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EFFECT OF COMPUTER SIMULATION AND ANIMATION-INTEGRATED INSTRUCTION ON PRE-SERVICE SCIENCE TEACHER TRAINEES CONCEPTUAL UNDERSTANDING AND RETENTION OF ACID-BASE CHEMISTRY AND STOICHIOMETRY

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Abstract

The study aimed to investigate the effect of computer simulation and animation-integrated instruction on pre-service science teacher trainees' conceptual understanding and retention of acid-base chemistry and stoichiometry. A quantitative approach with a pretest–posttest-delayed test quasi-experimental design was used. In the study area, there were only two sections of first-year trainees in the natural science department. So a comprehensive sampling technique of the two intact sections was employed. The two intact classes were randomly assigned to an intervention group (IG) and a comparison group (CG). Data was collected using Acid-Base Chemistry and Stoichiometry Conceptual Understanding of a two-tier multiple-choice Test (ABSCUT). Parametric statistics (independent sample t-test and ANCOVA) were used for the data analysis. The independent sample t-test was used for the pre-test analysis to examine the prerequisite experiences of trainees in the two groups and male and female trainees in the IG before the intervention. The result showed no significant difference between the mean score of the CG and IG. The result also showed no significant difference in the mean score of male and female trainees in the IG. The ANCOVA was used for post-test and delayed test analysis after the intervention. The result indicated that there was a statistically significant difference between the two groups on conceptual understanding, $F(1,49)=5.07$, $p=.029$, partial eta squared=0.094, in favor of IG. This tends to imply the concepts of the trainees who received the intervention outperformed the comparison group. The ANCOVA result also indicated that gender difference has no statistically significant difference in the IG, $F(1,24)=3.68$, $p=.067$. The delayed-test analysis showed that the IG has higher retention than the CG. Based on the results, this study recommended that policymakers, chemistry curriculum experts, chemistry curricular material developers, and practitioners alike consider the application of computer simulation-integrated chemistry instruction to enhance learners' conceptual understanding and retention.

Keywords – Conceptual understanding, Retention, Simulation, Animation.

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1. Introduction

Nowadays, chemistry education has been developing worldwide and becoming widely recognized as a research field (Taber, 2017). As a result, the use of effective chemistry instruction is the call of the day to better understand chemical concepts (Erduran & Scerri, 2003). The emphasis on the philosophy of chemistry education epistemologically underpins the knowledge of chemistry and has the potential to re-energize the importance of models and representations during the instructional process (Treagust, Chittleborough & Mamiala, 2002). A model-based representation in chemistry instruction can contribute to meaningful learning engagement and enhance conceptual understanding. As many chemistry concepts are complex and difficult to conceptualize, learners face challenges in constructing knowledge and achieving meaningful learning (Ali, 2012). To minimize the abstract nature and enhance meaningful chemistry learning, there is a need to integrate chemistry instruction with the three levels of representation (Treagust & Chandrasegaran, 2009). Macroscopic, submicroscopic, and symbolic levels are the three levels of representation (Hadinugrahaningsih, Rahmawati & Ridwan, 2017; Johnstone, 1991; Tang & Abraham, 2016).

Learning chemistry at the submicroscopic level often requires the aid of models and images, which are used to enhance the conceptual understanding and retention of the learners (Maehr & Meyer, 1997; Treagust, Chittleborough & Mamiala, 2003). Chemists developed the concept of mental visualization of submicroscopic molecules and the changes associated with them. Through this, mental representations can be expressed symbolically using equations, tangible models, graphs, and drawings (Al-Balushi & Al-Hajri, 2014; Kozma & Russell, 2005). Learners usually perceive the macroscopic phenomena, but they lack concentration on the basic building block of chemical concepts-the submicroscopic phenomena (Williamson, 2011; Williamson & Abraham, 1995). Moreover, studies indicate that superficial experiences of learners of the submicroscopic level of representation lead learners to miscomprehend the relationship that exists among the triplet levels of representing phenomena (Johnstone, 1993; Treagust & Chandrasegaran, 2009). Consequently, learners fail to link visual and conceptual representations, and they usually face misconceptions and learning difficulties about chemical concepts due to their abstract nature (Al-Balushi & Al-Hajri, 2014; Özmen, Demircioğlu & Coll, 2009; Susilaningsih, Fatimah & Nuswowati, 2019).

The abstract concepts of chemistry require a variety of learning strategies to enhance learners' conceptual understanding and minimize learning difficulties on different topics of general chemistry courses (Fensham, 1988; Hilton & Nichols, 2011; Kamisah & Nur, 2013; Sirhan, 2007; Taber, 2002; Zoller, 1990). Acid-base chemistry and stoichiometry are among the different contents usually incorporated into the general chemistry course that can be taught at the college level and have an application to everyday life. These topics are interrelated to each other and have several advantages for the knowledge and understanding of advanced chemistry courses. Although acid-base chemistry and stoichiometry have many advantages, they have some learning difficulties that hinder learners' conceptual understanding and cause difficulty in solving problems (Anderson, 2020; Hand, Yang & Bruxvoort, 2007; Kousathana, Demerouti & Tsaparlis, 2005; Ross & Munby, 1991).

Different scholars investigated learning difficulties in different concepts of acid-base chemistry and stoichiometry. For example, Alvarado, Garritz and Mellado (2015) indicated that learners could not differentiate the degree of acidity of different solutions with the same concentration. Similarly, Demircioglu, Ayas and Demircioglu (2005) and Hoe and Subramaniam (2016) showed that learners could incorrectly correlate chemical structures with acidity or basicity and attempt to explain them based on the presence of H and OH. Elham and Dilmaghani (2019) disclosed that learners believed that temperature does not affect the dissociation system of acidic or basic solution and assumed that pure water's pH is always seven. Other scholars, such as Kousathana et al. (2005) and Mubarokah, Mulyani and Indriyanti (2018), indicated that learners usually perceive a neutral solution as a solution that has pH=7. In pH calculations, learners usually assume that $[H_3O^+]$ is only just from the dissociation of the acid. They thought that a solution of 10^{-8} M HCl had a pH value of 8. Other studies, (e.g. Rohmah & Virtayanti, 2021; Sheppard, 2006) indicated that learners do not generally understand that pH is a measure of concentration rather than a measure of strength. Other scholars indicate the existence of learning difficulties on the topics of stoichiometry (Huddle & Pillay, 1996; Schmidt, 1990). The idea of stoichiometry is not only challenging for learners but also it is a prerequisite to learning about other topics in general chemistry, including acid-base reactions (Evans, Yaron & Leinhardt, 2008; Gupta, 2019; Hand et al., 2007). To alleviate these and other similar epistemological problems, therefore, scholars suggest different alternative instructional strategies that enhance learners' conceptual understanding and retention capacity at both symbolic and submicroscopic levels (Kozma & Russell, 2005; Treagust & Chandrasegaran, 2009).

