and adjusted errors, limiting and self-adjusting learning ways to suit objectives and learning goals.

2.3. Design and construct AR materials for teaching the Natural Science topic of "Atoms-Elements-Compounds"
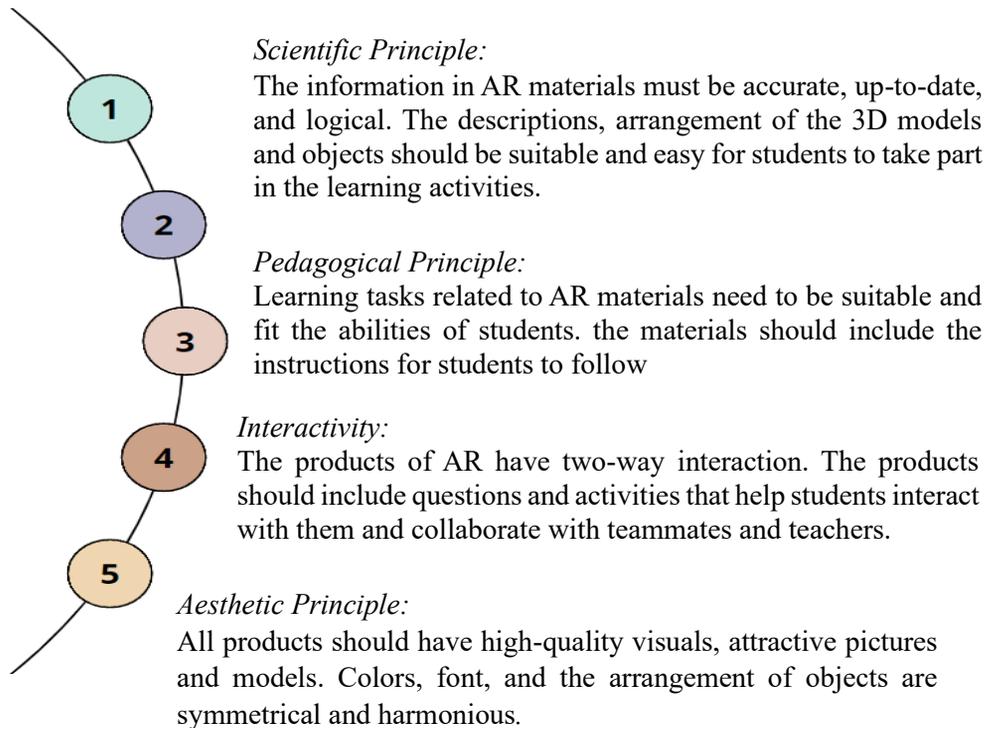
2.3.1. The reasons for the theme chosen

The reason for the themes chosen is that social life and the economy are undergoing increasing development nowadays. The development will create many opportunities, but it will also be a challenge for the country and all the citizens living in that society. To keep up with the global trends, our education system needs to provide students with qualities and competencies, so that learners can effectively engage with modern technology and information. Recently, there has been a major shift in our educational program transitioning from a content-oriented program to a program to develop general and core competencies and five main qualities [1]. The target of this program is to promote initiative, positivity, creativity, self-study methods, practical skills, and the application of knowledge and skills in practice.

