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Students' Acquisition of Science Process Skills in Chemistry through Computer Simulations and Animations in Secondary Schools in Tanzania

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Abstract. Scientists currently advocate the use of integrated science process skills to perform scientific inquiries in the natural world. In Tanzanian schools, however, the situation leaves a lot to be desired as we consider the poor acquisition of science process skills in the country. This article is an attempt to address the impact of computer simulations and animation in the acquisition of scientific skills. We compare the impact of computer simulations and animations to conventional materials on students' acquisition of integrated science process skills in teaching and learning chemistry. We use a mixed method approach in data collection and quasi-experimental research design coupled with the qualitative data collection process, i.e. focus group discussion. The study involved a total of 320 students. The findings revealed that the treatment group scored better (pre-test, mean = 42.26; standard deviation = 12.16, post-test, mean = 65.79; SD = 13.45) after they were exposed to computer simulations and animations than their counterparts in the control groups (pre-test, mean = 41.59; SD, 12.73, post-test, mean = 48.03; SD = 11.72). Furthermore, a statistically significant difference ($p = 0.000$, $\alpha = 0.05$) between the control and treatment groups was found using an independent sample t-test on instructional materials. Thematic analysis of data from students focus group discussion indicated that simulations drew their attention to specifics and made the subject easier to grasp than conventional materials. Therefore, the current study proposes that teachers employ computer simulations and animations to support students' science process skills at secondary school level.

Keywords: computer simulations; animations; conventional materials; science process skills

1. Introduction

Chemistry education is an important part of basic education because it provides students with the scientific information and skills they need in the workplace and the global economy (UNESCO, 2009). As a result, teachers ought to focus on developing scientific abilities, including science processes skills, in order to address issues such as global environmental change, food security, and safeguarding of clean water (Next Generation Science Standards [NGSS], 2013). For students to fully develop scientific skills in the twenty-first century, science process skills (SPS) become a prerequisite (Bete, 2020). Given the significance of chemistry education, chemistry curricula in many countries emphasises the importance for students to engage in the acquisition of knowledge and scientific skills, particularly SPS (Aydm, 2013; Abungu et al., 2014; Bete, 2020).

Recognizing this important requirement, students' SPS in both basic and integrated forms is included in Tanzania's chemistry subject curriculum, which is a competence-based curriculum (Ministry of Education Science, and Technology, [MoEST], 2015). In this regard, observing, categorizing, measuring, calculating, data recording, inferring, and communicating are all basic SPS. Aydoğdu et al. (2014) define integrated science process skills as intellectual skills or abilities utilised by scientists to undertake scientific inquiries in the natural environment. These include formulating scientific questions, hypotheses, identifying and controlling variables, planning experiments, data recording, interpretation, and drawing conclusions.

Although SPS are vital, and included in the newly revised competence-based chemistry subject curriculum in Tanzania, research in science education confirms that they are not well-developed (Mkimbili et al., 2017). This is due to ineffective teaching methods that focus on teacher-centeredness with rare inquiry activities and occasional practical work (Kinyota, 2020). Nevertheless, lack of laboratories and ICT instructional tools, as well as high-class sizes, is a major cause of ineffective teaching methods (Ngeze, 2017; Semali & Mehta, 2012). In summary, pedagogical approaches that promote inquiry and learning materials that support meaningful learning in chemistry remain a matter of concern in Tanzanian schools.

Moreover, computer simulations and animations (CSA) are one type of ICT tools that have become popular in education as a teaching and learning resource. This is due to their capacity to engage students in inquiry learning using hands-on activities (Moore et al., 2014; Nganyadi, 2021). Computer simulations are computer representations of actual or hypothetical events or natural phenomena that allow users to experiment with the effects of changing or altering parameters (Nkemakolam et al., 2018). It includes virtual laboratories and visualizations (Çelik, 2022). Students can use CSA to conduct scientific investigations through inquiry activities which are essential for SPS acquisition (Haryadi & Pujiastuti, 2020; Plass et al., 2012). Previous studies have reported that use of computer simulations and animations enhance students' acquisition of basic science process skills (Celik, 2022; Saat, 2004; Supriyatman & Sukarno, 2014; Sreelekha, 2018; Stieff, 2011). However, the mentioned studies were conducted in different domains and learning contexts other than chemistry in particular chemical kinetics, equilibrium, and energetics.

