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USING VIRTUAL EXPERIMENTS IN TEACHING THE TOPIC OF "ACID-BASE-PH-OXIDE-SALT" IN GRADE 8 NATURAL SCIENCE TO ENHANCE STUDENT LEARNING OUTCOMES

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Abstract. In teaching Natural Science, virtual experiments have been recognized as a significant tool in stimulating student's interest and helping them develop observational skills, problem-solving abilities, and experimental competencies. Consequently, this enhances students' scientific capacity, learning efficiency, and critical thinking. This study uses the AR Chemistry Lab application to organize lessons around experiments on the topic of "Acid-Base-pH-Oxide-Salt" in Grade 8 Natural Science. The proposal was implemented with 218 students across Ly Tu Trong Secondary School, Ninh Binh Province, Vietnam. The experimental results revealed that students in the experimental group not only achieved higher academic performance but also showed increased engagement in learning activities involving AR-based experiments. This study affirms the potential of AR technology in improving the effectiveness of experimental teaching in Natural Science and offers recommendations for future research in this field.

Keywords: virtual experiments, AR technology, learning efficiency, students, natural science.

1. Introduction

Experiments play a crucial role in teaching Natural Science subjects. Proper use of experiments not only helps students meet the requirements of forming and developing knowledge content but also enhances practical skills and scientific thinking. Moreover, it aligns with the educational goal of focusing on developing competencies, and qualities and improving student learning outcomes. To achieve this goal, teachers can employ various active teaching methods, including technology integration with modern teaching approaches such as flipped classrooms. This allows teachers to leverage the advantages of experiments, enhance visual learning, and stimulate student engagement and interaction during the learning process. In recent years, the emergence and development of Virtual Reality (VR) and Augmented Reality (AR) applications have facilitated the design of vivid virtual experiments and improved user interaction [1]. These experiments help students grasp knowledge more easily, spark their interest in learning, and enhance their ability to apply acquired knowledge and skills to solve problems in both academic settings and real-life situations [2]-[4].

Chemical experiments are an essential part of teaching Chemistry, a component of Natural Science. However, in the context of Vietnamese secondary schools, conducting real experiments is a significant challenge due to the limited and subpar physical infrastructure in many schools. Virtual experiments have been proven to offer numerous advantages, overcoming the limitations of using real experiments, such as issues related to chemicals, the ability to observe the inherent properties of substances involved in reactions, or dealing with hazardous experiments that affect the environment, health, and safety of participants.

The topic of "Acid-Base-pH-Oxide-Salt" in Grade 8 Natural Science contains many fundamental concepts that form the basis for students' understanding of essential chemical knowledge [5]. In teaching this topic, teachers need to use real experiments to meet the subject's requirements. This can help students better understand and visualize complex scientific phenomena. AR can be used to create three-dimensional representations of images and events that are difficult to visualize in traditional learning settings [6]. AR technology enhances learning motivation through its interactive and immersive nature, captivating students' attention and fostering intrinsic motivation [7], [8]. It also facilitates a deeper understanding and retention of scientific information by allowing students to manipulate virtual objects and observe dynamic processes [9]. The results of [10] Indicate that AR usage significantly increased students' engagement in learning, enhanced their understanding of substance composition and chemical bonding processes, and improved their ability to apply knowledge to solve learning challenges. Therefore, applying virtual experiments could be a viable alternative, overcoming the limitations of real experiments, fostering students' interest in learning, and helping them actively acquire knowledge in various spatial conditions, ultimately improving their academic performance. This study will assess the effectiveness of using AR tools to design virtual experiments combined with methods and tools to deploy virtual chemistry experiments in teaching the topic of "Acid - Base - pH - Oxide - Salt" in Grade 8 Natural Science to enhance student learning outcomes and interest in Natural Science education.

2. Content

2.1. Virtual chemistry experiments

In this era of rapid technological advancement, applying new technologies in education has brought about significant changes in teaching and learning methods. One notable application is the use of virtual chemistry experiments in teaching Chemistry. A virtual chemistry experiment can be understood as the simulation of a real experiment to verify theoretical concepts or to illustrate more clearly a technological process or a chemical transformation, such as the nature or mechanism of a reaction. Virtual chemistry experiments have the advantage of simulating critical situations, extreme conditions, or phenomena and scenarios that are difficult to replicate in the real world. This enables learners to observe different aspects of chemical processes, thereby helping students gain a deeper understanding of the underlying principles. As a result, virtual chemistry experiments stimulate students' passion for science and their curiosity to explore new knowledge. Thus, virtual chemistry experiments simulate real experiments through software, enabling students to engage with chemical processes and phenomena without needing a laboratory [11]. This saves time for teachers and students in experiment preparation and reduces costs for equipment and chemicals. In addition, it ensures safety during the learning process [10].