In the era of Industry 4.0, information technology is being applied in many different fields and professions including education. In Vietnam, according to documentary 117/QD-TTg from the Ministry of Education and Training, Department of Information and Technology, there is a need to increase the application of technology in learning and teaching and improve the facilities to support the use of information technology. The change creates many new requirements for teachers and students about methods, forms of learning, and teaching. However, the implementation of teaching and applying information technology still faces many difficulties and obstacles.
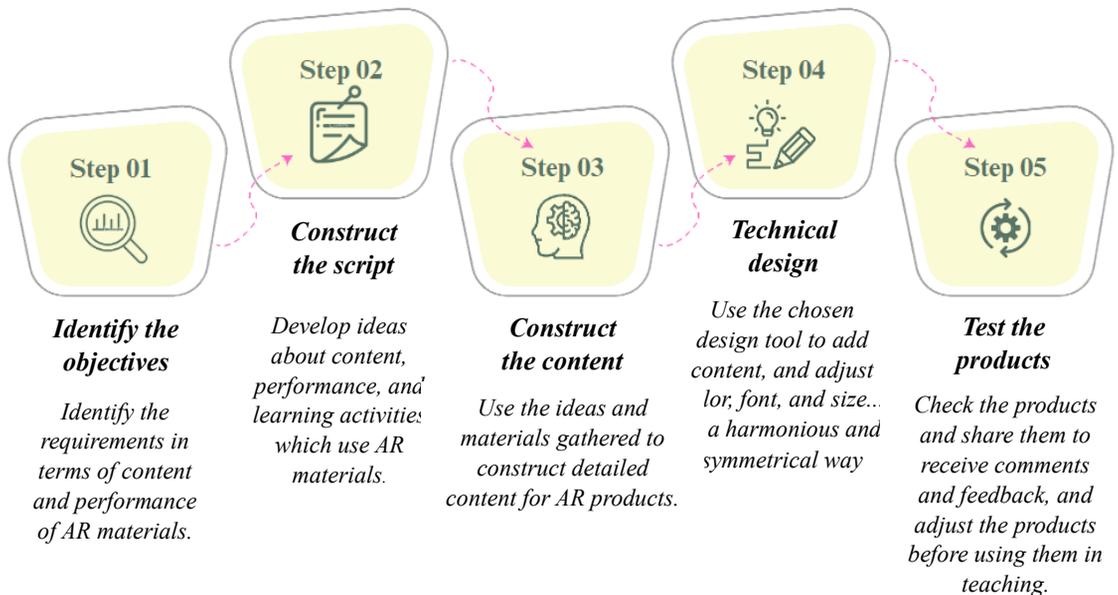
2.3.2. Design principles

To create AR materials with high quality and high effectiveness in learning Natural Science, it is needed to research and design the AR materials. We have referenced several research and developed some following principles [12, 19, 20].

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* 5 Design Principles

Scientific Principle:
The information in AR materials must be accurate, up-to-date, and logical. The descriptions, arrangement of the 3D models and objects should be suitable and easy for students to take part in the learning activities.

Pedagogical Principle:
Learning tasks related to AR materials need to be suitable and fit the abilities of students. the materials should include the instructions for students to follow

Interactivity:
The products of AR have two-way interaction. The products should include questions and activities that help students interact with them and collaborate with teammates and teachers.

Aesthetic Principle:
All products should have high-quality visuals, attractive pictures and models. Colors, font, and the arrangement of objects are symmetrical and harmonious.

* Five-step design process

Step 01

Identify the objectives

Identify the requirements in terms of content and performance of AR materials.

Step 02

Construct the script

Develop ideas about content, performance, and learning activities which use AR materials.

Step 03

Construct the content

Use the ideas and materials gathered to construct detailed content for AR products.

Step 04

Technical design

Use the chosen design tool to add content, and adjust lor, font, and size... a harmonious and symmetrical way

Step 05

Test the products

Check the products and share them to receive comments and feedback, and adjust the products before using them in teaching.

Figure 3. The five-step design process of AR products by specific topics [12]

2.3.3. Application used to design AR products

Adobe Aero is an AR authoring tool that can help designers create immersive content. Aero can be used to create 2D, 3D, and audio stater assets like abstract shapes, layered illustrations, plants, sound effects, and more. This app can run on IOS, Android, and Windows systems. This app runs more fluently when used on IOS systems. It is free and can be downloaded from the App Store to experience the AR materials. The experience of AR materials using Adobe Aero can be easily performed on a smartphone with internet access and the app installed. We have designed some AR materials and placed them in the Adobe Aero for students to experience. These are the AR materials. To view the products, you need to download Adobe Aero from the App Store (IOS) or Adobe Player (Beta) from the Google Play Store (Android).

Some suggested AR products can be used in learning the topic of "Atoms-Elements-Compounds".

Table 2. List of AR products designed

No	Name of product	Content	QR code of products			
1	Model of Sodium	Model of Sodium				
2	Element uses	Aluminum, gold, silver, and copper use				
3	Stations lab	Models of atoms, blocks of elements, Rutherford and Bohr information, and 3D models of substance.				