Some studies suggest applying computer simulation and animation-integrated instruction to ease learners' conceptual and multilevel understanding of chemistry. Today's computer technology provides graphical representations in the form of animations and simulations that help learners relate their prior experience to scientific concepts and construct their mental models of chemical phenomena and theories (Liu, 2005). Animated images can improve students' perception, cognitive thinking levels, understanding, and attention by altering their mental ideas into concrete images and relating basic science concepts to real-life experiences (Akçay, Feyzioğlu & Tüysüz, 2003; Sanger & Greenbowe, 2000). These reports suggested that conventional method integrating with simulation and animation(CMISA) can help learners to concretize abstract concepts by explaining the submicroscopic phenomena from macroscopic phenomena (Engida, 2017). According to studies, integrating technology into chemistry instruction has the potential to provide a multisensory stimulus and enhance learners' conceptual understanding of chemical concepts at all levels of representation (Barnea & Dori, 1996; Wilujeng, Tadeko & Dwandaru, 2020). Applying computer simulations and animations for abstract topics provides an opportunity for learners to construct meanings and understand difficult concepts more easily by creating an interactive learning environment and enhancing retention (Mihindo, Wachanga & Anditi, 2017; Nduudee & Arokoyu, 2021; Sung & Ou, 2002). Scholars investigated the effect of technology on students' retention capacity in chemistry learning and indicated that students who taught chemistry through technology-based instruction showed better retention than those taught through traditional methods (Hussain, Suleman, Din & Shafique, 2017; Rastegarpour & Badeleh, 2012). Proper utilization and application of simulation and animation can generally increase the quality of learning by allowing learners to express their real reactions (Suits & Srisawasdi, 2013). It can also create the opportunity to compress experiments at the classroom levels, dynamically present micro-mechanisms, enrich the learning methods by strengthening the connection between experiments and theories, and stimulate motivation for learning (Belletti, Borromei & Ingletto, 2006). Simulation allows learners to view and interact with models of phenomena and facilitate understanding phenomenal processes at the molecular level (Plass, Milne, Homer, Schwartz, Hayward, Jordan et al., 2012; Stieff, 2011).

There are conflicting reports on the effect of simulation and animation-based chemistry instruction on students' conceptual understanding of differences by gender. For instance, Mihindo et al. (2017), Nkemakolam, Chinelo and Jane (2018), Poripo (2008), Sentongo, Kyakulaga and Kibirige (2013), and Ezeudu and Ezinwanne (2013) reported that simulation-based chemistry instruction does not show a significant difference between male and female students' learning. Likewise, other researchers found that male and female students performed equally well in chemistry using computer-based instructional packages (Adesoji & Babatunde, 2005; Gambari, 2004). On the other hand, Chen and Howard (2010) indicated that male students show more positive motivation and learning towards simulation-based chemistry instruction. Similarly, Nduudee and Arokoyu (2021) researched the chemistry performance of gender differential effects of secondary school students in simulation-based instruction and found that the instruction caused differences, in favor of male students.

Eventhough a large number of studies indicated that computer simulation and animation enhance learners' conceptual understanding and retention; some studies do not support the use of simulation and animation to enhance learning. For example, Jong (2010) and Kock (2018) cited in Krüger, Höfer, Wahl, Knickmeier and Parchmann (2022) reported that computer simulation causes cognitive and metacognitive difficulties in students' learning. Similarly, Winberg (2006) indicated that the use of simulation as an instruction creates multimodal representation, causes split attention, and increases cognitive load on learners. The cognitive load theory claims that meaningful learning can only occur when the cognitive capacities of learners' working memory cannot be overburdened (van Merriënboer & Sweller, 2005). Similarly, Hattie (2012) cited in Krüger et al. (2022) reported that computer simulation has low effects on the learning process (d=0.33). Another study by Sanger and Greenbowe (2000), indicated that college learners did not need visual aids like computer simulation in their teaching-learning process. This is because; the learners are mature enough to visualize mentally the chemical process at a submicroscopic level.

In addition, Kirschner (2002) indicated that visual representations for instruction can burden the limited learners' working memory by imposing high intrinsic loads that affect conceptual understanding. Other scholars (e.g. Tversky, Morrison and Betrancourt (2002), indicated that animation-integrated instruction may not provide benefits over static graphics because animations are often complex, transitory, and fast-paced which increases the cognitive load in the learners' mind, causing difficulty in understanding the instruction. Scholars like Schnotz and Grzondziel (1996) and Mayer, Heiser, and Lonn (2001) indicated that learners who used animation achieved lower results in content questions and conceptual understandings, and caused learning impediments than static images.

As indicated, even though, most scholars agree that computer simulation and animation-integrated instruction enhances learning, some findings that do not support learning enhancement of computer simulations and animations. Therefore, there exists a lack of conclusiveness about the effect of simulation and animation-integrated instruction. In addition to this, most of the research was done mostly at the middle school and secondary school and rarely at primary school levels. To my knowledge, there are scarcities of such kinds of research among college pre-service teacher trainees, especially in the Ethiopian context. Therefore, this study intended to investigate the effect of computer simulation and animation-integrated chemistry instruction on pre-service science teacher trainees' conceptual understanding and retention. To this end, the study was designed to provide an authentic answer to the following research questions:

1. Do computer simulation and animation-integrated instruction affect learners' conceptual understanding of chemical concepts in acid-base chemistry and stoichiometry?
2. Do computer simulation and animation-integrated instructions cause gender differential effects on male and female learners' conceptual understanding of acid-base chemistry and stoichiometry?
3. Do computer simulation and animation-based instruction enhance learners' retention of chemical concepts in acid-base chemistry and stoichiometry?