Nevertheless, little is known about how computer simulations and animations enhance students’ acquisition of integrated science process skills, which are essential for higher-order thinking in chemistry learning and in daily life application. Thus, this study compares the impact of computer simulations and animations on students' acquisition of integrated SPS in teaching and learning chemistry to conventional materials. The goal of the study is to provide answers to the question: how do computer simulations and animations affect the students’ acquisition of integrated SPS in learning chemistry? Answers to the question would equally shed light on the use of computer simulations and animations in the teaching and learning of chemistry in Tanzanian secondary schools as viable alternative instructional resources.

2. Literature Review

2.1 The Role of Science Process Skills in Science Learning

The development of students' SPS is emphasised in various nations' chemistry curriculum. Moreover, in Turkey, the development of students’ SPS is considered a priority in the chemistry curriculum by allowing students to address practical issues (Aydm, 2013). In a similar vein, chemistry curriculum in Nigeria incorporates SPS to inculcate real life applications in students (Jack, 2018). Similarly, chemistry subject curriculum in Tanzania MoEVT (2010) emphasises on students' development of SPS. This emphasis is based on the importance of SPS in scientific knowledge and an individual's life.

SPS allow students to investigate the environment and build their own meaning during the learning process (Athuman, 2017). When students are engaged in inquiry learning activities that are investigative, such as experiments, hands-on activities, and discussion, they can construct meaning for themselves (Chebii et al., 2012; Mulyeni et al., 2019). Students have the chance to create and test hypotheses, gather and analyse data, make observations, and draw conclusions while participating in these activities (Aydoğdu, 2015). Students develop their own meaning about the world around them through these inquiry activities, which are scientific process skills. As a result, learning chemistry is made simple and relevant by incorporating SPS into the teaching and learning process.

Furthermore, scientists employ SPS to perform scientific studies. Thus, they are used as research skills (Abungu et al., 2014: Aydoğdu, 2015). In addition, scientists identify the problem, formulate hypotheses, conduct experiments including the identification and control of factors, collect, analyse and interpret data (Abungu et al., 2014). To explain the results and reach a conclusion, students may use graphs, tables, phrases, and diagrams to portray the data (Yadav & Mishra, 2013). Therefore, learning of SPS becomes critical among the primary goals of chemistry instruction (Bete, 2020). Once students have learned these skills, they may be transferred from one learning setting to another (Chebii et al., 2012). Consequently, students may use them to address issues in real-life situations. In addition, according to Athuman (2017), engaging students in SPS improved their attitudes and enthusiasm in learning science.

2.2 Teaching and Learning Practice in Chemistry Classroom

As a science subject, chemistry needs a constant stream of practical or hands-on activities to explain abstract ideas and inculcate relevant scientific skills required for problem solving (Kinyota, 2020). Therefore, practical works or hands-on activities are the most essential learning technique for involving students in inquiry learning activities that allow students to discover scientific facts and concepts (Bilgin, 2006; Yadav & Mishra, 2013). Furthermore, practical works are more interesting than lectures in the classroom—they provide an opportunity for students to collaborate and engage with one another and their teachers; and enhance their sense of ownership of their learning (Abungu et al., 2014). In summary, in order for learners to become excellent scientists, and develop conceptual knowledge and gain required abilities, utilization of practical works or hands-on activities for inquiry learning should be given priority in chemistry learning.

In contrast, research reveals that, in most developing countries, including Tanzanian school classrooms, chemistry instruction employs teacher-centered setting with rare hands-on activities, and discussions that may engage students in inquiry learning activities (Mkimbili et al., 2017). Practical activities are frequently postponed until when the final national examinations are approaching (Kinyota, 2020), and students seldom acquire knowledge of such experiments instead of following processes and declaring success (Semali & Mehita, 2012). Besides, demonstrations are utilised in very few classrooms. Where demonstrations are done, it is usually by the teacher demonstrating, while students remain passive (Kinyota, 2020; Omorogbe & Celestine, 2013). It is obvious that this type of learning impedes the acquisition of SPS as well as learners' capacity to create knowledge rather than cramming it. One of the reasons is a lack of instructional materials and ineffective teaching techniques. Therefore, the current article explains how computer simulations and animations are potential solutions to the problem.

