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A Comparison of the Effects of the Integration Sequence of Interactive Simulation on Pre-Service Science Teachers' Scientific Explanation of Buffer Solutions

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ABSTRACT
The purpose of this study was to find out the influence of the integration sequence of interactive simulation on the construction of the scientific explanation of buffer solutions. This study was conducted with 30 pre-service science teachers. The control group was randomly assigned to study with lecture first and then interactive simulation-based inquiry learning, and the experimental group was randomly assigned to study with interactive simulation-based inquiry learning and lecture respectively. The finding showed that after the posttest there was no statistically significant difference between the control and experimental groups. This suggests that the sequence of interactive simulation during inquiry activities in the chemistry classroom does not affect the construction of the scientific explanation. However, the mean score between the pretest and posttest in the control group shows a statistically significant difference. This study yields productive information regarding the role of interactive simulation providing clear evidence to scaffold pre-service science teachers in learning the abstract concept.

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Introduction

Scientific inquiry refers to the systematic ways in which scientists typically study the natural world in order to propose potential explanations based on evidence derived from their investigation (Borrull & Valls, 2021). The implication of this concept in the science classroom implies the activities in which students develop an understanding of scientific knowledge as well as an understanding of how scientists study phenomena through various processes (Cairns, 2019). To easily clarify this definition, five features of classroom inquiry are presented as follows: a) students actively engage in scientific questions, b) students give priority to evidence which is consistent with scientific questions, c) students generate scientific explanations based on empirical evidence, d) students connect scientific explanations to blend with knowledge, and e) students communicate and justify scientific explanations reasonably (National Research Council, 2000; Özdemir & Işık, 2015).

As mentioned earlier, scientific explanations are addressed in most of the features. They have been considered a central practice in classrooms and have become of great interest in science education research (Antonio & Prudente, 2021; Cabello et al., 2021; McNeill & Krajcik, 2008a; McNeill et al., 2004; Nawani et al., 2019; Reiser et al., 2012; Yao & Guo, 2018). Numerous studies in science education research have revealed the strong points of scientific explanations. Firstly, engaging students in explanation enhances their understanding of the nature of science and scientific literacy (Chang et al., 2016). Secondly, scientific explanations are a driving element to attain the goal of inquiry in which students comprehend natural phenomena (Englehart, 2014). Finally, formulating explanations can increasingly promote students' understanding of scientific content (Driver et al., 2000). This suggests that an in-depth understanding of scientific content is portrayed as the capability to elucidate phenomena (Novak & Treagust, 2018; Park & Choi, 2013).

It is an unfortunate fact that most teachers encounter problems in their classrooms in training their students to formulate scientific explanations (Cabello et al., 2021; Nawani et al., 2019). As reported in the literature, whenever teachers focus on rote memorization of either knowledge fragments or a series of conceptual facts, accomplishing the goal of inquiry is difficult for their students (Gobert, 2005). Concerning the construction of scientific explanations in the science classroom, teachers should put greater emphasis on knowing how to generate scientific explanations. In other words, scientific learning goes beyond what scientific terminologies, formulas, and symbols are (Antonio & Prudente, 2021). An earlier study reveals that giving reasoning to describe explored phenomena helps students more simply comprehend what scientists normally do to answer those questions (Reiser et al., 2012). Therefore, designing instructional activities should be concerned with engaging, guiding, as well as structuring students in involving scientific inquiry practices, especially the construction of scientific explanations.

Literature suggests that training students in the formation of scientific explanations lets them observe experiment results and perform their investigation in an authentic environment (Nawani et al., 2019; Tschaepe, 2012). Also, generating scientific explanations can be incorporated into science classroom activities in different ways (e.g., connecting scientific explanations to everyday events (Díaz, 2011; Kuhn & Reiser, 2005), modelling and critiquing scientific explanations (McNeill & Krajcik, 2008b). However, before the practice with students, pre-service science teachers need to learn how to form a scientific explanation (Masters, 2020). In other words, having pre-service science teachers participate in the context of generating scientific explanations helps them better conceptualize it and finally teach it to their students.