2. Methodology

2.1. Research Method and Design

In this study, a quantitative research approach with a non-equivalent pretest-posttest-delayed test control group quasi-experimental design was employed. The quantitative research method was chosen as it helps to reduce prejudice, and the findings were presented in numerical formats that were mostly free of subjectivity. The study used a quasi-experimental design because the research participants were not assigned randomly into groups. After all, the researchers did not have the chance to form artificial groups. So naturally existing (intact) classes were used for the investigation technique(Creswell, 2014).

This study was conducted at Woldia College of Teachers Education (WCTE), Amhara Regional State, Ethiopia. It was conducted on pre-service science teacher trainees because the trainees are expected to be primary and middle school science teachers, which will have a great impact on the foundation of science education in general and chemistry education in particular. Moreover, the principal researcher could easily get permission from the college authorities and collaboration from the chemistry instructors to carry out the intervention. This collaboration could enhance and enrich the data by minimizing research administration constraints. In the college, there were 62 pre-service natural science teacher trainees in two sections (31:31) at the beginning of the 2022/2023 academic year. However, ten students were moved to

Ethiopian Universities for remedial program, and 52 (27:25) trainees left at the college. The study used all the 52 trainees in the two sections using a comprehensive sampling technique and these two intact classes were randomly assigned to IG and CG. The diagram at Figure 1 indicated that the main sequential stages undertake in the research design.

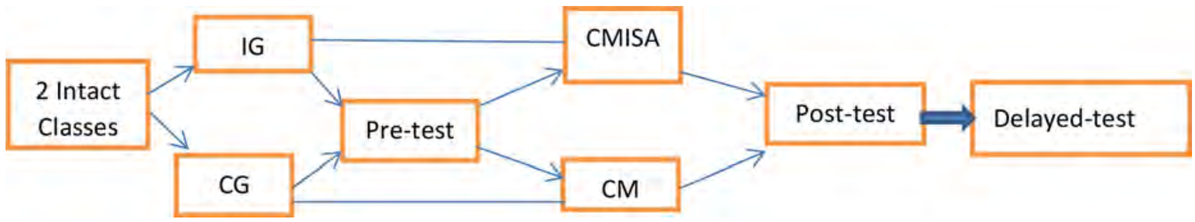

Figure 1. Research Design Flow Chart

2.2. Research Procedures

Before implementing the intervention, the college officials and the participant pre-service science teacher trainees signed the informed consent. The researcher adjusts a classroom having computers for IG by using the goodwill of the college dean and the department head. The researcher gave training to the course instructor about how simulation and animation can be integrated into the gapped lecture and cooperative lecturing method. The pretest was given to gather information about the conceptual understanding of the trainees before the intervention. An independent sample t-test was run to analyze this pre-test score and the result showed that there was no statistically significant difference in the mean score of the CG($M=22.96$, $SD=6.52$) and IG ($M=21.07$, $SD=6.71$); $t(50)= -1.03$, $p = .31$. This result showed that the IG and CG have similar pre-existing conceptual understandings about the general chemistry.

The two groups were taught acid-base chemistry and stoichiometry in a series of lessons. The topics covered during the instruction included in the acid-base chemistry and stoichiometry parts of the general chemistry course were; the nature and properties of acids and bases, dissociation of acids and bases, ionization constants of acids and bases, autoionization of water, hydrolysis of salts, methods of calculating pH and pOH, buffer solution, and quantitative relationship in chemical reactions(determining limiting reactants, excess reactants, theoretical yields, actual yields, and percentage yield). The comparison group was taught the selected topics through the conventional (cooperative and gapped lecture) methods alone, while the intervention group was taught the same topics with conventional methods integrated with computer simulation and animation, CMISA, which creates interactive lecture demonstrations. This means that the instructor used cooperative and gapped lecture pedagogy for both groups but employed computer simulation and animation-integrated approach for the IG. Fortunately, the two groups were taught the course by one instructor. The intervention stays for seven weeks, three hours per week, and the instructor prepared two types of lesson plans that showed the conventional approach and integration of simulation and animation into the conventional classroom.

Conventional method: In this method, the instructor taught the selected contents to the trainees in the comparison group through gapped lectures and cooperative instructional methods. Most instructors in the college usually use these two pedagogical methods.

Conventional method integrated with simulation and animation (CMISA): the instructor taught the selected contents to the trainees in the IG through the conventional method–integrated with simulation and animation that creates an interactive lecture demonstration. Samples of simulation and animation used during the instruction were given in Figure 2.

The simulation in Figure 2a showed that the pH of the acidic solution on the left side is 1.99 whereas the pH of the acidic solution on the right side is 4.50. The two solutions have similar concentrations but differ in strength, which indicates that pH is a measure of strength rather than concentration. Similarly,

Figure 2b indicates that the pH of a certain solution can be negative or positive depending on the concentration. On the left side of the workbench, the pH meter indicates the pH of 10MHCl is -1.00 whereas the right side workbench contains 10M NaOH and the pH meter indicates (reads) a pH value of 15.00. This concept widen the idea of the trainees bounded that pH runs from 0 to 14.

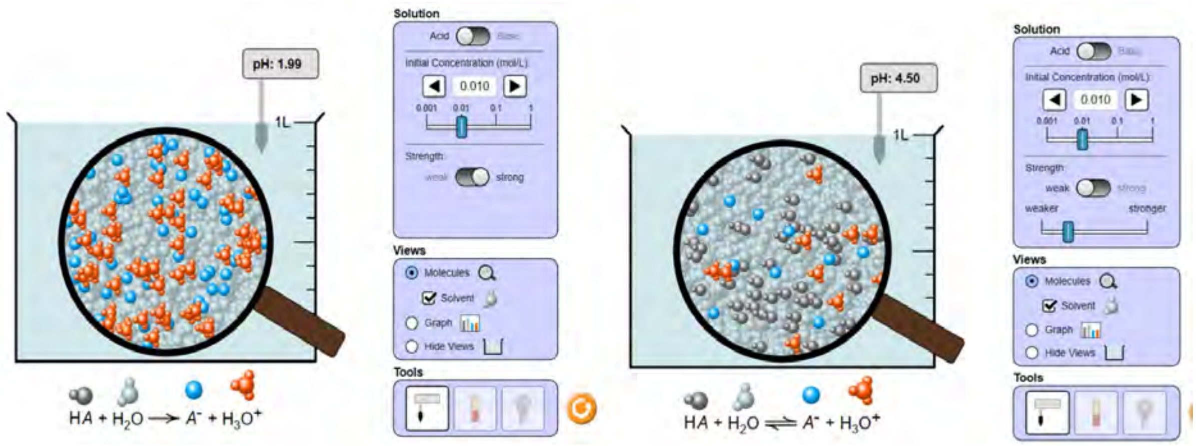

Figure 2a. Simulation that Shows pH is a Measure of Concentration but not Strength
(Downloaded from http://phet.colorado.edu)

