

# The Effectiveness of Computer-Based Simulations and Traditional Hands-on Activities on Secondary School Students' Performance and Science Process Skills in Practical Chemistry

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## Abstract

Practical activities are used as a catalyst in understanding chemistry concepts because it helps students to develop science process skills. However, research investigating the use of computer-based simulation practical activities to improve students' science process skills is scarce. Hence, the study compared the mean gain of students' performance and science process skills (SPS) using computer-based simulation and traditional hands-on instructional strategies. The study utilized a quasi-experimental design, using a pre-test, post-test, and control variable. The sample for the study was 92 senior secondary students, 48 for the computer-based simulation (experimental) and 44 for the traditional hands-on (control group) purposively selected. Two research instruments were used, a tagged science process skills rating scale (SPSRS) and a 20-item multiple choice question (MCQ). The findings showed that traditional hands-on activities had a higher mean gain on students' performance while computer-based simulation improved students' science process skills more than traditional hands on. The study recommended that there is a need to blend traditional hands-on activities with updated and computer-based simulations to improve students' science process skills and performance in science classrooms.

**Keywords:** computer-based simulation, traditional hands-on activities, performance, science process skills

## 1. Introduction

Nigeria, a developing nation, has embraced science and technology to allow for its growth and productivity (Agbaje & Alake, 2014; Ifamuyiwa & Alebiosu, 2008). According to Nigeria's national education policy, the primary goal of science education is to prepare students to live effectively in the modern era (FRN, 2013). This can be accomplished by teaching students the necessary scientific skills in subjects like chemistry. A nation's progress is essentially dependent on the chemical composition of the environment we live in. The proper teaching and learning of chemistry as a core science subject make it easier for students to enroll in many professional fields at higher educational institutions.

Despite the significance of chemistry in science development, the performance of students in the subject at the senior school certificate examination (SSCE) has been inconsistent in both internal and external examinations (Giginna, 2013). There has been a wide cry each year when the West African Examination Council (WAEC) and National Examination Council (NECO) released their results for better performance, especially in the practical aspect of the exam (Salami, Mohammed, & Ogunlade, 2012). The practical

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aspect of chemistry entails experimental work carried out within or outside the laboratory to do carryout results that can be used to learn and understand theoretical chemistry concepts practically. Meanwhile, many authors have considered practical activities to be crucial to the chemistry curriculum and the backbone of science subjects (Abonyi, 2014; Aktamis & Ergin 2008; Fadzil & Saat, 2013; Hofstein & Lunetta, 2004; Ozgelen, 2012; Schwichow, Zimmerman, Croker, & Hartig, 2016). Roberts (2008) also designed a booklet on high-quality practical activities in science. This is because practical work assists in arousing and sustaining the students' interest as well as cultivating a scientific attitude toward chemistry and its related phenomena (Hofstein & Lunetta, 2004). While carrying out practical activities, the students get an opportunity to develop their abilities to design, conduct, interpret, and report scientific investigations. Through these, students can better grasp scientific ideas and develop an interest in chemistry when practical science is taught with creativity and expertise. The empirical underpinnings of scientific inquiry are taught to students through practical science, which is also a crucial component of scientific knowledge. However, practical work in most Nigerian laboratories is confronted with a variety of issues, including the fact that ineffective instructional strategies that do not foster science process skills are being employed. Research studies (Samuel & Ukpoh, 2021; Opataye, 2009) have reported that students who fail chemistry lack science process skills like observations, manipulation of equipment, inferences, and prediction in practical activities. Aktamis and Ergins's (2008) study reveals that the development of science process skills (SPS) contributes to the overall enhancement of students' performance in science and other subject areas. The scientific method, scientific thinking, and critical thinking have been used at various times to describe these scientific skills. Popularized by the curriculum project Science: A Process Approach (SAPA), these skills are defined as a set of broadly transferable abilities appropriate to many science disciplines and reflective of the behavior of students.