Accomplishing this movement requires an instructional approach that shapes pre-service science teachers in constructing evidence-based explanations. Multimedia materials have been accompanied by a great expectation for science education researchers to foster learning. Simulation tends to be used as an alternative tool which matches a good teaching method in learning science (i.e., offering students opportunities for active learning and providing visualizations to clarify abstract or difficult concepts (Arıcı & Yılmaz, 2020; Kohnle & Benfield, 2017; Sentongo et al., 2013; Zohar & Levy, 2019). With various methods in the use of interactive simulation in a classroom, one of the accepted instruction strategies which are appropriate in the science setting is inquiry (Sarı et al., 2020). Learning activities designed in a classroom inquiry setting highlight student participation. Little research places more emphasis on the construction of scientific explanations with interactive simulation-based inquiry learning. It is interesting to examine how an interactive simulation is able to help pre-service science teachers by participating in an inquiry setting using visualized empirical data from it to potentially generate acceptable and reasonable explanations.

Buffer solutions is an important topic which is first introduced in secondary school science. An understanding of this conceptual domain in chemistry knowledge is fundamental to subsequent study in higher education. Unfortunately, undergraduate students experience difficulties in explaining the unobservable mechanism of why a buffer solution can resist pH change (Demerouti et al., 2004). Taking into account that an explanation of this content requires prior in-depth knowledge in terms of chemical equilibrium and acid-base chemistry respectively –Le Châtelier's principle is used to explain why a buffer solution can maintain the constant pH as well as the basic idea of acids and bases is used to identify what life forms in aqueous solutions can behave as a buffer solution. These ideas are considered to be a problem in explaining microscopically observable results.

Consequently, the integration of interactive simulation into the lecture class is designed to assist pre-service science teachers in visualizing a buffer solution and an abstract chemical concept, to engender them to generate scientific explanations based on the observed evidence. Furthermore, the current research is interested in whether the integration sequence of an interactive simulation has a positive effect on pre-service science teachers' scientific explanations. To address the mentioned issues, two research questions guided this study: 1) Is there a statistically significant difference between the pre-service science teachers assigned to study with lecture first and then interactive simulation-based inquiry learning and those assigned to study with interactive simulation-based inquiry learning and lecture in terms of their scientific explanation of buffer solutions? and 2) Is there a statistically significant difference between posttest and pretest in a group of pre-service science teachers assigned to study with lecture first and then interactive simulation-based inquiry learning and those assigned to study with interactive simulation-based inquiry learning and lecture in terms of their scientific explanation of buffer solutions?

Integrating lecture and computer simulation-based inquiry is to offer pre-service science teachers the possibility of extending their investigations beyond set-up procedures to aid them to formulate scientific explanations. The findings from this research will be productive for science educators or lecturers to prepare the readiness of pre-service science teachers to gain insight into the construction as well as the importance of scientific explanations to attain the goal of classroom inquiry.

Literature Review

This section will cover three main bodies of literature on science education research related to this study. First, the benefits and the importance of simulation in teaching sciences will be mentioned. Second, the element of scientific explanation will be described. Last, the connection between the literature and the current research will be summarized.

Simulation

Simulation is an alternatively instructional technology which has become an interesting tool in the digital age. It is a computer program based on a scientific model that attempts to imitate an abstract idea of a particular system (Jaakkola et al., 2011). Currently, the interactive simulation-based educational environment is considered an approach that allows students to perform real hands-on lab investigations (Arıcı & Yılmaz, 2020; Nafidi et al., 2018; Sarı et al., 2017; Taşlıdere, 2013). A crucial advantage of an interactive simulation is that it offers students to directly manipulate materials and observe results at both the macroscopic and microscopic levels instantaneously (Sentongo et al., 2013; Watson et al., 2020). Furthermore, prior numerous research studies have widely documented strong impacts of an interactive simulation (e.g., attitudes (Salame & Makki, 2021; Sarı et al., 2017), conceptual understandings (Jaakkola et al., 2011; Fan et al., 2018; Taşlıdere, 2013; Wang & Tseng, 2018; Watson et al., 2020), and cognitive processes (Falloon, 2019)). In literature, it was argued that teaching chemistry via interactive simulations makes the abstract contents more understandable (Falloon, 2019; Kohnle & Benfield, 2017; Zohar & Levy, 2019), since it can be easily visualized and provide useful feedback responses to remedy their difficulties abruptly (Kohnle & Benfield, 2017; Sentongo et al., 2013). Thereby, the use of interactive simulations in chemistry classrooms is rapidly growing to actively enhance learning activities (Blackburn et al., 2019; Kohnle & Benfield, 2017; Salame & Makki, 2021; Wang & Tseng, 2018; Watson et al., 2020; Wu et al., 2021; Zohar & Levy, 2019).