In Tanzania, students' learning of SPS as a way of building abilities and competences in developing critical thinking and problem solving in students' everyday life experiences is emphasised in Tanzania's newly updated chemistry subject curriculum. It also encourages the use of inquiry-based techniques in the teaching and learning process such as practical activities. However, teacher-centeredness continues to dominate chemistry teaching and learning, despite the fact that most of the instruction is done theoretically (Mkimbili et al., 2017; Semali & Mehita, 2012). As a result, students' ability to acquire SPS is hampered (Kalolo, 2015). Furthermore, the curriculum encourages students to have access to and use ICT resources, such as computer simulations (MoEVT, 2007). Despite these suggestions, little is known about the effect of computer simulations and animations on students' acquisition of integrated SPS.

2.3 Computer Simulations and Animations, and Science Process Skills Acquisition in Learning

Previous studies have been carried out to investigate how computer simulations and animations affect students' acquisition of SPS. For example, a study was conducted by Supriyatman and Sukarno (2014) on the role of computer simulation in SPS acquisition among student-teachers. The findings indicated that students improved basic SPS in observation, prediction, communication and in making conclusions. Çelik (2022) explored the role of computer simulations in improving science process skills, the findings indicated that although computer simulations improve science process skills, teaching methods is crucial. Furthermore, Stieff (2011) examined the effect of computer simulations and animations in enhancing students' basic SPS in learning the states of matter at microscopic, macroscopic, and symbolic levels among students in secondary schools. It was found that simulations and animations improved students' skills in making observations, predictions, analyzing patterns, and making inferences, which are basic SPS.

Further, Ardac and Sezen (2002) explored the effectiveness of computer simulations-based instruction on process skills for controlling variables of boiling point elevation and freezing point depletion among students in secondary schools. The findings indicated that students learning with simulations improved SPS by developing the ability to control different variables. Similarly, Saat (2004) investigated students' ability to acquire SPS among students learning science using simulations. The findings indicated that students could develop skills for controlling variables. Saputri (2021) and Siahaan et al. (2017) indicated that computer simulations can be used as a solution to deal with students' low science process skills in science teaching. Generally, computer simulations and animations have been shown to be beneficial in helping students to acquire relevant basic SPS. However, little is known on how computer simulations and animations enhance integrated science process skills in chemistry context.

2.4 Theoretical Framework

This study employed Levy Vygotsky's social constructivism theory, which considers knowledge production as an active process that includes social interaction between learners, teachers, and instructional materials (Vygotsky & Cole, 2018; Vygotsky, 1978). Students participate in active learning to create meaningful learning through enhanced social interaction with the use of instructional resources. In essence, learners learn best when they actively participate in the production of information in a learning-by-doing setting. Furthermore, Demirci (2009) believes that learners must learn by doing something rather than merely listening. Therefore, the utilisation of virtual reality technologies, in particular, computer simulations and animations, creates an exploratory learning environment in which students participate in hands-on activities for inquiry learning (Moore et al., 2014).

In this study, students were exposed to inquiry activities and classroom discourse during the teaching and learning process.

This kind of learning enables students to be active participants in constructing scientific knowledge and process skills in lessons (Onwioduokit, 2013). It was assumed that the learning approach could ensure social interaction among teachers, students, and instructional materials to ensure active learning. Moreover, students working in small groups allow interaction among themselves and with their teachers using computer simulations and animations during the teaching and learning process. Thus, it is critical to create a conducive learning environment that encourages learners to generate knowledge through interaction.

On the other hand, to encompass the important components of technology use as supported by CSA, additional theory was required. This was done in order to gain a better grasp of the leaner prior knowledge as well as the utilization of multimedia resources like CSA. In this case, Richard Mayer's Cognitive Theory of Multimedia Learning (CTML) was applied (Mayer, 2005). According to the CTML process assumption, learners should first choose relevant visual and verbal information into coherent verbal and visual mental representations, and then integrate these mental representations with one another and past knowledge (Mayer, 2001). For example, a student may use a computer simulation and animation to explore chemical kinetics, equilibrium, and energetics. This learner would benefit from the addition of icons for temperature, catalyst, reactant concentration, and molecule movements all of which are important pieces of information for construction of knowledge hence understanding the topic.

3. Methodology

3.1 Research Design and Approach

This study used a mixed research method. Quantitatively, a quasi-experimental design using a pre- and post-test design involving both control and experimental groups was employed. Quasi-experimental research offered the benefit of comparing the two groups (control and treatment) based on naturally occurring treatment groups (Cohen et al., 2018). Students in level three were grouped into treatment and control groups to form intact classes that were comparable. An independent sample t-test was used to establish the comparability between the two mentioned groups. Each class had 40 students who were randomly selected to participate in the current research. In addition, quantitative data were triangulated with qualitative data from focus group discussions with students. This followed the explanatory sequential form of collecting and analyzing first quantitative and then qualitative data (Cresswell & Clark, 2018).