2.4. Construct lesson plan

In this article, we took an example of using AR products with one activity "Stations lab" in the lesson. Students can experience new skills and new learning methods in this lesson. Learning stations are a teaching method where students are divided into small groups and rotate through different stations to learn and practice specific skills or knowledge. In this lesson, we designed four stations and integrated AR into them. Each station will have its tasks and requirements for students to develop skills.

Students will be divided into small groups and perform tasks at the assigned station. After receiving a station change notification, all students will move to the next station under the guidance of the teacher. Students will need to explore information, images, and 3D models by using their phones, and tablets to access the AR application. Then, students will fill in the results on the provided sheets to complete the tasks of that station.

This activity helps students develop better information-gathering, searching, and filtering skills. After completing the task sheets, students will also present their research in front of the class and receive feedback and comments from their classmates and teachers. Details about this teaching activity and lesson plan of the lesson are provided below.

Augmented Reality takes the real world into projects virtual, computer-generated augmentations to it, to enhance our experiences. AR is a new type of technology and widely used in recent times. In education, AR creates opportunities for teachers to help students grasp abstract concepts. By using the interaction and experimentation that AR technologies offer, teachers can enhance classroom experiences, teach new skills, inspire student minds, and get students excited about exploring new academic interests.

For the above reasons, we have chosen the topic of "*Developing self-study competence for secondary school students through study materials including augmented reality in Science 7 - Topic: Atoms, Elements, and Compounds.*"

Table 3. Activities of teacher and students with corresponding assessment criteria

Teacher's activities	Students' activities	Assessment
Give students learning tasks: A Self-study guide paper on the topic consists of steps and tasks that students need to perform during the self-study process. The teacher gives the guide paper to students in the previous lesson, and answers questions (preparation step).	Learn about the topic, accept learning tasks according to the teacher's instructions ask questions if the task is unclear, ensure correct understanding, and self-implement learning activities at home. Then students complete the study tasks and report the results. Discuss online with classmates or teachers via online platforms like *Padlet* or group *Zalo* to resolve unclear issues. If problems are still unsatisfactory, write them down in your notebook and discuss them in class with the teacher and classmates.	Criteria evaluate 1-2-3.
Create AR products to be used in learning the topic of "Atoms-Elements-Compounds" and suitable worksheets which are self-study resources for students during learning processes (at home and in the class with Station Lab).	Use books and given AR learning materials to solve suitable worksheets and write in the notebook. Take the photos of notebook. Submit the photos to the class group *Zalo* with the teacher after completing the worksheets. Receive teacher feedback (if any) and make corrections.	Criteria evaluate 3-4-5-6.
Prepare a Self-study Notebook Template, which requires students to use this	Students need to set up their learning plan; note content; Evaluate, adjust, and learn from the self-study process so that students	Criteria evaluate 7-8.

notebook during the learning process and pay attention to the notes that students record.	understand what needs to be changed during the experiment process.	
Create the test with related questions on the topic to evaluate students' competence after the learning process. Rely on the results of self-practice exercises to reinforce for students the content they have not achieved during class time.	After completing the lesson according to the given materials with AR; Students do self-practice exercises (quiz/google form) to consolidate knowledge. Students can repeat the quiz several times. Based on the results of the quiz (test) students self-evaluate the effectiveness of their practice for the first time, second time, and so on…, reinforcing unclear knowledge and noting some unclear questions to ask the teacher.	Criteria evaluate 6-7-8.
Create a rubric with 8 criteria and 3 levels for teachers and students to evaluate the progress of students' self-study competence.	Self-assessment.	Criteria evaluate 1-2 and 7-8.

In this article, we took an example of using AR products with the activity "Stations lab" in the lesson Title: *Atoms, elements, and compounds* (Natural Science grade 7) with a time of 90 minutes.

Table 4. Short description of Station Lab - Activities

Learning Objectives	Research the knowledge about atomic models and visualization, State the biography of two scientists Rutherford and Bohr, and the model of the atom proposed by Rutherford and Bohr. Explore the first 20 elements and 3D models of some substances.
Contents	Students participate in stations to complete the worksheet (lab activity) using the Adobe Aero application.
Products	Worksheets done by students.
Activity	Stations Lab with teacher's and students' activities. The teacher shows a QR code for students to scan and take part in the activity. About the design ideas, the teacher set up 4 stations around the class and gave students a worksheet for these stations. There are missions and rules that students must follow to finish the worksheet.