Scientific Explanation

It is well accepted that science is a core conceptual area which is an important key in exposing natural secrets as well as helping students understand and explain why phenomena in everyday life can occur under different conditions (McNeill et al., 2004). Typically, the construction of a scientific explanation is to describe new phenomena by providing claims and giving empirical evidence. Besides this, scientists give potential reasons to justify such claims and to persuade others to willingly agree to these scientific explanations (Novak & Treagust, 2018). In terms of the definition of scientific explanation, three crucial elements of scientific explanations are clarified: 1) a claim (an answer or a conclusion of a scientific question), 2) evidence (data supporting a claim), and 3) reasoning (a justification derived from scientific principles or theories to describe the relationship between such a claim and evidence) (McNeill et al., 2008b). To facilitate students in building scientific explanations, they are required to get involved in such authentic environmental inquiry learning enthusiastically and directly (McNeill & Krajcik, 2008b). According to Osborne and Patterson (2011), it is to concern and allow students the creation of scientific explanations in order to help them understand a causal mechanism of generated-scientific explanation to describe a natural phenomenon. Literature reveals that the integration of constructing causal scientific explanations into everyday science lessons through activities (e.g., organising, analysing, and interpreting data) is challenging (Nawani et al., 2019). Therefore, novice teachers should be prepared to teach scientific explanation construction, since it is one of the core practices in science (Masters, 2020). This study provides pre-service science teachers with an opportunity to learn this practice.

Summary of the Literature Review

Numerous studies have documented the positive impacts of an interactive simulation on students' academic performance. However, little research focuses on the construction of scientific explanations with interactive simulation in chemistry classrooms. Also, there are few studies that investigate the appropriate integration sequence of an interactive simulation to support the construction of a scientific explanation.

Aim of the Research

To find out the influence of the integration sequence of interactive simulation on pre-service science teachers' scientific explanation of buffer solutions.

Hypothesis

The experimental group assigned to study with interactive simulation-based inquiry learning and lecture have significantly higher levels of scientific explanation of buffer solutions than the control group assigned to study with lecture first and then interactive simulation-based inquiry learning.

Methodology

This chapter includes the research setting, participants, teaching interventions, the sources of data, as well as the method used in analyzing the data. Details for each section of the methodology are presented in the following paragraphs.

Research Design

In this study, the pretest-posttest nonequivalent comparison group, a type of quasi-experimental research design, was purposefully utilized. It is commonly used to investigate the outcomes of an experimental study in educational research (Çepni, 2014). Therefore, this design is suitable for the aim of the research. This study was performed with a total number of 30 pre-service science teachers. They were divided into two groups. Each name was written on a piece of paper and dropped in two different boxes and then picked by an independent authority who was not involved in the study to establish the control and experimental groups. The first 15 pre-service science teachers were assigned to the control group and the following 15 pre-service science teachers were assigned to the experimental group. A summary of the integration sequence of teaching interventions used in each group is presented in Table 1.

Table 1

The Integration Sequence of Teaching Interventions in Each Group

<table>
<tr><th>Group</th><th colspan="6">Integration sequence of teaching interventions</th></tr>
<tr><td rowspan="3">Control group</td><td colspan="3" rowspan="3">Lecture</td><td colspan="3">Interactive simulation-based inquiry learning</td></tr>
<tr><td>Question</td><td>Methods</td><td>Conclusion</td></tr>
<tr><td>(X)</td><td>(-)</td><td>(-)</td></tr>
<tr><td rowspan="3">Experimental group</td><td colspan="3">Interactive simulation-based inquiry learning</td><td colspan="3" rowspan="3">Lecture</td></tr>
<tr><td>Question</td><td>Methods</td><td>Conclusion</td></tr>
<tr><td>(X)</td><td>(-)</td><td>(-)</td></tr>
</table>

Note. The X indicates that the teacher provided a question to the pre-service science teachers and – indicates that the pre-service science teachers do their own investigations.

Participants

Convenience sampling was used to select the participants since it is easy to access (Merriam, 2009). 30 pre-service science teachers who studied in the third- and fourth-year undergraduate program in the faculty of education and enrolled in the chemistry concept in school science (course code 232 313) in the first semester of the 2016 academic year were included in the study. All of the participants were willing to participate in this research. There were 28 third-year pre-service science teachers and two fourth-year pre-service science teachers transferred their credits from other programs, therefore they could not enroll in this course like the other fourth-year pre-service science teachers. Typically, the chemistry concept in school science is a required subject for third-year pre-service teachers in the science education program with a major in chemistry. All conceptual areas of chemistry in school science were provided in this course to help the pre-service science teachers gain an in-depth understanding. This course was aimed at preparing the readiness of pre-service teachers prior to enrollment in the internship course in the last course of the science education program.