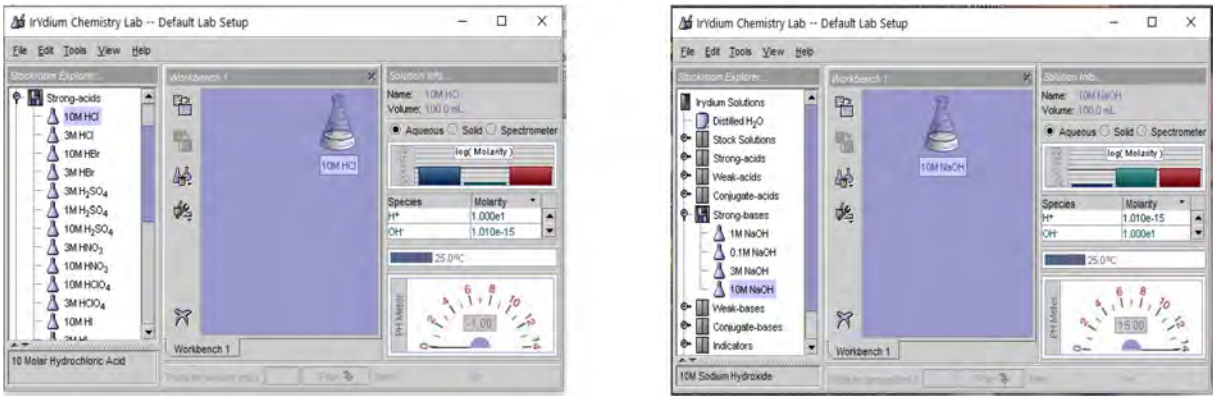

Figure2b. Simulation that Show pH can be Positive or Negative (Snapshot from Vlab Animation Software)

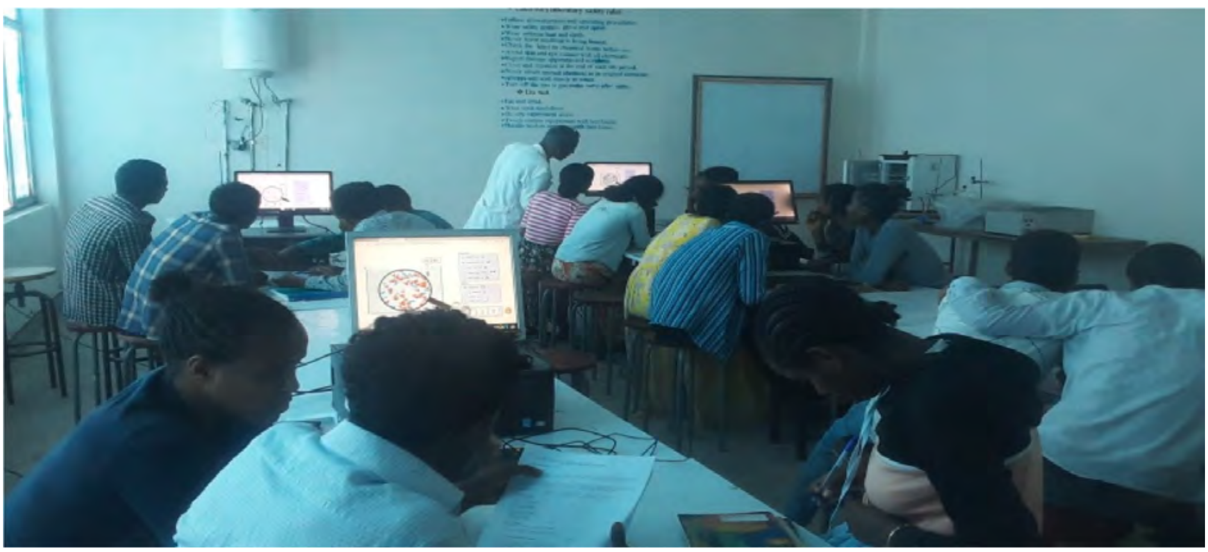

Figure2c. Snapshot of Actual Classroom Instruction of the IG

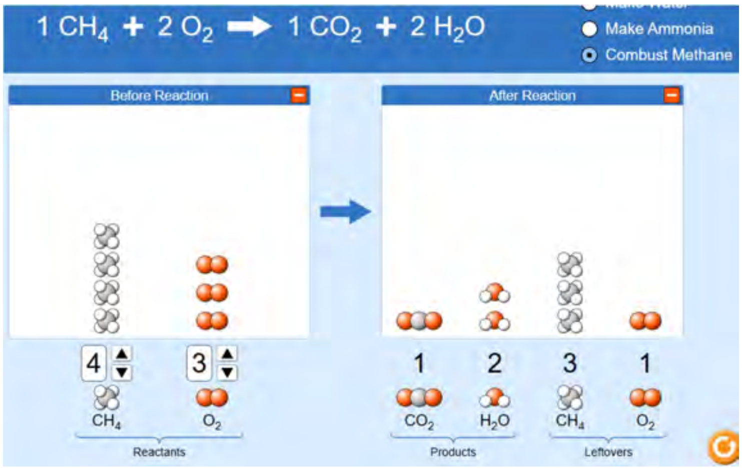

Figure 3. Sample of Simulation for the Concepts of Stoichiometry (Snapshot from PhET Simulation)

Figure 3 shows the symbolic and submicroscopic representation of the combustion reaction of methane. In the simulation, the trainees got the chance to visualize the submicroscopic aspects of the reaction and it helped the trainees to identify the concepts of limiting reactant, excess reactant, and leftover amounts.