Science process skills (SPS) are also defined as the adaptation of the skills used by scientists for composing knowledge, thinking about problems, and drawing conclusions (Sahin, et al. 2008). They are also the abilities everyone is supposed to possess in a science-based community as a science-literate person (Temiz, 2007). Ajunwa (2000) observed that science process skills have a general commonality in all science subjects, serving as tools for information gathering, problem-solving, decision-making, and adaptation. Science process skills are classified as basic (observing, measuring, classifying, collecting data, and using number relationships), casual (predicting, identifying variables, and drawing a conclusion), and experimental (forming hypotheses, making models, experimenting, controlling variables, and deciding). Sevilay (2011) posited that the mastery of science process skills enables students to conceptualize, at a much deeper level, the content they know and equips them for acquiring content knowledge in the future. The skills facilitate learning in the physical sciences and ensure active participation by students in practical situations. Science process skills are inseparable in practice from the conceptual understanding that is involved in learning and applying science. Nevertheless, it is useful to identify and discuss the instructional approaches teachers can employ in different science subjects to promote these skills in students.

During chemistry teaching and learning, effective instructional strategies that engage students in science practical activities like traditional hands-on are essential for the development of science process skills. Alkan (2016) discovered that when learners are fully engaged in traditional hands-on activities, they are likely to appreciate and learn what they are being taught theoretically. Hands-on activities are any activity that allows students to use their hands to carry out experiments in the laboratory. In hands-on activities, learners interact with equipment and materials. Oludipe et al. (2020) describe hands-on activities as a method of teaching whereby students are actively engaged in class activities with the use of their hands and intellect under the guidance of a teacher. Archarya (2019) highlighted that those hands-on activities had a high degree of positive effect on students' achievement. Practical work as hands-on activities allows students to absorb more information by doing rather than listening or seeing. According to Sreelekha (2018), hearing alone may give room for forgetfulness, while seeing promotes retention, and doing brings about an understanding of concepts. Modern science teaching emphasizes a hands-on approach as well as students' active

participation. Through hands-on activities or labs, students explore, manipulate, and make connections between concepts with concrete manipulatives. Laboratories provide students with the opportunity to develop problem-solving and science process skills. Active participation of students in science lessons is also important as it tends to instill discipline and students' management problems. Activity-based science programs that provide students the opportunity to interact with objects and materials are often recommended to teachers on the grounds that they improve scientific skills.

However, recently, due to the limited time, space, resources, and apparatus, it has become impossible to engage students in traditional hands-on activities all the time. Therefore, there is a need for an alternative lab where practical steps in videos can be shown on computers or phones. Alternative labs involve blending texts with multimedia, meeting curriculum objectives, and using simulations to aid in the demonstration. The computer is used to aid in graphical displays, calculations, animations, simulations, and gaming. The use of computers in the form of simulation, for instance, not only helps with students' understanding of content but also positively impacts their engagement in lessons and their attitude toward learning.

Simulations have been given different meanings by different authors; however, in a broad sense, simulations are imitations of systems. Simulations are computational models of real or hypothesized situations or natural phenomena that allow users to explore the implications of manipulating or modifying parameters within them. They are also tools that facilitate learning through representation and practice in a repeatable, focused environment (Aldrich, 2004). Computer-based simulations are therefore computer-generated versions of real-world objects. They provide a near-authentic environment, context, and situation for task-based learning. Computer simulations enable learners to view events, processes, and activities that otherwise may not have been available to them through interactive engagement. It is believed that simulations are effective in the process of enhancing students' performance, self-efficacy, and scientific skills. Also, in computer-based simulation, it is possible to perform dangerous experiments without endangering oneself or others. The equipment required to perform the hands-on activity is physically set up, and the students who perform the activity are asked to be physically present in the laboratory. Computer-based simulations protect students and teachers from hazards, given that there is no direct contact with toxic or radioactive chemicals. They also provide flexibility in performing experiments. Exposure to hazards may discourage female students from partaking in traditional hands-on practical activities. Though, recently, Nwosu and Ndanwu (2020) have proven that there is no significant difference between the genders in terms of intelligence, there is still the belief that male students feel more comfortable working with "dangerous ventures" than female students.

There have always been concerns about female underrepresentation and underachievement in science (Gipps, 2004). Gender has remained a copying issue and has likewise remained applicable in schooling since it has been linked to achievement and participation in certain professions (Ventura, 2008). However, there have been conflicting findings on how gender influences the type of instructional method that should be used in the classroom. While Kabigting's (2021) results showed that there was a significant relationship between the sex and performance of the student respondents who were exposed to the computer simulation method while the performance of the male and female student respondents exposed to the conventional lecture method did not differ, Nwosu and Ndanwu's (2020) results found that there was no significant interaction effect of teaching method and gender on the mean interest scores of students in electronic libraries. It seems the influence of gender varies according to the type of instructional strategy employed for school subjects (Afuwape, & Olatoye, 2004). In addition, previous studies also suggest that there is a dissimilarity in science process skills between male and female students, which leads to students' low performance.