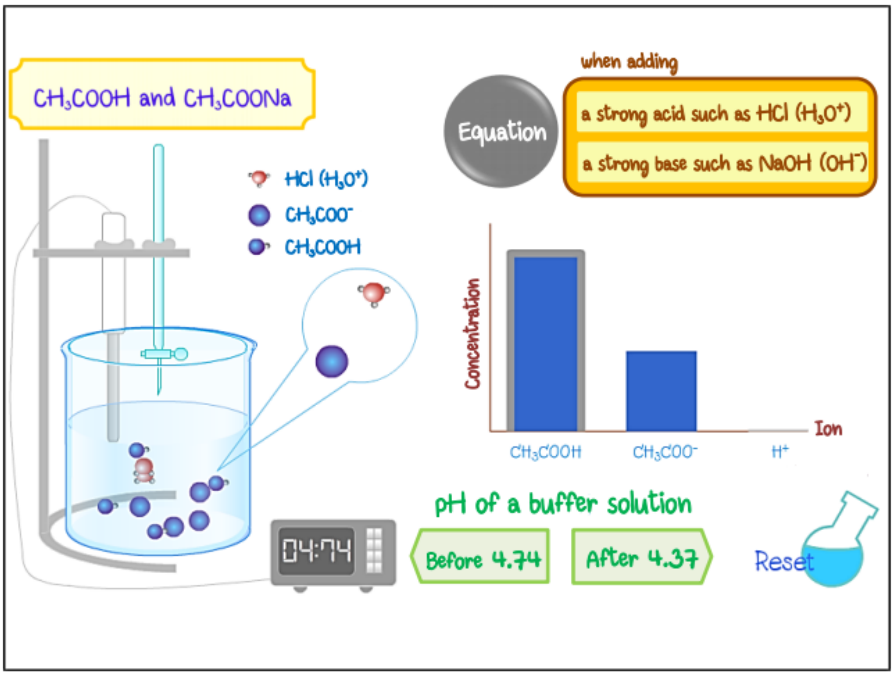
Teaching Interventions

As mentioned earlier, the participants were 30 pre-service science teachers and they were asked to test their performance in generating scientific explanations. Results from the pretest were used to examine whether the basic performances of scientific explanations between the control and experimental groups were different. More details of the pretest were shown and discussed in the data source section. The control group was randomly assigned to study with lecture first and then interactive simulation-based inquiry learning and the experimental group was randomly assigned to study with interactive simulation-based inquiry learning and lecture respectively. Both groups were also taught by the same teacher.

In the lecture class of the control group, the 15 pre-service science teachers were assigned to find out alternative conceptions in the literature regarding buffer solutions at the secondary school level and they presented those alternative conceptions individually. After a class discussion on the alternative conception issue, they were instructed on the definition of buffer solutions, the composition of buffer solutions, the pH of buffer solutions, and the importance of buffer solutions in the human body and daily life, respectively. They were then studied with interactive simulation-based inquiry learning. The teacher provided them with a scientific question on how buffer solutions could control pH when adding a small amount of hydrochloric acid (HCl) and hydroxide (OH^-) solution before allowing them to learn using the designed simulation. They sought out the answer by doing their own investigations. In the interactive simulation, there were four buffer solutions and they could freely select one to test the pH after adding an acid or base solution by observing microscopic results and chemical equations. They also wrote down their understanding in the worksheet individually. All pre-service science teachers in this group and the teacher discussed and drew a conclusion based on a scientific question which was given at the beginning of the simulation class.

Figure 1

Screenshot of Buffer Solution Simulation: Effect on pH by Adding a Strong Acid or Base to a Buffer System



On the other hand, the experimental group (15 pre-service science teachers) studied using interactive simulation-based inquiry learning. Before introducing them to instruction with the designed simulation, the same teacher provided them with a particular scientific question on how buffer solutions could resist the pH change due to the addition of a small amount of hydrochloric acid (HCl) and hydroxide (OH^-) solutions, respectively. Each pre-service science teacher attempted to seek out the answer. Four buffer systems (i.e., CH_3COOH/CH_3COONa, $H_2CO_3/NaHCO_3$, NH_3/NH_4Cl, and H_3PO_4/NaH_2PO_4) in the interactive simulation were given microscopic results including chemical equations. They then wrote down their understanding on a worksheet as shown in Figure 2. All pre-service science teachers in the experimental group and the teacher discussed and summarized the key concept from studying the interactive simulation together. A week later, they were required to seek alternative conceptions of buffer solutions in the literature before going to the lecture class. The scope of alternative conceptions of buffer solutions was only strict at the secondary school level. They presented alternative conceptions found in the literature individually. Then, they and the teacher discussed the alternative conceptions together. They were finally received with the study in the following concepts: the definition of buffer solutions, the composition of buffer solutions, the pH of buffer solutions, and the importance of buffer solutions in the human body and daily life.