After the completion of the intervention, the posttest was given to both groups to investigate the effect of the intervention on the conceptual understanding of acid-base chemistry and stoichiometry of pre-service teacher trainees. Finally, after four weeks of the post-test, a delayed test was given for both groups to check the retention capacity of the trainees in the intervention group relative to the comparison group. Designations of phrases were given in Table 1.

Groups	Pre-test	Intervention	Post-test	Delayed-test
IG	PrT_I	CMISA	PoT_I	DeT_I
CG	PrT_C	Conventional	PoT_C	DeT_C

Table 1. Representation of Nonequivalent Pretest-Posttest-Delayed Test Quasi-Experimental Design

Key: **CG and IG: C**omparison and Intervention group respectively.

PrT_I and PrT_C: Pre-test for intervention and comparison group respectively.

Conventional Method: Gapped lecture and cooperative learning approach usually applied at the college.

CMISA: Conventional Method Integrated with Simulation and Animation.

PoT_I and PoT_C: Post-test for intervention and comparison group respectively.

DeT_I and DeT_C: Delayed –test for intervention and comparison group respectively**.**

2.3. Population, Sample Size and Sampling Technique

The number of pre-service science teacher trainees registered at the natural science department of WCTE in the 2022/2023 academic year was 62 and they were assigned into two sections by the College registrar. However, the number of trainees who participated in this study was 52, because the rest 10 trainees were shifted to Ethiopian Universities to join the remedial program. Due to the presence of a small population of trainees in the natural science department at the WCTE, the study used a comprehensive sampling technique, which allowed us to include the entire population as research participants. So the two intact sections were assigned as IG (n=27) and CG (n=25).

2.4. The Situation of Potential Contamination

To limit the scope of possible contamination, the principal researcher analyzed the participant trainees' background experience in computer simulation and animation in a face-to-face discussion. In the discussion, the researcher confirmed that the trainees lack important prior information, which may cause contamination between the groups. Furthermore, none of the trainees had a personal laptop, and they had no opportunity to utilize a desktop computer at the college except in the controlled information technology laboratory. Furthermore, the principal researcher informed the comparison group that simulation-integrated instruction would be provided for them at the end of the intervention to prevent psychological stress. Based on the information gathered from the trainees, the researchers assumed that any physical interaction between the two groups should not create meaningful contamination.

2.5. Data Collection Tool

The data collection tool was Acid-Base and Stoichiometry Conceptual Understanding two-tier 20 multiple-choice Test (ABSCUT). The test was prepared from the subtopics; acid-base definitions, natures and properties of acids and bases, autoionization of water, pH determination, dissociation of acids and bases, determination of limiting and excess reactants, microscopic representation of molecules, a quantitative relationship of reactants and products, meanings and proprieties of buffer solution and the principles of acid-base dilution. The test was prepared based on the principles of two-tier test construction and test item specification. In this case, the first tier focused on the concepts associated with selected topics with two to four alternatives, and the second tier focused on the reasoning ability to diagnose their conceptual understanding and has three to five alternatives (including one blank space as an alternative). ABSCUT was developed based on David Treagust's steps (Duit & Treagust, 1995; Treagust, 1986, 1988, 1995). The procedure includes three phases and ten steps, the first phase with four steps, the second phase with three steps, and the third phase with three steps. The details have given in Table 2.

Phase	Title	Steps
I	Defining the Content	1. Identify the prepositional knowledge statement about acid-base and stoichiometry 2. Develop a concept map for acid-base and stoichiometry 3. Relate propositional knowledge to the concept map 4. Content validation
II	Obtaining alternative conception	5. Review related literature about acid-base and stoichiometry 6. Conduct interview(use personal experience) about the difficulties of the selected contents 7. Conduct multiple-choice content items with free responses (using personal experience)
III	Developing instrument	8. Develop 20 two-tier items 9. Design a table of specifications about the identified propositional knowledge statements 10. Refine the test and make it ready for the implementation

Table 2. Steps Used for the Preparation of ABSCUT Adapted from (Treagust, 1988)

2.6. Validity and Reliability of the ABSCUT

2.6.1. Validity

Two college chemistry lecturers evaluated the content validity of the test while two educational psychologists who were college lecturers and two English language lecturers checked the face validity of the test. The judgments from the lecturers showed eighteen questions from the two tiers were essential to measure the intended objectives and the rest two questions were useful but needed minor revision to be essential. Therefore, the content validity ratio(CVR) of each question was calculated using Lawshe's principle and found to be 0.99 (Lawshe, 1975). Finally, the research supervisors checked the validity of the test and their comments were included.

2.6.2. Reliability

Piloting was conducted on 24 second-year university students, who took acid-base chemistry and stoichiometry as part of their general chemistry course, to examine the reliability (internal consistency) of the two-tier ABSCUT instrument. The data obtained from the piloting was converted to dichotomous data (correct and incorrect approaches) and could be investigated to determine the internal consistency of the tool using the Kuder-Richardson formula (KR20). The Kuder-Richardson formula (KR20) is the best acceptable method for evaluating the internal consistency of objective test questions that will be recorded as correct and incorrect approaches (Ajayi, 2017). The reliability coefficient value, KR20, was found to be 0.80 for the first and 0.77 for the second tier, respectively. Item analysis was computed for the piloted test to check items' difficulty and discrimination levels and the analysis results were given in Table 3. This table showed that most of the ABSCUT items were well discriminating and had medium item difficulty levels in both the first and the second tiers. Two items of the test were reconstructed to remove their ambiguity.