Despite the advantages of computer-based simulations, traditional hands-on activities remain tremendously important because the acquisition of manipulative skills is only possible using real instruments and real experimental data. Thus, this study

investigates which of the two will better improve students' performance and science process skills. The present study is important, given the acceptability and popularity of simulation-based teaching in various educational settings, as it examines the role that gender may play in explaining students' engagement with computer-based simulation-based learning processes.

## 2. Literature Review

Recently, it has become more challenging to include all students in traditional hands-on activities constantly due to the restricted time, space, resources, and equipment. There is a demand for an alternate lab where users may see practical instructions via videos on desktops or mobile devices. Alternative labs use multimedia with texts, curricular goals, and simulations to help with the demonstration. Graphical displays, computations, animations, simulations, and games are all aided by computers. These simulations' usage on computers, for instance, not only aids in students' conceptual comprehension but also has a favorable effect on their involvement in scientific skills and attitude. Though, computer simulations cannot be considered an equivalent replacement for hands-on laboratory experiences. Emerging research shows that computer-based simulation labs can be used as alternative labs where materials and equipment are used safely, and students' experiences are guided. The present study proposes that computer-based simulations can be used in conjunction with hands-on labs and activities to address students' science process skills and the literature review is targeted toward studies that address the concepts targeted by the simulation to support students' science learning.

### 2.1 Computer-Based Simulation

Computer-based simulations are digital recreations of actual items for task-based learning. They offer a setting, context, and scenario that are remarkably genuine. With the use of computer simulations, students may see events, procedures, and activities that they otherwise might not have had access to through direct interaction. Simulations are seen to be useful in raising students' performance, self-efficacy, and scientific aptitude. The use of computer simulations is changing the very nature of scientific works and providing unique insights into the way the world works (Nxumalo-Dlamini & Gaigher, 2019). The use of computer simulations is changing the very nature of scientific works and providing unique insights into the way the world works (Nxumalo-Dlamini & Gaigher, 2019). To engage students in the authentic making of science, many science educators have begun using models and simulations in the classroom as well (Feurzeig & Roberts, 2000; Nxumalo-Dlamini & Gaigher, 2019).

The authors pointed out some potentials of computer-based simulations:

1. They allow students to do more complicated and hazardous experiments;
2. They allow students to obtain reproducible results quickly;
3. They also foster a deep understanding of the experiments;
4. They are economical in terms of money.

The study conducted about computer-based simulations and their impacts on students' performance and attitude in chemistry revealed that they increase the knowledge of all learning groups, pre-test, and post-test results showed that this learning method improves the students' comprehension of science concepts.

Computer-based simulations help to visualize abstract learning topics, including the movements of electrons, chemical reactions, and reaction mechanisms (Lou, et al. 2005). The students who were taught using this method receive higher scores than those who were taught by using more traditional teaching methods.

Thompson and Dass (2000) found that students who were engaged in the simulations showed an increase in self-efficacy that was significantly larger than gains due to learning by the case method approach. Mohafa et al. (2022) reported that simulations enhanced students' performance. Furthermore, Jabeen and Afzal's (2020) result of an independent sample t-test indicated that there was a significant difference between the performance of the control group and the experimental group in favor of the experimental group (simulation).

Ulukök and Sari (2016) interview of preservice teachers revealed that computer-assisted laboratory applications had a significant effect on preservice teachers' attitudes toward science teaching. Moreover, they mentioned that simulations were effective for their learning, supported their knowledge, and affected their attitude and motivation toward the lesson in a positive way. Overall, simulations are more effective at enhancing performance and skills compared to non-simulations in practical classrooms, as they also allow students to experiment with trial and error several times without or with reduced cost implications.

## 2.2 Traditional Hands-On Activities

This is a method whereby chemistry students for the present study are engaged actively in laboratory activities with the use of their hands under the guidance of the teacher. Hannel and Cuevas (2018) describe hands-on activities as a method of instruction where a learner uses his/her hands in carrying out laboratory activities that would enhance his/her learning experiences. By implication, laboratory activities are activities that involve using laboratory apparatus. These include weighing, measuring, demonstrating, and carrying out chemical experiments/tests and any other activities that could enhance students' achievement and retention.