Data Sources

Data from the scientific explanation test and worksheet was used to assess the pre-service science teachers' generated-scientific explanation of buffer solutions:

The Scientific Explanation Test of Buffer Solutions (SETBS)

The SETBS which used open-ended test questions was used as a research instrument to investigate pre-service science teachers' generated-scientific explanations. They were four main conceptual domains and each item required the pre-service science teachers to provide a claim, evidence, and reasoning. In total, 12 items were included in the SETBS and details of four main conceptual domains are shown in Table 2.

Table 2

The Conceptual Domain of the SETBS

Item	The main concept underlying a scientific question	Given buffer system
1	The pH change when adding a small amount of a strong acid to the given buffer system	CH_3COOH/CH_3COONa
2	The pH change when adding a small amount of a strong base to the given buffer system	CH_3COOH/CH_3COONa
3	The pH change when adding a small amount of a strong acid to the given buffer system	NH_3/NH_4Cl
4	The pH change when adding a small amount of a strong base to the given buffer system	NH_3/NH_4Cl

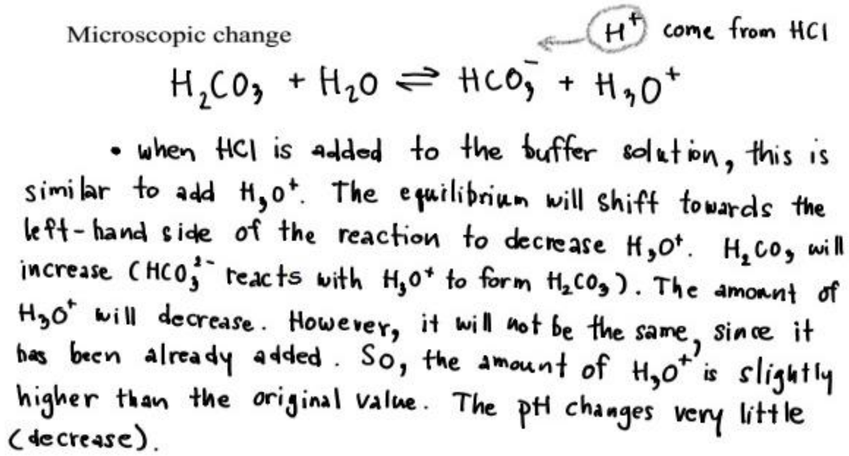
To enhance content validity, the test was verified by a chemistry lecturer and two science educators. The experts' suggestions were used to revise the test items. The SETBS was determined after being piloted by the fourth and fifth-year pre-service teachers who had enrolled on the chemistry concept in school science completely. The Cronbach alpha reliability coefficient of the SETBS was 0.88. The reliability of this test is acceptable, according to Nunnally (1978). After this, it was applied as the pre and posttest to both groups of pre-service science teachers.

Worksheet

Similar to the development process of test items, the worksheet was designed and developed by the author. It consisted of open-ended questions which aimed to assess three elements of the scientific explanation. To ensure that each item of the worksheet was appropriately constructed, it was also verified by the same experts mentioned earlier. After getting feedback from the experts, it was revised and then piloted prior to the study. The worksheet which is presented below required the pre-service science teachers to understand buffer reaction when adding a few drops of a strong acid and base. Moreover, they needed to write down the chemical equations including their explanations showing how a buffer solution works by controlling the pH, particularly changes at the microscopic level. Figure 2 shows an example of a pre-service science teacher's worksheet of buffer action. The worksheet data which was provided for them in both groups was additional information support and trained the pre-service science teachers on how to generate scientific explanations.