According to a study by Herga & et al. (2016), virtual experiments have proven effective in helping students gain a deeper understanding of scientific concepts while improving their academic performance compared to classes that do not use this method [12]. Virtual experiments foster observational, analytical, and critical thinking skills, enabling students to actively experiment and observe without being limited by space or time. Furthermore, VR and AR applications, such as AR Chemistry Lab and Chemist by Thix, provide interactive and visual learning environments, allowing students to manipulate and observe chemical phenomena directly on their mobile devices (Zhang J, 2021). Additionally, using software to construct and conduct experiments enables students to observe complex reactions, including those that produce harmful substances to the experimenter and the environment [14].

Virtual experiments not only replace traditional experiments but also expand students' learning potential, helping them grasp difficult concepts through repeated experiments and the adjustment of various conditions. This also supports teachers by reducing issues related to time and safety when organizing experiments in the classroom.

In natural science, using virtual experiments in teaching allows students to learn theory and apply knowledge effectively through practical lessons, experiments, and hypothetical real-world scenarios [15]. Virtual chemistry experiments are confirmed to play a vital role in education, fostering students' proactivity and creativity while developing competencies in Chemistry, particularly experimental skills [16]. However, many studies have shown that the development and design of virtual experiments in teaching Natural Science subjects, including Chemistry, have not received sufficient attention from teachers, as evidenced by surveys in related research. Therefore, designing and using virtual experiments in teaching Natural Science subjects to enhance the role of experiments in education is essential. This study applies AR Chemistry Lab to design virtual experiments in teaching the topic of "Acid-Base-pH-Oxide-Salt" in Grade 8 Natural Science to improve students' learning outcomes.

2.2. Application of AR chemistry lab in designing virtual experiments

2.2.1. Application of AR chemistry lab

Virtual experiments have been shown to enhance students' self-directed learning abilities and problem-solving skills. These experiments not only reduce costs and safety risks but also allow learners to practice anytime and anywhere. AR Chemistry Lab - an augmented reality (AR) application developed by the technology company ARVRTech - enables users to perform chemistry experiments safely and engagingly on mobile devices. In 3D virtual laboratories, learners can explore and design experiments through intuitive, three-dimensional interactions. Under indirect guidance from instructors, students can conduct experiments independently and observe phenomena that may be challenging to visualize in an actual laboratory setting. Additionally, teachers can utilize virtual laboratories for teaching, archiving, and sharing content during lessons, providing a highly interactive environment through vivid visualizations.

AR Chemistry Lab simulates the processes of bond breaking and formation to generate chemical reactions while also providing tools that allow learners to interact with virtual laboratory equipment such as beakers, chemicals, and measuring instruments in an AR environment. As a result, students can conduct experiments without needing a physical lab, thereby minimizing risks, costs, and preparation time. Users have access to a range of chemicals (e.g., acids and bases) and can observe real-time reactions on their mobile device screens. The application includes containers and measuring instruments that help students perform accurate and safe measurements.

Through the AR Chemistry Lab, students can engage in chemistry experiments without handling hazardous chemicals or facing risks from improper procedures. The integrated 3D simulations enable them to observe chemical phenomena, molecular structures, and reaction processes. The application also provides reference materials on chemical reactions and fundamental chemical concepts, aiding students in understanding the theoretical underpinnings of their experiments. This design allows learners to repeat experiments multiple times, thereby facilitating deeper comprehension and supporting differentiated learning based on individual needs.

2.2.2. Process for Building Virtual Experiments

Building on previous studies of AR Chemistry Lab's role in education, as well as an analysis of the application's distinctive features compared to other software, we propose a five-step process—organized into two phases—for developing virtual chemistry experiments with AR Chemistry Lab. This process specifically targets the Grade 8 Natural Science topic of "Acid-Base-pH-Oxide-Salt".