Oludipe et al. (2020) describe hands-on activities as a method adopted by a teacher to teach through activities in which the students participate thoroughly and bring about an efficient learning experience. It is a method in which the child is actively involved both mentally and physically. Learning is the main focus of this method and the more a person learns the longer he/she retains. It means an organized behavior that the teacher and student engage in for a common purpose. Hands-on activities learning is a method adopted by the teacher whereby activities are used to bring about an effective learning experience.

Roseman and Jones (2013) describe hands-on activities as consisting of different activities for the overall development of the learners. According to the author, laboratory activities should be prepared from low-cost materials which are available in the locality. In this way, the teacher may offer students a variety of active educational experiences structured according to the learning cycle.

A hands-on approach can also provide authentic learning experiences for students (Bulunuz, 2012). However, the effectiveness of the hands-on approach should not be taken for granted just like the computer-based simulation (Klahr, Triona, & Williams, 2007; Oludipe et al., 2020). Learning design principles underlie hands-on instructional activities should be the focus. In this context, Acharya (2018) concluded in his research that students exposed to hands-on science instruction frequently get significantly higher scores in science than those students who experienced only mind-on activities in teaching and learning activities. This is so because the learning activities force the child to formulate hypotheses, control variables, make operational definitions, and carry out various scientific skills and processes. Oludipe et al. (2020) examined the effectiveness of hands-on and minds-on activities on Junior Secondary Basic Science Students' Learning outcomes in Ogun State Junior Secondary Schools and found that students in Hands Mind on Group performed better than students in the Conventional teaching group.

### 2.3 Science Process Skills

Science process skills (SPS) are cognitive and psychomotor skills used in problem-solving, they are tools and abilities needed to apply scientific concepts to laboratory and practical work. The science process involves learning to do, define, refine, and resolve activities in the laboratory (Jack, 2018; Ngwenya, 2015; Zeidan, & Jayosi 2015; Ozgelen, 2012). Baiyelo (2007) observed that science process skills are logically linked to a series of activities that can easily be learned. Science process skills enable individuals and society at large to tackle their problems in a systematic and orderly way developing an approach to solve problems that are not only scientific but also social (Nwosu, 2007). Science process skills also encourage the active involvement of children in the learning process (Zeidan & Jayosi, 2015). Science process skill is often grouped into two categories which are the basic and integrated skills though Jack (2018) further classified it as three: basic, causal, and integrated skills, the generally accepted classification as used in this study is the basic and integrated skills. The basic skills include observation, communication, classification, measurement, predicting, and inference while the integrated process skills are formulating hypotheses, naming, and controlling variables, making operational definitions, experimenting, transforming the data and interpreting data.

Researchers (Jack, 2018; Ngwenya, 2015; Zeidan, & Jayosi 2015; Ozgelen, 2012; Baiyelo, 2007) have oftentimes reported that students' level of basic skills of observation, predicting, and measuring are high while integrated science process skills are low. The present study proposes that computer-based simulations could be used to improve the integrated science process skills of students.

## 3. Methodology

This chapter describes the method and procedure that were used in carrying out the study. It was discussed under the following sub-headings: research design, the population of the study, sample, source of data collection, method of data analysis, reliability of the instruments, procedures for data collection, and validity of instruments.

### 3.1. Methods

The present study implemented an exploratory quasi-experiment with a pre-test–post-test design in October 2022. The study population comprised all senior secondary school students in Ijebu-Ode local government area Ogun state, in Nigeria.

### 3.2. Participants

Two secondary schools were purposively selected because they have computer facilities in the school. Students in intact classes in each school were thereafter used as participants in the study. 92 students in total were selected, 48 students for the computer-based simulations group (experimental) and 44 students for the traditional hands-on.

### 3.3. Instrumentation

For this study, two research instruments were used: a 20-item questionnaire containing acid-based titration questions titled Chemistry Multiple-Choice Question (CMCQ) and a Chemistry Students Science Process Skills Observation Checklist (CSSPSOC). The CMCQ was used to elicit information on students' performance while CSSPSOC was used to assess the student's science process skills in the study area.