The detailed process is described as follows:

Table 5. "Stations lab" details activities of the teacher and students on the topic of "Atoms-Elements-Compounds"

Learning tasks transferred by the teacher	Students complete the study tasks and report the results
The teacher divides the class into 4 groups. Each group consists of 5 - 7 students. The teacher creates a game of questions related to the main content of the lesson to assess how students self-study at home. Then the teacher summarizes the key knowledge. The teacher answers students' questions that arise during self-study.	Students join their groups. Students play the game. Students write it down in their notebooks.
Teacher allows them to use devices such as phones, and tablets with internet access. The teacher gives students similar learning tasks with AR through the worksheets since students are used to performing the learning tasks at home. The teacher shows the QR code on the board, sets up and guides students about the starting point, hands out the worksheet to the groups, and explains the rules.	Students can use from 1 to 2 devices to enhance their learning process. Students scan the QR code, scan the starting point as guided by the teacher, access Adobe Aero, navigate to different stations according to the teacher's instructions, and complete the worksheets.
The teacher observes the group of students performing tasks, helps them if needed, and evaluates the students' self-study ability through the criteria list.	Students experience each station together, complete each station's tasks write them down in the notebooks, and move to other stations when the teacher allows.
After time is up, the teacher requests students to put away their devices, and go back to their seats. The teacher checks their notebooks answers their questions and summarizes the content of the topic.	Students put away their devices, report results, discuss the questions, and take notes.

By using AR technology in teaching, students feel engaged and motivated in their learning process. AR also provides students with a different perspective compared to using traditional materials such as images, or videos.
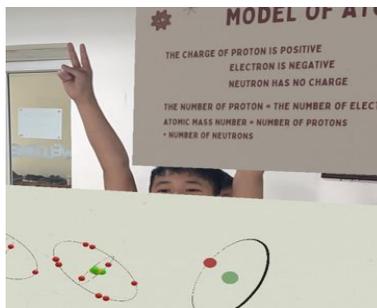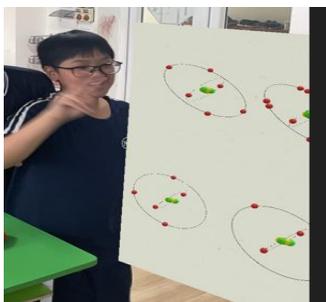
The detailed content of the lesson plan for the topic of "Atoms-Elements-Compounds"

Station Lab 1: *Read it- Students read the text and received information about scientists Rutherford and Bohr*
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Station Lab 2: *Explore it; Students put the substances in the correct column for elements or compounds and distinguish between elements and compounds*

Station Lab 3: *Watch it! Students described an atom as an electrically neutral entity made up of electrons, protons, and neutrons*

Station Lab 4: *Remember it. Students stated the names, symbols, and numbers of the 20 first elements*

Figure 4. Students engaging in learning using AR products in pedagogical experiments

2.5. Pedagogical experiments

2.5.1. Contents of pedagogical experiment

To assess the possibility and effectiveness of using AR products in teaching Natural Science to increase the self-study competence of students on the topic of "Atoms-Elements-Compounds", we conducted the pedagogical experiment at Newton 5 Primary and Secondary School, Thanh Oai province, Hanoi with three different academic programs. This process took place in May 2023. The participants were 15 students of 7G, 22 students of 7C, 24 students of 7A1, 20 students of 7A2. Characteristics of students' results in Natural Science Subject - Second Semester in 2022-2023 school year of each class were shown in Table 3. The data has shown that these classes have similar percentages of very good and good students. Therefore, we took the pedagogical experiment with four classes by using the same lesson plan and analyzed the data together.