Phase 1: Creating a Virtual Experimental Environment (2 Steps).

Step 1: Select Experiment Content.

In accordance with the curriculum, teachers identify relevant chemical concepts from the "Acid-Base-pH-Oxide-Salt" unit. This topic is crucial for Grade 8 students because it requires an in-depth understanding of basic chemical reactions and related phenomena. Therefore, educators should carefully select experiments that encourage investigation and demonstrate the underlying chemical processes, helping students grasp the nature of the reactions.

Step 2: Build the Virtual Laboratory Environment.

Teachers or instructional designers use AR Chemistry Lab to create a simulated laboratory space containing test tubes, containers, acids, bases, pH meters, and any necessary indicators. This virtual setting appears on a tablet or mobile phone screen, thereby providing immersive, interactive learning.

Phase 2: Conducting and Assessing the Virtual Experiments (3 Steps).

Step 3: Set Up the Chemical Reaction.

Within the AR Chemistry Lab, students choose from the available 3D virtual models of chemicals (e.g., acids and bases) and lab equipment to initiate reactions. Using a virtual pH meter, learners can track pH changes upon mixing various substances. They may also adjust parameters such as chemical quantities, reaction temperature, or duration to model authentic experimental conditions.

Step 4: Observe and Record Results.

Learners document observable phenomena such as color changes, gas release, or pH shifts upon completing each experiment. The application can automatically save experimental data for subsequent review.

Step 5: Evaluate and Provide Feedback

The application may offer quizzes or guided questions that prompt students to predict outcomes before conducting experiments. This approach helps assess their comprehension of the material and ability to apply theoretical knowledge. Feedback can be used to reinforce learning objectives and guide further study.

Figure 1. Some images from the AR Chemistry Lab application

By following this structured process, educators can leverage augmented reality technology to create meaningful, interactive experiences in chemistry education, thereby supporting students' conceptual understanding and fostering scientific curiosity.

2.2.3. Experiment design for the content of "Acid-Base-pH-Oxide-Salt" in Grade 8 Natural Science

With an AR chemistry lab, users can interact with virtual tools and chemical substances to perform experiments in an AR environment. The application offers a variety of chemicals, ranging from acids to bases, allowing users to combine them to create chemical reactions and observe the results on their mobile device screens. Within the scope of this article, we will analyze and guide eighth-grade students in designing several experimental activities under the topic of "Acid-Base-pH-Oxide-Salt" as follows:

Acid-Base: After conducting the experiments, students can explain the concepts of acids, bases, and their characteristic properties by performing experiments on neutralization, the reaction of acids with metals, and measuring pH. Students select chemicals such as HCl (acid) and NaOH (base) from the virtual library, mix them, and observe the neutralization process. They use the virtual pH meter to monitor the shift from acidic to neutral and then to alkaline conditions.

pH: This helps students develop the concept of pH and the ability to use the pH scale to determine the acidity or alkalinity of a solution. Students use a virtual pH strip or meter to measure available solutions and, based on the results, analyze and conclude the solution's properties. This experiment may include measuring the pH of common solutions like water, vinegar, and saltwater.

Oxide: Students distinguish between different types of oxides (metal oxides and non-metal oxides) and their properties. They choose oxides (such as CaO and CO_2) to react with water, then add other oxides to the resulting solution, observing phenomena like the formation of a base solution or a precipitate.

Salt: This helps students explain the composition of salts and the formation of salts through chemical reactions. Students conduct precipitation experiments by mixing salt solutions, such as NaCl and $AgNO_3$, to form a precipitate (AgCl).

Table 1. Steps and objectives of the experiment

Content	Goal	Chemical	Tool	Expected Results
Acid-Base	Articulate the concept of neutral reaction	HCl, NaOH	Test tubes, pH meters	pH changes from acidic to alkaline
pH	Usable pH scale	HCl, NaOH	pH Range, pH Meter	Determine the pH of solutions
Oxide	Classification of oxides, the reaction of oxides	CaO, CO_2, H_2O	Test Tube	Forms a base solution or precipitate
Salt	Observe precipitation	NaCl, $AgNO_3$	Test Tube	AgCl white precipitation

2.3. Experimentation of research outcomes

2.3.1. Experimental methodology

The experimental process was conducted with 218 students from Ly Tu Trong Secondary School, Ninh Binh City, Vietnam. These students were randomly assigned to two groups, namely the experimental group consisting of classes 8C (n = 56) and 8D (n = 53), and the control group consisting of classes 8A (n = 53) and 8B (n = 56). Motive: Both groups were selected based on similar class performance, cognitive abilities, and class size. The same teacher taught all lessons to control for consistency in instruction.