#### 3.3.1. Chemistry Multiple-Choice Question (CMCQ)

The 20-item objective questions on acid-base titrations were drawn from a pool of 50 questions from the WAEC questions on acid-base titration for secondary school 2. It was validated according to suggestions made by experts by rephrasing some of the questions and answers to suit the purpose of the study. The reliability was determined by subjecting the scale to the Kuder-

Richardson formula 21, and a score of 0.84 was obtained as the reliability coefficient. The instrument was therefore concluded to be reliable.

### 3.3.2. Chemistry Students Science Process Skills Observation Checklists (CSSPSOC)

The instrument used for collecting the students' science process skills was the chemistry student's science process skills inventory (CSSPSOC), which is a rating scale for measuring students' basic and integrated skills in their chemistry practical classes. This instrument was adapted from Ugwu (2007). The instrument CSSPSOC consisted of two sections: section A and section B. Section A was concerned with the background information relating to the students, such as the names of schools, sex, and class. While Section B consisted of statements of practical activities under each science process skill, there have been 15 science process skills discussed in the literature, but only seven were assessed based on the common ones according to the WAEC standard. The items were adapted based on activities that indicated the seven (7) science process skills regularly measured in senior secondary schools. The seven science process skills that the students were assessed on include basic skills (observation, communication, measurement, recording, and inference skills) and integrated skills (experimenting and controlling variables). The teachers rated the students using scale points of:

Very Good (VG) – 4 points

Good (G) - 3 points

Fair (F) - 2 points

Poor (P) - 1 point and

Very Poor (VP) – 0 point.

The items on the rating scale were modified in line with the suggestions and comments made by the professionals. Field testing of the instruments was also carried out by administering the instruments to 20 non-participating Chemistry teachers in Osun State. The reliability test used was Cronbach's alpha reliability technique and it yielded a value of 0.78.

### 3.4. Intervention

The intervention in this study is the computer simulation of "visualizing" the steps taken to perform an acid-base titration. Students in the computer-based simulation (experimental) group 1 were shown a video from the site <https://youtu.be/lruv4YoB3gA> and <https://youtu.be/nEwnKnzXO7Y>. The control was allowed to carry out the titration experiment by gathering the apparatus and reagents together. The intervention took place for a period of four weeks. Different assessments like written and oral questions were used to assess students in the class during these activities before administering the instrument to them.

### 3.5. Procedure

The two groups (experimental and control) of students were first given the 20-objective test to assess their original performance level on practical knowledge tagged as the pre-test at the same time. The pre-test was followed by the actual teaching of the experimental and control group by the same lecturer. During the lessons, the experimental group was taught using the video animations from Youtube videos (treatment) while the other group (control group) was exposed to traditional hands-on activities. At the end of the practical activities, both groups were subjected to write the same test again as a post-test. The results of the post-test were useful to determine the mean gain in the performance of students using computer-based simulation and traditional hands-on activities.

### 3.6. Results and Analysis

Data collected from the participants were analyzed using descriptive and inferential statistics. Mean and standard deviation scores were used to answer research questions, while the null hypotheses were tested at a 0.05 level of significance using a statistical test (t-test) and analysis of covariance (ANCOVA).

**Research question 1:** What is the level of students' science process skills in chemistry practical?

The science process skills of students were assessed after the intervention had taken place and the rating scores were used to determine the level of students' science process skills.

**Table 1. Descriptive statistics of students' level of science process skills**

Basic skills	N	Rating		Mean	Standard Deviation	Science process skill level
Observation	92	Low Medium High	0-6 7-12 13-16	13.79	2.68	High
Measuring skills	92	Low Medium High	0-5 6-10 11-15	10.38	3.05	medium
Recording skills	92	Low Medium High	0-4 5-9 10-12	8.04	2.34	Medium
Communication skills	92	Low Medium High	0-4 5-9 10-12	8.27	2.00	Medium
Integrated skills						
Controlling variable	92	Low Medium High	0-8 9-17 18-24	16.79	3.32	Medium
Experimenting	92	Low Medium High	0-3 4-6 7-9	6.04	2.17	Medium
SPS LEVEL	92	Low Medium High	0-27 28-54 55-83	63.32	12.10	High

Table 1 shows the descriptive statistics of students' level of science process skill with the level of their observation skill at the highest with a mean score of (M = 13.79; SD = 2.68). This shows that the level of observation during practical activities was at a high level. This suggests that after the intervention had taken place, students were able to collect accurate and reliable data, notice patterns and develop hypotheses. Other science process skills as shown from Table 1 were at a medium level (measuring M = ; recording, M = ; communication M = ).