Figure 2

Example of a Pre-Service Science Teacher's Worksheet Presenting His Explanation of Why a Buffer Solution can Resist pH Change Using Le Châtelier's Principle



Procedures

In response to the research setting, the pretest-posttest nonequivalent comparison group was utilized in the present study. This study started with the administration of the SETBS as the pretest. The SETBS, a testing instrument, was piloted with a group of samples (fourth-year pre-service teachers) who had already studied buffer solutions and enrolled in the chemistry concept in a school science course. They took approximately 50-60 minutes to complete the SETBS. About one week before the implementation of the teaching intervention, both groups of pre-service science teachers were assigned to do the SETBS as the pretest. During the implementation of the three-week teaching intervention period (one week for lecture and two weeks for interactive simulation-based inquiry learning), the control group were instructed with lecture first and then interactive simulation-based inquiry learning and the experimental group were received with interactive simulation-based inquiry learning and lecture respectively. After the teaching interventions were fully implemented for one week, the SETBS was administered again as the posttest to both groups at the same time.

Data Analysis

Based upon the main interest of this study, the level of pre-service science teachers' scientific explanations of buffer solutions prior to and after using the teaching interventions was investigated. Three key elements of scientific explanations were described: 1) claim: an answer or a statement of a scientific question, 2) evidence: data used to support a claim, and 3) reasoning: a judgment occurring in a process of thinking carefully, and expresses the connection of claim and evidence together. Details of the scientific explanation and scoring rubric are presented in Table 3. This assessment rubric was adapted based on McNeil, Lizotte, Krajcik, and Marx's (2006) work.

Table 3

Example of Scientific Explanation Scoring Rubric

Key elements of scientific explanations	Levels of pre-service science teacher-generated scientific explanations		
	1 (Low)	2 (Medium)	3 (High)
Claim	Blank, or identifies a claim which is not related to a scientific question or answered the wrong claim. E.g., the pH of a buffer solution absolutely changes.	Provides a claim directly related to a scientific question, but such a claim is ambiguous. E.g., the pH of a buffer solution may be changed.	Provides a specific claim directly relating to a scientific question. Such a claim is correct. E.g., the pH of a buffer solution slightly changes and its change is very little.
Evidence	Blank or does not identify evidence, or gives some evidence which is not relevant to a scientific question. e.g., Observes the colour change of a solution.	Identifies relevant evidence, but this evidence is not sufficient to support such a claim. e.g., Observes the pH of a buffer solution when adding a strong acid or base.	Identifies sufficient relevant evidence based on the data which is provided in a scientific question to support such a claim. e.g., Measures the pH of a buffer solution by using the pH meter.
Reasoning	Blank or does not give reasoning, or provides reasoning which does not connect the claim and evidence. The reasoning is not consistent with relevant scientific principles or theories, e.g., CH_3COOH + CH_3COONa → CH_3COONa + H_2O -- (1) CH_3COONa + HCl → CH_3COOH^+ + NaCl -- (2) Hydrochloric acid solution dissociates to give H^+.	Gives potential reasoning which connects a claim and evidence, but repeats the evidence and/or mentions relevant scientific principles or theories insufficiently and incompletely. e.g., the pH of a buffer solution slightly changes which can observe from a pH meter. When adding a hydrochloric acid solution, a buffer solution (CH_3COOH/ CH_3COONa) attempts to maintain a constant pH.	Gives sufficient and complete reasoning which directly connects such a claim and evidence including relevant scientific principles or theories. e.g., The pH of a buffer solution, which can be observed with a pH meter, changes slightly. When a few drops of a hydrochloric acid solution is added, a buffer solution (CH_3COOH/ CH_3COONa) attempts to maintain the constant pH, since a conjugate base (CH_3COO^-) will remove H^+ which comes from HCl.

As shown in Table 3, each element was also categorized by considering (a) the consistency between a claim and a scientific question, (b) the relevance and sufficiency of the evidence, and (c) the completeness and sufficiency of the reasoning based on the conceptual quality. After completing the categorization, the pre-service science teachers' responses were scored 1, 2, and 3, respectively. All responses scored by the author were justified by the science educators who verified the SETBS.

Discrepancies in data analysis were discussed until a consensus was reached. A comparison of test scores between the pre and posttest in each group was calculated through the use of a paired samples t-test. A comparison of the pretest of the control and experimental groups as well as the posttest of both groups was calculated through the use of an independent t-test. Although the number of pre-service science teachers in each group was less than 30, parametric tests were used. For small sample sizes, normality tests are not often used. It was found that a p-value from the Shapiro-Wilk normality tests was greater than 0.05 which indicated the normal distribution of data (Ghasami & Zahediasl, 2012). These comparisons were performed with SPSS version 22.

Results and Discussion

This section will present the results in terms of pre-service science teachers' scientific explanations of buffer solutions based on two research questions.