Table 3. Characteristics of students in each class

Class	Number of students	The results of the study of the natural science in the 1st semester							
		Very good		*Good*		*Average*		*Weak*	
		Number of students	*%*	*Number of students*	*%*	*Number of students*	*%*	*Number of students*	*%*
7G	15	14	93.33	1	6.67	0	0	0	0
7C	22	19	86.36	3	13.64	0	0	0	0
7A1	24	15	62.50	9	37.50	0	0	0	0
7A2	20	15	75.00	5	35.00	0	0	0	0

Notes: The differences of Science courses between A, G, and C – Academic Programs.
For A - Academic Program (7A1-7A2 classes): The learning information is sent to students directly and briefly. The knowledge of Natural Science chapters is simple and clear. Learning activities are not as many as other academic programs like C and G.
For C- Academic Program (7C class): The course doesn't have many topics, but it has lots of activities and exercises for students.
For G- Academic Program (7G class): This course has more topics compared to other courses. The level of knowledge is higher than the other courses.
However, in terms of the topic of "Atom-Element-Compounds", the learning outcomes of the three above academic programs are similar.

2.5.2. Results of the pedagogical experiment

Before the pedagogical experiment, the criteria of self-learning ability were evaluated based on the evidence of students' notebooks and self-editing their performance after self-study and self-assessment of learning processes through previous topics using common (traditional) exercises without the support of AR. We surveyed all students before and after they finished learning the lesson. Students self-assess before and after completing the course. After that, we collected the data and information, and the results are shown in Table 4.
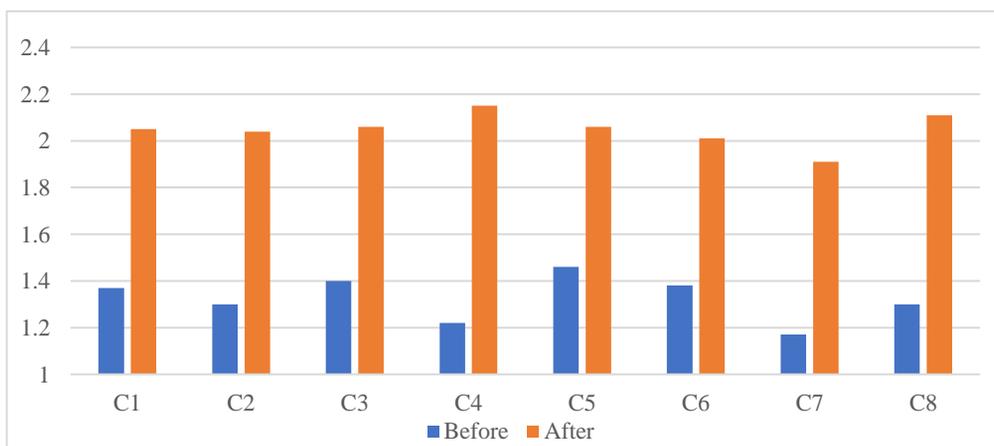
The statistics indicate that the average self-study competence of students is higher after attending lessons with AR in all 8 criteria with an average score around 1.33 before the pedagogical experiment going up to 2.04 after that. This demonstrates that the use of AR technology in teaching Natural Science had a positive impact on the self-study competence of students, especially the fourth criterion "document search and information gathering". The influence value (ES of 1.18) indicates a significant influence on the development of self-study competence. The p-value was less than 0.05 indicating that there is no change occurring randomly in the average scores of self-study competence of students before and after using AR products in

teaching topics of "Atoms-Elements-Compounds". This suggests that the use of AR in teaching had a positive impact on the development of self-study competence of students.

Table 4. The summary table of evaluation results about student's self-study competence

Criteria	Before pedagogical experiment				After pedagogical experiment			
	Number of students scored mark			*Criterion GPA*	*Number of students scored mark*			*Criterion GPA*
	1	2	3		1	2	3	
1	56	20	5	1.37	8	61	12	2.05
2	63	12	6	1.30	8	62	11	2.04
3	56	18	7	1.40	6	64	11	2.06
4	65	14	2	1.22	8	53	20	2.15
5	54	17	10	1.46	8	60	13	2.06
6	58	15	8	1.38	10	60	11	2.01
7	69	10	2	1.17	15	58	8	1.91
8	62	13	6	1.30	7	58	16	2.11
Average score				1.33	Average score			2.04
Standard deviation				0.60	Standard deviation			0.51
p t-test dependent = 1.35×10^{-7}								
Level of influence ES = 1.18								

The statistics indicate that the average self-study competence of students is higher after attending lessons with AR in all 8 criteria with an average score around 1.33 before the pedagogical experiment going up to 2.04 after that. This demonstrates that the use of AR technology in teaching Natural Science had a positive impact on the self-study competence of students, especially the fourth criterion "document search and information gathering". The influence value (ES of 1.18) indicates a significant influence on the development of self-study competence. The p-value was less than 0.05 indicating that there is no change occurring randomly in the average scores of self-study competence of students before and after using AR products in teaching topics of "Atoms-Elements-Compounds". This suggests that the use of AR in teaching had a positive impact on the development of self-study competence of students.