**Research question 2:** What is the mean gain of students' performance of those taught the computer-based and traditional hands-on instructional strategies in the study area?



**Table 2. Mean gain of students' performance**

Instructional strategy		N	Mean	Standard deviation	Mean gain
CBS	PRE-TEST	48	9.42	3.52	0.97
	POST-TEST		14.42	3.52	
THO	PRE-TEST	44	8.45	3.18	1.65
	POST-TEST		12.77	3.11	
TOTAL	PRE-TEST	92	8.93		1.31
	POST-TEST		13.59		

Note: CBS---- Computer-based simulation instructional strategy  
 THO----- Traditional hands-on strategy

The result in Table 2 reveals that the pre-test mean scores for computer-based simulation and traditional hands-on were (M = 9.42) and (M = 8.45) respectively with their standard deviation scores of 3.52 and 3.18 respectively, while the post-test mean scores were 14.42 and 12.77 respectively with their standard deviation scores of 3.52 and 3.11 respectively. However, the mean gain for CBS group was 0.97 (M = 0.97) and 1.65 (M = 1.65) for the traditional hands-on group. This indicates that the traditional hands-on group had a slightly higher mean gain than the computer-based simulation.

**Hypothesis 1:** There is no significant difference in the performance of students taught with computer-based simulations and those taught with traditional hands-on.

**Table 3. T-test for performance of students using computer-based simulations and traditional hands-on**

Variable	N	Mean	SD	Df	t	Sig.	Remark
Computer-based simulation	48	14.41	3.5239	90	2.361	.020	Null Hypothesis is Rejected
Traditional hands-on	44	12.77	3.1168				

Table 3 shows the t-test of the performance of students using computer-based simulations and those using traditional hands-on with computer-based having a mean score of 14.41 and 12.77 for the traditional hands-on. The t-test was 2.361 and p was .020 at a 0.05 level of significance. This means that there is a significant difference in the performance of students using computer-based simulation and those using traditional hands-on, the null hypothesis is therefore rejected.

**Hypothesis 2:** There is no significant main effect of computer-based simulation and traditional hands-on on students' science process skills.

**Table 4. ANCOVA test for the main effect of computer-based simulations and traditional hands-on on students' science process skill**

Source	Type III sum of squares	Df	Mean square	F	Sig.
Corrected model	6345.283a	2	3172.641	42.976	.000
Intercept	4581.310	1	4581.310	62.057	.000
Pre-test	53.494	1	53.494	.725	.397
Method	6074.387	1	6074.387	82.282	.000
Error	6570.326	89	73.824		
Total	477540.000	92			
Corrected total	12915.609	91			

a. R Squared = .491 (Adjusted R Squared = .480).

ANCOVA test result in Table 4 reveals that there is a significant main effect of computer-based simulations and traditional hands-on on students' science process skill F (82,282), P(0.0001 < 0.005). The null hypothesis is therefore rejected, this implies that computer-based simulations and traditional hands-on are effective on students' science process skills.

**Hypothesis 3** There is no significant interaction effect of gender and instructional strategies (computer-based simulations and traditional hands-on) on students' performance.

**Table 5. ANCOVA test for an interaction effect between gender and instructional strategies on students' performance**

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	.198 <sup>a</sup>	2	.095	.421	.658
Intercept	2.008	1	2.008	8.923	.004
Pre-test	.026	1	.026	.116	.734
Gender	.146	1	.146	.650	.422
Error	20.028	89	.225		
Total	62.000	92			
Corrected total	20.217	91			

a. R Squared = .009 (Adjusted R Squared = -.013)

ANCOVA test result in Table 5 reveals that the interaction effect between gender and instructional strategies on the performance of students is not significant ( $F (.650), P .422 > 0.005$ ). The null hypothesis is therefore accepted, this means there is no need for separation of instructional strategies between males and females since computer-based simulations and traditional hands-on can be successfully used for both.