Item analysis Category	**First tier (20 items)**		**Second tier (20 items)**	
	Item difficulty level	**Item discrimination**	**Item difficulty level**	**Item discrimination**
<0.33	(2 items) Less difficult	(3 items) Undiscriminating	(2 items) Less difficult	(5 items) Less discriminating
0.33-0.67	Medium(13 items)		Medium(13 items)	
>0.67	(5 items) Very difficult	(17 items) Well discriminating	(5 items) Very difficult	(15 items) Highly discriminating

Table 3. Item Analysis Results for the pilot test of the ABSCUT

2.7. The Scoring Methods of ABSCUT

There are four main sorts of responses for correct and wrong answers for a two-tier multiple-choice test items pair. Among these, getting both answers incorrect is the lowest level of student understanding, while getting both answers correct is the highest level of understanding and the two intermediate categories are incorrect and correct; correct and incorrect answers, as given in Table 4. Moreover, the scoring of this research employed partial credit scoring of grade response model method result obtained from a two-tier acid-base and stoichiometry conceptual understanding test (Dawati, Yamtinah, Rahardjo, Ashadi & Indriyanti, 2019; Satriana, Yamtinah & Indriyanti, 2018; Zhou, Liu, Koenig, Li, Xiao & Bao, 2021).

Answer		
First Tier	**Second Tier**	**Scores**
Correct	Correct	3
Correct	Incorrect	2
Incorrect	Correct	1
Incorrect	Incorrect	0

Table 4. Scoring Category of Two-Tier Test Item (Dawati et al., 2019; Satriana et al., 2018)

2.8. Data Analysis Techniques

The data collected using ABSCUT was analyzed by descriptive and inferential statistical techniques using SPSS version 26. This study employed parametric data analysis techniques, particularly independent sample t-test and ANCOVA. Since the collected data met the assumptions of normally distributed, homogeneity of variance, homogeneity of slops, and commonly known simple assumptions, parametric statistics (independent sample t-test and ANCOVA) were used. The Independent samples t-test was used to test Statistical differences between the means scores of the two groups and gender in the IG before the intervention. The ANCOVA was employed to compare the post-test and delayed-test scores of the comparison and the intervention groups and genders in the IG using the pre-test scores of the group as a covariate to control the pre-test sanitization effect on the dependent variable (post-test scores and delayed test).

3. Results of the Study

This study was intended to investigate the effect of integrating computer simulation and animation-based instruction into conventional classroom instruction (cooperative and gapped lecture method) on learners' conceptual understanding and retention.

3.1. The Pre-ABSCUT Score Analysis

Before the implementation of the intervention, the pretest was administered to both groups to compare whether or not learners in the two groups were different in their conceptual understanding. After checking the homogeneity of variances of the pretest in Levene's test (equal variances were assumed), an independent sample t-test was computed to investigate whether or not a significant mean score difference exists between the CG and IG in conceptual understanding of acid-base chemistry and stoichiometry. The descriptive and inferential statistics results were given in Table 5 and Table 6.

Table 5 showed that the pre-ABSCUT mean scores of the trainees in the intervention and the comparison group before the intervention. As indicated the mean score of the comparison group is higher than the mean score of the intervention group.

Table 6 revealed that Levene's test for equality of variances indicated that there was no significant difference in the variances of the two groups (Sig. value = .971 is greater than p = .05) and therefore, equal variance is assumed. The t-test for the equality of means also indicated that there was no significant difference in the mean score of the CG (M = 22.96, SD = 6.52) and IG (*M=21.07, SD = 6.71*); t(50) = -1.03, p = .31.

Group Statistics					
Participants' Groups		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Pre-Abscut Score	Intervention	27	21.07	6.714	1.292
	Comparison	25	22.96	6.522	1.304

Table 5. Descriptive Statistics for Participant Groups

Levene's Test for Equality of Variances		t-test for Equality of Means						
							95% Confidence Interval	
F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
0.001	.971	-1.026	50	.310	-1.838	1.875	-5.578	1.806

Table 6. Independent Sample T-test of Pre-ABSCUT Scores Analysis of Participant Groups

The pre-ABSCUT score analysis also used to check whether a significant mean scores difference exists between male and female trainees in the CG or not, using the independent sample t-test which was given in Table 7 and Table 8.

Table 7 shows that the pre-ABSCUT mean scores of male trainees in the intervention group is higher than the mean scores of their counterparts of female trainees.

Table 8 revealed that Levene's test for equality of variances indicated no significant difference in the variances of males and females in the intervention group. Moreover, the t-test for the equality of means indicated that there was no statistically significant difference in the mean score of the males (M = 23.36, SD = 6.57) and females (M = 18.62, SD = 6.18); t (25) = 1.93, p = .065.

	Sex	N	Mean	Std. Deviation	Std. Error Mean
Pretest Score	Male	14	23.36	6.57	1.76
	Female	13	18.62	6.18	1.72

Table 7. Gender-wise Descriptive Statistics of Pre-ABSCUT for the Intervention Group

Levene's Test for Equality of Variances			t-test for Equality of Means						
								95%Confidence Interval	
Assumption	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Equal variances assumed	.044	.836	1.93	25	.065	4.742	2.461	-.326	9.809

Table 8. Independent Sample T-test of the Pre-ABSCUT between Genders in the Intervention Group

3.2. Findings of the Post-ABSCUT Scores Analysis

3.2.1. Effect of Simulation and Animation Integrated Instruction on Conceptual Understanding

After the intervention was completed, slightly modified ABSCUT was administered to both groups as a posttest. The result was analyzed using ANCOVA to compare the intervention and the comparison groups to see whether or not the pre-service science teachers trainees' conceptual understanding in the two groups had statistically significant differences due to simulation-based intervention. To do this, preliminary checks were conducted to ensure there was no violation of assumptions of normality, linearity, homogeneity of variance, homogeneity of regression slopes, and reliable measurement of the covariate. The results of the preliminary check analysis showed that there was no violation of assumptions. The descriptive and inferential statistical results of the ANCOVA were given in Table 9 and Table 10.

Table 9 indicated the post-ABSCUT mean scores of the trainees in the intervention and the comparison group after the intervention. The result showed that the mean score of the IG is higher than the mean score of the CG.

The ANCOVA results in Table 10 indicated that the covariate (pretest) significantly influenced the post-ABSCUT (sig. value=0.02, which is less than the alpha value). The ANCOVA results from between-subject effects of post-ABSCUT indicated that there was a statistically significant difference between the intervention and comparison groups for the post-ABSCU after controlling the pretest score (covariate)(the Sig. = .029, which is less than the alpha value). The partial eta squared value (.094 or 9.4%) indicated that a medium effect size was observed based on the guideline that indicated .138 or 13.8% is a large effect size (Cohen, 1988).