Figure 5. Student's self-study competence assessment chart

Besides, we assessed the experience of students after the lessons that use AR products in learning. The results are provided in Table 5.

Table 5. The survey results on student's attitudes about AR application in the learning process after the experiment

No.	Contents	Level of agreement					
		1		**2**		**3**	
		N_o	%	N_o	%	N_o	%
1	Applying augmented reality (AR) information technology in the lesson helps you improve your self-study competence.	3	3.7%	12	14.8%	66	81.5%
2	Applying AR information technology in the lesson helps you understand more clearly and remember longer than in traditional lessons.	4	4.9%	21	25.9%	56	69.2%
3	Applying AR information technology in the lesson helps you search and collect information more quickly, and actively.	4	4.9%	26	32.0%	51	63.1%
4	You feel that the 3D models make it easier to visualize and remember.	2	2.5%	10	12.3%	69	85.2%
5	3D models in AR information technology are clear, high quality, and artistic.	0	0.0%	8	9.9%	73	90.1%
6	AR's materials are consistent with the textbook's contents.	0	0.0%	16	19.8%	65	80.2%
7	You agree that the lesson is more interesting and meaningful.	0	0.0%	6	7.4%	75	92.6%
8	You think that your ability to analyze and process information has been improved.	9	11.1%	18	22.2%	54	66.7%
9	Applying AR information technology in learning helps you improve your self-study competence.	5	6.1%	24	29.6%	52	64.3%
10	You want to keep learning lessons that apply AR information technology.	0	0.0%	6	7.4%	75	92.6%

Based on the data of the assessment (Table 5), It can be seen that 81.5% of students feel that AR products help them improve their self-study competence while about 70% of students found that AR products allow them to remember and understand more clearly than in a traditional lesson. Over 60% of students agreed that AR products help them search and collect information quickly and actively. About AR products, more than 80% of students think that these products are clear, high quality, easy to visualize, and make the lesson more interesting and meaningful. A very high

percentage of more than 90 % of participants enjoyed lessons that applied AR products and wanted to keep learning and experiencing it.

After finishing the lesson, we had a 15 minute-test about the knowledge that they had learned from the lesson. The average score for 81 students was 8.90/10 with a standard deviation of 0.9696 and a median of 9 (Figure 6).
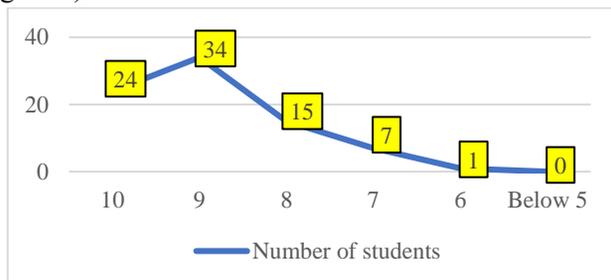
Figure 6. The result of the 15-minute test

The result of the test proves that this technique created high effectiveness in teaching abstract topics. The standard deviation is less than 1 and the median is 9 shows that students have a high level of understanding of the knowledge and achieve good results after learning the lesson. Therefore, it is no double to confirm that using AR materials, AR products can help teachers achieve the learning objectives, make the lesson more interesting, increase the interest in learning of students, and support students in the self-study process.

3. Conclusions

The application of AR in teaching has yielded positive outcomes for both teachers and students. Our results based on the questionaries after the pedagogical experiments clearly show that AR has heightened students' interest and improved their self-study competence in learning Science, making it more understandable and engaging. Through learning the topic of "Atoms-Elements-Compounds" as the specific example the study has shown that students have found the content of the topic easier to understand and remember leading to improved self-study competence. The research results initially indicate the potential of using AR in teaching Natural Science with different topics.

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