### 3.6. Discussion

Previous studies have oftentimes concluded that students only possess basic process skills while lacking the integrated skills of experimenting and the use of control variables. The present study showed that computer-based simulation and traditional hands-on instructional strategies improved both the basic and integrated science process skills (SPS) of students. The result implied that the basic skill of observation was at a high level and other basic skills like communication skills, recording skills, and measuring skills were at a medium level. The integrated skills, which are the experimenting and controlling variables, were also at a medium level. This established the opinion of Aktamis and Ergin (2008) that effective instructional strategies will improve students' science process skills.

There has been much debate on whether computer-based simulations or traditional hands-on methods are more effective at improving students' performance. While there are advantages to both methods, findings from this study have shown that students who used traditional hands-on simulations performed better than those who used computer-based simulations. This is possibly because most students do better when they repeat traditional hands-on activities, which they are accustomed to performing. Additionally, it may be explained by the fact that students who are often exposed to traditional hands-on activities have a greater interest in chemistry practical's and have mastered the calculation aspect, which enables them to do better in such activities. Some researchers suggest that computer-based simulations combined with traditional hands-on learning in the real world may provide the best experience. The findings of this study are in accordance with several other studies, like Oyeniran, et al (2021), and Acharya (2018), where there was a significant difference in the performance of students exposed to computer-based simulations and those exposed to traditional hands-on in favor of the traditional-hands on. Additionally, Hannel and Cuevas's (2018) study discovered that the traditional hands-on lab had a greater impact on achievement in the subject of the concept of density because the control group (traditional hands-on lab) showed significantly greater gains from pretest to posttest compared to the experimental group (computer-based simulation lab). The results, however, disagreed with those of Jabeen and Afzal (2020) and Mohafa et al. (2022) studies.

Also, findings from this study reveal that there is no significant difference in the science process skills of students taught with computer simulation and traditional hands-on activities. Computer-based simulation and traditional hands-on were both effective in developing the science process skills of students in the laboratory. This finding indicates that, besides, presenting information with just computer simulation, incorporating the traditional hands-on activities will help to improve students' science process

skills better, as both provide students with the opportunity to develop and improve science process skills. For instance, while hands-on laboratories provide students with the opportunity to manipulate real equipment, observe real actions, and record data, CBS allows students to carry out several tests, create scenarios, and verify the behavior in the simulation environment. To support these findings, Hannel and Cuevas (2018) indicated that both traditional hands-on activities, which work with real instruments and tools, and CBS are effective at developing students' science process skills. Therefore, they can either be used side by side or separately. However, Huppert, Lomask, and Lazarowitz (2002) and Umoke and Nwanfor (2014) disagree with this conclusion. In their case, computer-simulated experiments improved students' science process skills better than the traditional hands-on activities as they help to address the complex activities of the problem-solving process.

The study also revealed that there is no significant interaction between instructional strategies and gender on the performance of students in the chemistry laboratory. The result supports the finding of Nwosu and Ndanwu (2020), whose results indicated no significant interaction effect of gender and instructional strategy. This shows that computer-based simulations and traditional hands-on are effective irrespective of gender in fostering performance. Treatment interaction according to Abonyi (2014) implies that different genders with different characteristics may profit more from one type of instructional strategy than from another and that it may be possible to find the best match of a learner's characteristics and instructional strategies to maximize the learning outcome. In this case, there is no need to separate instructional strategies for males and females since computer-based simulations and traditional hands-on activities could be used successfully for the two groups.

#### 4. Conclusions and Recommendations

The study concluded that traditional hands-on activities improved students' performance better than computer-based simulation. However, both were effective in improving the level of students' science process skills in the chemistry laboratory. No gender disparity exists in the performance and science process skills of students in the chemistry laboratory taught using computer-based simulations and those taught using traditional hands-on. This means that there is no need for separation of instructional strategies for males and females since computer-based simulations and traditional-hands on activities can be used successfully for the two groups.

The study recommended that there is a need to blend traditional hands-on activities with updated and modified emerging computer-based simulations such as PhET interactive simulations to improve students' science process skills and performance in science classrooms. Also, the government should make computers available so that when teachers do not have access to apparatus and reagents, they can opt for the use of computer-based simulations in science practical classrooms. Also, teacher educators should be prepared to use computer-based simulations to conduct practical activities at the secondary school level. Finally, hands-on activities require that there should be a standard laboratory and sufficient instructional materials. Therefore, schools should provide good laboratories and sufficient instructional materials that will not be the usual recite-book for students to carry out experiments in the chemistry laboratory.

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