The study design was a quasi-experimental design with a pre-test intervention and a post-test. While the experimental group conducted virtual experiments with the AR Chemistry Lab, the control group learned through traditional teaching methods. The conventional way was to perform real experiments, if it was possible, or for the teacher to show experiments and discuss results verbally. The influence of both virtual and in-person teaching approaches on learning outcomes could be compared directly.

All students were administered a standardized pre-test to assess baseline knowledge and skills before intervention. As for the pre-test, it was designed to test theoretical knowledge and practical knowledge of the subject. If the groups differed on pre-test scores, they could be considered equivalent, with similar levels of pre-intervention knowledge, thus providing a valid basis from which the subsequent results on tests from the experimental and control groups could be compared.

The intervention involved two lessons on the topics of "Acid" and "Base". We designed the experimental group for lessons using the AR Chemistry Lab application by conducting virtual experiments. In the augmented reality environment, students interacted with virtual instruments and chemical materials. Those activities included observing neutralization reactions, tracking pH changes with virtual equipment, and exploring the properties of acids and bases and the control The group not using AR technology.

Two post-tests were administered to assess the effectiveness of the intervention. A pen and paper test was given to the students after the first lesson as a test 1 assessment to understand their readiness to apply the concepts about acids and bases. The last test took place after the second tutorial and tested the knowledge and understanding of the contents of the package in the field of "Acid-Base-pH-Oxide-Salt". Both tests include questions designed to assess knowledge and the application of that knowledge. The performance of the experimental and control groups is evaluated based on the test results.

Data were collected through test scores, classroom observations, and student feedback. The results were summarized using descriptive statistics (i.e., mean, variance, and standard deviation). These were assessed for significance and effect size using inferential statistics (p-values, Standardised Mean Difference (SMD)). Conclusion This comprehensive approach offers strong evidence to evaluate how virtual experiments affect students' academic performance and engagement in learning actions.

The result of Test 1 and Test 2

The plan of 02 lessons of "Acid" and" Base"

2.3.2. Results and statistical analysis

The purpose was to establish a baseline for the knowledge and skills of both groups before the intervention. The average scores were derived from the academic performance at the pre-experiment stage, with the experimental group and the control group scoring 5.8 and 5.7, respectively. Statistical analysis confirmed no significant differences between the groups ($p > 0.05$), indicating comparable initial academic levels. This ensures that any differences observed in subsequent tests can be attributed to the teaching methods employed during the study.

Test 1 results: Test 1, conducted after the first lesson on "Acid", assessed the student's ability to apply theoretical knowledge and conduct experimental tasks. The experimental group achieved an average score of 7.4, while the control group scored 6.45. The difference in mean scores was statistically significant ($p < 0.05$), with an SMD value of 0.774, indicating a relatively large effect size. This suggests that virtual experiments provided by the AR Chemistry Lab enhanced students' understanding and engagement compared to traditional methods.

Test 2 results: Test 2, conducted after finishing the topic of "Acid-Base-pH-Oxide-Salt", evaluated the students' comprehensive understanding and their ability to apply knowledge across all subtopics. The experimental group scored an average of 7.73, significantly higher than the control group's average of 6.78 ($p < 0.05$). The SMD value of 0.698 further confirmed the positive impact of virtual experiments, demonstrating their effectiveness in fostering deeper learning and problem-solving skills.

Statistical analysis: Key statistical parameters for Test 1 and Test 2 are summarized in Table 2.

Table 2. Key statistical parameters of Test 1 and Test 2

Parameter	**Test 1**	**Test 2**
Mean (Experimental)	7.4	7.73
Mean (Control)	6.45	6.78
Standard Deviation (E)	1.36	1.26
Standard Deviation (C)	1.23	1.36
Variance (E)	1.86	1.58
Variance (C)	1.51	1.85
SMD	0.774	0.698
p-value	0.000219	0.00025

The p-values for both tests were < 0.05, indicating statistically significant differences in the performance of the experimental and control groups. The SMD values (close to 0.7 and above) signify a large effect size, confirming the strong influence of AR-based virtual experiments on student learning outcomes.