Research question 1: Is there a statistically significant difference between the pre-service science teachers assigned to study with lecture first and then interactive simulation-based inquiry learning and those assigned to study with interactive simulation-based inquiry learning and lecture in terms of their scientific explanations of buffer solutions?

The pre-service science teachers in the control and experimental groups were examined using the pretest scores of the SETBS during the same period before they started learning. Table 3 shows the results from an analysis of an independent t-test of the pretest score between the control and experimental groups.

Table 4

Independent t-test for the Pretest of the SETBS of the Control and Experimental Groups

Group	n	Mean	S.D.	t	*p*
Control group	15	11.00	3.42	1.649	0.110
Experimental group	15	13.20	4.59		

As shown in Table 4, the mean score of the pretest in the control group (Mean = 11.00) was lower than that in the experimental group (Mean = 13.20). However, a comparison of the results of pre-service science teachers' scientific explanations both before and after the implementation of the integration sequence of teaching approaches does not affect pre-service science teachers' scientific explanations, since there was no statistically significant difference in the pretest scores (t = 1.649, $p > 0.05$). This result suggests that the construction of scientific explanations for both groups of pre-service science teachers were similar.

Table 5

Independent t-test for the Posttest of the SETBS of the Control and Experimental Groups

Group	n	Mean	S.D.	t	*p*
Control group	15	15.80	5.49	0.462	0.648
Experimental group	15	15.00	3.85		

Table 5 shows that the mean score of the posttest in the control group (Mean = 15.80) was slightly higher than that in the experimental group (Mean = 15.00). To answer research question 1, an independent t-test of the posttest score between the control and experimental groups was also applied. It was found that there was no statistically significant difference between the control and experimental groups (t = 0.462, $p > 0.05$). It seems that the integration sequence of interactive simulation yields a benefit in generating scientific explanations equally. In the related literature, an interactive simulation educational environment offers students to immediately observe experimental results at both macroscopic and microscopic levels (Kohnle & Benfield, 2017; Sentongo et al., 2013; Watson et al., 2020). Therefore, interactive simulation has been used widely in teaching abstract science concepts (Arıcı & Yılmaz, 2020; Blackburn et al., 2019; Falloon, 2019; Kohnle & Benfield, 2017; Watson et al., 2020; Wu et al., 2021; Zohar & Levy, 2019).

Research question 2: Is there a statistically significant difference between posttest and pretest in a group of pre-service science teachers assigned to study with lecture first and then interactive simulation-based inquiry learning and those assigned to study with interactive simulation-based inquiry learning and lecture in terms of their scientific explanation of buffer solutions?

At the end of the teaching interventions, the SETBS was distributed to the pre-service science teachers of both two groups. Comparisons within each group were calculated using paired samples t-test and the results of the analysis were given in tables. Tables 6 and 7 present the posttest scores through the use of paired samples t-test for the control and experimental groups respectively.

Table 6

Paired Samples t-test of the Pre and Posttest Scores in the Control Group

Key elements of scientific explanations	n	Posttest	Pretest	t	*p*
		Mean (S.D.)	Mean (S.D.)		
Claim	15	6.53(2.42)	5.60(2.03)	1.468	0.164
Evidence	15	3.47(2.07)	4.00(2.20)	-0.866	0.401
Reasoning	15	5.80(2.27)	3.60(2.16)	2.690	0.018*
All key elements	15	15.80(5.49)	11.00(3.42)	3.200	0.006*

Note. * $p<0.05$

When considering each key element of scientific explanations, only in reasoning did the pre-service science teachers in the control group score higher in the posttest than the pretest. Surprisingly, this element seemed to be easy for them. This result was in contrast to previous work (Masters, 2020; McNeill & Krajcik, 2008b; McNeil et al. 2006; Ruiz-Primo et al., 2010; Yang & Wang, 2014) which revealed that giving reasoning was challenging for both students and teachers in constructing scientific explanations. Overall, Table 6 shows that statistically there was a significant difference for all key elements of scientific explanations between the pre and posttest scores of the control group. This suggests that the integration of interactive simulation-based inquiry learning and lecture was successful for them. In this case, the sequence of instruction was a very essential factor in helping pre-service science teachers generate scientific explanations. Based on the nature of scientific explanations, they had to give a claim and evidence to blend with their relevant reasoning when *the* pre-service science teachers in the control group received some important basic information from studying in a lecture. An interactive simulation which was purposefully used in the present study was considered a laboratory experiment to fill the gap of learning difficulty in buffer solutions since it provided useful visualizations and virtual laboratories (Fan et al., 2018; Wang & Tseng, 2018). Thus, the sequence of instruction was a very important issue in learning (Thampi et al., 2020; Zacharia & de Jong, 2014). In contrast to a previous study, students who performed the interactive computer simulation (or laboratory) activities first and followed by the reading assignment significantly scored higher on the posttest than the pretest when compared to those who learnt in the opposite sequence (Gokhale, 1991). In the study by Stefaniak & Turkelson (2014), students who participated in the simulation before the lecture increased their knowledge when compared with students who participated in the simulation after the lecture. Additionally, the findings of this study are inconsistent with those of previous studies which highlighted the advantages of using simulation activities preceding lectures to promote students' learning (Thampi et al., 2020; Zacharia & de Jong, 2014).