Groups	Mean	Std. Deviation	N
Intervention	35.67	6.019	27
comparison	32.28	7.226	25
Total	34.04	6.779	52

Table 9. Descriptive Statistics for Post-ABSCUT Scores Between Groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	380.033	2	190.016	4.741	.013	.162
Intercept	2994.229	1	2994.229	74.707	.000	.604
pretest	231.150	1	231.150	5.767	.020	.105
groups	203.305	1	203.305	5.073	.029	.094
Error	1963.890	49	40.079			
Total	62592.000	52				
Corrected Total	2343.923	51				

$\alpha = 0.05$

Table 10. Tests of Between-Subjects Effects of the Post-ABSCUT for the Two Groups

Figure 4 indicated that the mean score of the IG was higher than the maximum score of the CG after adjusting the effects of the covariate.

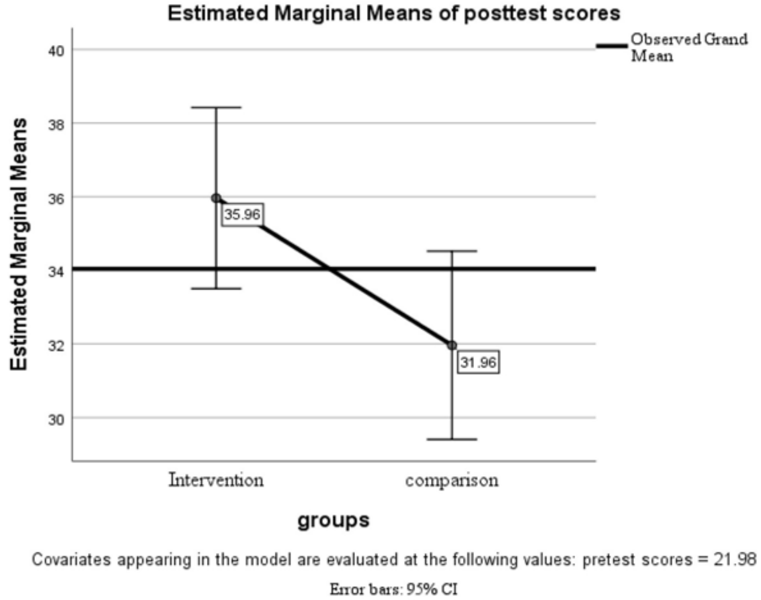

Figure 4. Estimated Marginal Means of the Post-test Scores

3.2.2. Gender Differential Effect of Simulation and Animation-Integrated Instruction

The intervention group's post-ABSCUT data was analyzed to investigate the gender differential effect of conventional method integrated with simulation and animation on pre-service science trainees' conceptual understanding of acid-base chemistry and stoichiometry. The descriptive and inferential statistics of the ANCOVA results were given in Table11 and Table 12.

Table 11 shows that the post-ABSCUT mean score of male trainees in the intervention group is higher than the mean scores of their counterparts of female trainees.

The ANCOVA results for the post-ABSCUT between genders of the IG indicated the sig. value was .065, which is greater than the alpha value. This result indicated that there was no statistically significant difference between males and females in the post-ABSCUT after controlling for the pretest score (covariate).

Sex	Mean	Std. Deviation	N
Male	37.79	7.192	14
Female	33.38	3.404	13
Total	35.67	6.019	27

Table 11. Descriptive Statistics of the Post-ABSCUT Score of Genders in the Intervention Group

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	132.379	2	66.189	1.962	.162	.141
Intercept	2837.410	1	2837.410	84.111	.000	.778
Pretest	1.813	1	1.813	.054	.819	.002
Gender	124.239	1	124.239	3.683	.067	.133
Error	809.621	24	33.734			
Total	35289.000	27				
Corrected Total	942.000	26				

$\alpha = 0.05$

Table 12. Tests of between-Subjects Effects Post-ABSCUT of Gender the Intervention Group

3.2.3. Effect of Simulation and Animation Integrated Instruction on Retention

After the post-ABSCUT- four weeks later- slightly modified ABSCUT was administered to both groups as a delayed test. The result was analyzed using ANCOVA to investigate the retention capacity of trainees in the IG because of CMISA instruction. The ANCOVA results of the analysis were given in Table 13 and Table 14. Table 13 shows the delayed –ABSCUT mean scores of trainees in the intervention and the comparison groups. The results indicated that the mean score of the intervention group was higher than the mean score of the comparison group. Table 14 revealed that the existence of a noted difference between the mean retention score of trainees taught using CMISA and those taught using the conventional method is significant at 0.05 alpha levels (Sig. value is .045).

Groups	Mean	Std. deviation	N
Intervention	33.89	7.949	27
Comparison	28.20	6.733	25
Total	31.15	7.860	52

Table 13. Descriptive Statistics of the Delayed- ABSCUT for the two groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1063.722	2	531.861	12.487	.000	.338
Intercept	293.491	1	293.491	6.891	.012	.123
Posttest(covariate)	643.619	1	643.619	15.111	.000	.236
groups	180.657	1	180.657	4.241	.045	.080
Error	2087.047	49	42.593			
Total	53620.000	52				
Corrected Total	3150.769	51				

$\alpha = 0.05$

Table 14. ANCOVA for Tests of Between-Subjects Effects of Delayed-ABSCUT of the Two Groups

4. Discussion of the Findings

In this study, a pretest was administered to investigate the prior conceptual understandings of pre-service science teacher trainees about acid-base chemistry and stoichiometry. The pretest result indicated that there was no statistically significant difference between the intervention and comparison groups in conceptual understanding. After a seven-week intervention, the posttest was administered and the result was presented in the data presenting section, and showed three main findings. The first finding indicated that integrating computer simulation and animation in to a conventional method i. e CMISA, tends to enhance the conceptual understanding of college pre-service trainees; the second finding implied that CMISA enhances the retention capacity of the trainees. The third finding implied that gender does not have differential effects on simulation and animation-integrated instructions.