Table 3. Grade results of the control and experimental group

Group	**Entrance test score (Average)**	**Tests 1 score (Average)**	**Tests 2 score (Average)**	**Points increase from entry to the end of the term**
Experimental	5.8	7.4	7.73	+1.93
Control	5.7	6.45	6.78	+1.08

Learning gains: The improvement in scores from the pre-test to Test 2 was more pronounced in the experimental group compared to the control group. The experimental group showed an increase of 1.93 points on average, while the control group improved by 1.08 points (Table 3). This highlights the advantages of virtual experiments in enhancing students' understanding and application of scientific concepts.

Qualitative observations: Classroom observations revealed that students in the experimental group demonstrated higher levels of engagement and enthusiasm during lessons involving virtual experiments. The AR Chemistry Lab provided interactive and visually stimulating experiences, enabling students to explore chemical phenomena in a safe and controlled environment. Feedback from students indicated that the virtual tools helped them better understand abstract concepts and increased their interest in learning chemistry.

The results indicate that virtual experiments significantly improve learning outcomes compared to traditional teaching methods. The higher scores and greater engagement observed in the experimental group suggest that AR-based tools provide an effective means of teaching complex scientific topics. These findings support the integration of virtual experiments into Natural Science education to enhance students' conceptual understanding, practical skills, and motivation.

3. Conclusions

Using virtual interactive experiments using the AR Chemistry Lab application significantly enhances the learning of students in the Grade 8 Natural Science with the matter of "Acid-Base-pH-Oxide-Salt". The integration of AR technology provided students with immersive and interactive learning experiences that helped them better grasp action-needed chemical concepts and contextualize the knowledge they had gained to apply in practical situations.

The experimental group outperformed the more active control group. The mean score on Test 2 was 7.73 in the experimental group compared with 6.78 in the control group ($p < 0.05$). This gap exemplifies the usefulness of virtual labs in strengthening students' conceptual understanding and allowing them to use their scientific skills. Moreover, AR-implemented students showed higher levels of engagement and motivation, indicating that virtual experiments positively impact students' academic achievement and also motivate students to learn.

The findings are in line with other studies. For instance, Herga et al. noted that the dynamic visualization and interactive environments of the virtual laboratories help to improve students' academic understanding and performance in academic [17]. Furthermore, these results correlate with the discoveries of Hoai et al. (2023) for demonstrating the potential use of AR tools to develop self-learning potency as well as students' critical thinking in Chemistry for teaching and learning.

The study adds novel factual value as compared to its predecessors by offering statistical evidence further validating the reported learning gain from AR-based virtual experiments. Earlier studies, including one by Nguyen et al. (2022), focus more on the motivational functions of AR applications, and this study makes a global analysis that integrates data from the pre-test, Test 1 and Test 2, and qualitative observations. Based on Cohen's rule of muscle error interpretation [18], the strength of the influence of virtual experiments on learning outcomes is classified as large on the SMD of tests 1 test (0.774) and tests 2 (0.698).

This study corroborates this idea by providing solid evidence supporting meaningful advances toward academic achievement (in terms of grades obtained) as well as engagement indicators from such a curricular integration of AR-based virtual experiments. This study is a shot in the arm for the adoption of newer technologies that can transform education even in resource

-constrained settings. Technology is not only encouraging academic achievement but also empowering students with the important ability to solve problems in self-directed and creative ways by giving students the chance to experiment with theoretical principles in a secure, virtual atmosphere.

Future Work should explore the effectiveness of the virtual experiments in other sciences, such as Physics and Biology, to test broader impact. Future research may look at students' academic trajectories and aspirations for STEM careers using AR-based learning over the long term. Advanced augmented reality tools that employ artificial intelligence could deliver this level of personalization to fit different learners' needs.

In the end, the article offers a compelling case for transforming science education through AR-based virtual experiments. Thus, virtual experiments are a powerful tool to update education by making learning outcomes better, increasing engagement factors, and addressing the limitations of teaching in traditional classrooms, making sure that students are better equipped with the fundamental skills needed to thrive further in a technologically advancing society. The findings from this study contribute to the literature that demonstrates the value of blending technology with teaching and how this technology can transform the learning experience.

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