Table 7

Paired Samples t-test of the Pre and Posttest Scores in the Experimental Group

Key elements of scientific explanations	N	Posttest	Pretest	t	*p*
		Mean (S.D.)	Mean (S.D.)		
Claim	15	6.40(2.03)	4.27(1.03)	4.000	0.001*
Evidence	15	3.73(2.37)	4.07(2.43)	-0.638	0.534
Reasoning	15	4.87(1.77)	2.67(1.45)	4.680	0.000*
All key elements	15	15.00(3.85)	13.20(4.59)	1.111	0.285

Note. * $p<0.05$

From Table 7, it seemed that the pre-service science teacher performances in the experimental group in identifying a claim and giving reasoning in the pre and posttest were statistically different. However, it is very interesting that the overall results from Table 7 show no statistically significant difference between the pre and posttest scores. This implies that the integration sequence of an interactive simulation did not affect pre-service science teachers' scientific explanations. Thus, the hypothesis of this study is rejected. The experimental group assigned to study with interactive simulation-based inquiry learning and lecture did not display better performance in generating scientific explanations of buffer solutions compared to those assigned to study with lecture first and then interactive simulation-based inquiry learning. Possibly, most pre-service science teachers in the experimental group had a good background in related concepts of buffer solutions as seen in the pretest scores in Table 4. When they were engaged in both lecture and interactive simulation-based inquiry learning, the increased mean scores of the posttest might then not affect the formulation of scientific explanations. Similarly, Castaneda (2008) revealed that there was a greater increase in student knowledge gain when an interactive simulation was implemented after online instruction than a pure simulation used before starting the online instruction. Even though previous research studies proposed that teachers could move laboratory activities to engender students to be curious before they began learning at the beginning of the chapter (Proulx, 2013; Stefaniak & Turkelson, 2014; Thampi et al., 2020). It is important that the new knowledge must be related to the background that they already know *since* the explanation of phenomena involves scientific knowledge (Cabello et al., 2021). Similar to other studies, it was indicated that the combination of simulation and physical laboratory was more effective than using them separately (Arıcı & Yılmaz, 2020; Jaakkola et al., 2011; Wang & Tseng, 2018).

Conclusıons and Recommendatıons

The findings of this study suggest that differences occurred among the pre-service science teachers when the sequencing of teaching approaches was applied. The pre-service science teachers who participated in the lecture first and then studied in interactive simulation-based inquiry learning demonstrated increased knowledge compared with the pre-service science teachers who participated in the lecture after interactive simulation-based inquiry learning. The designed simulation helped the pre-service science teachers to obviously create images of buffer solutions much better than only the lecture did. Thus, the lecture in combination with interactive simulation-based inquiry allowed pre-service science teachers to visualize the mechanism of pH resistance of buffer solutions when adding a small amount of a strong acid (base) and thereby created a better understanding which can move them towards a reasonably generated scientific explanation. The results of this study show that teachers and researchers should realize the use of interactive simulation and pre-service science teachers' background knowledge in learning abstract chemical concepts. Also, having sufficient background knowledge will support pre-service science teachers to generate scientific explanations.

Further research will investigate how pre-service science teachers implement scientific explanations in the lesson by integrating interactive simulation.

Constructing explanations of phenomena involves scientific knowledge which can be based on theories, principles, and concepts (Cabello et al., 2021). Explanations in science education commonly contain abstract knowledge or concepts. To support pre-service science teachers to explain phenomena, they should be provided ample opportunity to learn what a scientific explanation is and how to generate explanations. The elements of scientific explanation (i.e., claim, evidence, and reasoning) should be introduced at the beginning of the lesson, including giving simple examples to help them become familiar with such elements. Furthermore, more practice will help them develop their scientific explanations.

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