Accordingly, the first research question, which stated as- do computer simulation and animation-integrated instruction affect learners' conceptual understanding of chemical concepts in acid-base chemistry and stoichiometry?- was answered by the results presented in Table 10. The finding indicated that computer simulation and animation-integrated instruction significantly enhanced the conceptual understandings of the pre-service trainees. The posttests mean score of the intervention group was higher than the mean score of the comparison. It was found that the difference was statistically significant at alpha value of 0.05. The finding of this study was consistent with the finding of Engida (2017), which indicates integrating computer-based technology with pedagogy helps learners to conceptualize the abstract concepts of chemistry. The current research finding is also consistent with the finding of Plass et al. (2012), which showed that the effectiveness of simulation for chemistry learning and their result indicated that students gain better comprehension of the difficult questions and lower prior knowledge learners were more advantageous than others. Other scholars indicate the integration of technology in chemistry instruction provides a multisensory stimulus and is used in the process of understanding learners' chemical concepts at all levels of representations of chemical phenomena (Barnea & Dori, 1996). These different studies and the current findings showed that appropriate utilization of scholar computer simulation and animation-integrated instruction enhances the conceptual understandings of the trainees.

However, some findings were conflicting with the current research findings. For example, the findings of Winberg (2006) indicated that the use of simulation as an instruction creates multimodal representation, causes split attention, and increases cognitive load on learners. Another study by Kirschner (2002) indicated that visual representations for instruction can burden the limited learners' working memory by imposing a high intrinsic load that affects conceptual understanding. The research finding by Sanger and Greenbowe (2000), indicated that college learners did not require visual aids like computer simulation in their teaching-learning instruction. This is due to college learners being mature enough to understand chemical concepts without aids. Other scholars (e.g. Tversky et al. 2002) indicated that animation-based instruction may not provide benefits over static graphics because animations are often complex, passing, and fast-paced which increases the cognitive load in the learners' minds and causes difficulty in understanding the instruction. Scholars like Schnotz and Grzondziel (1996) and Mayer et al. (2001) indicated that learners who used animation achieved lower results in content questions and conceptual understandings, and caused learning impediments than static images.

The second research question, which stated as- do computer simulation and animation-integrated instruction cause differential effects on male and female learners' conceptual understanding of acid-base chemistry and stoichiometry?- was answered by the summary results of ANCOVA in Table 12. Eventhough the mean score of male students was higher than the mean score of female students as indicated in Table 11, the difference was not statistically significant at alpha value of .05 as shown in Table 12 ANCOVA results. This result was consistent with the findings of Mihindo et al. (2017), Nkemakolam et al. (2018), Poripo (2008), Adesoji and Babatunde (2005), Sentongo et al. (2013), and Ezeudu and Ezinwanne (2013) which, indicated that simulation-based chemistry instruction do not have significant difference in mean scores between male and female students. This means that simulation and animation-integrated instruction do not cause gender stereotype rather it services male and female trainees in similar manner. However, the current finding contradicted the findings of Chen and Howard (2010) which, indicated that male students show a more positive learning approach toward simulation-based chemistry instruction. Similarly, Nduudee and Arokoyu (2021) showed that male students were more advantageous than female students in simulation-modeled chemistry instruction at secondary school.

The third research question, which reads- do computer simulation and animation-based instruction enhance learners' retention of chemical concepts in acid-base chemistry and stoichiometry?- was answered by the ANCOVA results analysis presented in Table 14. The finding indicated that CMISA-based chemistry instruction enhances the retention capacity of the trainees. This research finding is consistent with the findings of Nduudee and Arokoyu (2021), who indicated that CMIAS-based instruction provides opportunities for learners to construct meanings and understand difficult concepts more easily by creating an interactive learning environment and enhancing retention. The current finding is also consistent with the findings of Hussain et al. (2017), who indicated that technology-based chemistry instruction enhances students' retention.

Even though some scholars' research findings disagree with the current research findings, the researchers want to emphasize that proper and effective integration of computer simulation and animation into conventional classrooms has a positive effect on the trainees' chemistry conceptual understanding and retention. The emphasis also extended to remark gender differential effects have no statistically significant effect on computer simulation -based chemistry instruction. The difference between those studies and the current study may be the result of contextual and methodological differences between those studies and the current study that might be one potential research area in the future.

5. Conclusion and Recommendation

5.1. Conclusion

This study investigated the effect of computer simulation and animation-integrated instruction on pre-service science teacher trainees' conceptual understanding and retention capacity using pretest-posttest-delayed test quasi-experimental design. When the pre-test results were compared between the IG and CG, there was no statistically significant difference observed between the two groups. However, when the post-test and delayed test scores were compared, the scores of the intervention group showed a statistically significant difference from the comparison group, in favor of the IG. This means that trainees in the IG who taught the provided topics using computer simulation and animation-integrated instruction showed enhanced conceptual understanding than trainees in the CG who were taught with conventional (cooperative and gapped lecture) methods of chemical concepts. Furthermore, the findings also indicated that simulation and animation-integrated instruction enhance the concept memorization or retention capacity of the trainees. This enhancement is due to the characteristics of computer simulation and animation-based instructions, which are used to grasp the intentions of the trainees and create mental images. The findings of the current research also indicated that simulation and animation-integrated instruction did not result in gender disparity in terms of conceptual understanding and retention capacity. Some research findings indicated that college students might not need simulation and animation-based instructions because they are mature enough to understand the concepts to be disclosed. However, the current research concludes that simulation and animation-based instruction are more likely enhance the learners' conceptual understanding ability and concept retention capacity than conventional instruction, which usually employs static pictures.

5.2. Recommendation

Based on the findings of this research, the researchers suggest their recommendations to the concerned bodies such as policymakers, curriculum designers and developers, and others. To this end: Policymakers, chemistry curriculum developers, chemistry curriculum materials producers, and practitioners alike can consider the application of computer simulation and animation-integrated chemistry instruction to enhance learners' conceptual understandings and retention. Chemistry curriculum designers and developers should integrate this strategy into the curriculum flow chart, curriculum guidebook, and syllabus in order to incorporate it into the chemistry teaching materials.

5.3. Limitations of the Study

The limitation associated with this study was the sample size, as it used a quasi-experimental design; the sample size affects the external validity and, therefore, it would affect the external validity when attempts are made to generalize the current finding externally to other similar contexts.

Declaration of Conflicting Interests

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