3.2 Sampling and Sample Size

Four schools were involved in this study: two from the Dodoma region and two from the Singida region of Tanzania. These regions were chosen because they have a severe shortage of facilities and resources for teaching and learning chemistry in secondary schools (MoEST, 2019). They are ranked poorly in science, including chemistry (MoEST, 2018, 2019, 2020). Therefore, the chosen research sites could provide a more comprehensive picture of the use of computer simulations and animations in teaching and learning chemistry in terms of instructional resources. In addition, schools from the study sites were chosen based on the availability of a computer laboratory at the school. Hence, twenty secondary school chemistry teachers were involved in this study based on the criteria of inquiry pedagogy. Moreover, the teachers were chosen based on their willingness and experience as secondary school chemistry teachers. The same teachers taught both the control and treatment groups. Moreover, a total of 320 students from the four schools were involved, where 80 students from each school were randomly allocated to treatment (40) and control groups (40) to form eight intact classes.

3.3 Data Collection Process
Consent from both students and teachers was acquired prior to the commencement of data collection. This was done verbally or in writing. The data were gathered using the two stages of study design described below:

Stage 1: Pre-test
In this study, before the start of teaching and learning, students in treatment and control groups were subjected to a pre-test SPS to determine their prior knowledge of SPS (appendix 1). Students were tested to establish a baseline for the acquisition of SPS. The chemistry SPS test, with 25 items based on the higher-level cognitive domains of Bloom's Taxonomy, was used as a data collection instrument (Huitt, 2011). Subject teachers and the research team worked together to gather student scripts for grading and assigning marks, which were set at 100 percent and categorised as follows: 0-20 very poor, 21-40 unsatisfactory, 41-50 average, 51-65 good, 66-80 very good, 81-100 excellent. Moreover, a focus group discussion with students was conducted (appendix 3).

Stage 2: Intervention and Post-test
In the intervention, students in the treatment and control groups learned concepts about chemical kinetics, equilibrium and energetics using computer simulations and conventional materials, respectively. The intervention started before the topic was taught in selected schools. A series of classroom observations were conducted, with at least eight at each school, to assist teachers in the appropriate use of computer simulations and animations in chemistry instruction and students' learning. Level three students in the treatment and control group were exposed to inquiry and hands-on activities. Teaching and learning were framed by Bybee et al. (2006) 5Es instructional model. Teachers acted as facilitators during the teaching and learning process rather than being the custodians of knowledge.

Moreover, throughout the teaching, students were encouraged to participate in inquiry activities such as exploring problems, making hypotheses, sharing their ideas in small groups, performing experiments, discussing observations, making interpretations, making conclusions, and sharing their observations with classmates. For example, students explored the factors affecting the rate of chemical reactions which they could conduct investigations and observations in classrooms. Nonetheless, the role of the teacher was to promote discourse, reflections, scaffolding when required, and guide students in both the treatment and control groups. Teachers acted as facilitators rather than custodians of knowledge to involve students in learning SPS. Learning activities were designed in a way that require students' active engagement in practical activities, and allow opportunities for students to reflect on learning experiences. The difference was that the treatment groups used computer simulations and animations while the control group did not.

In the last session, the post-test was administered to check the students' acquisition of SPS (appendix 2). The test acted as a data collection tool at this point. The test measured five integrated science process skills (ISPS) which include: stating hypotheses, identifying variables, designing investigations, identifying variables, operationally defining, interpreting data, and drawing conclusions. The test was based on previous studies like Burns et al. (1985) and Kazeni (2005), which had a reliability of 0.89 and 0.81 respectively. The questions were changed to fit the current chemistry competence curriculum in the Tanzania context. The reliability of the current SPS test was 0.75, which is good. This multiple-choice test with 25 items was designed to address issues close to students' material applications in everyday life. Teachers and members of the study team graded the test once more. In addition, focus group discussions were conducted with students to gather information on their thoughts about the use of simulations and animation as a substitute resources for real-world chemistry classroom practice (appendix 4). The whole process of data collection lasted for 9 weeks.

3.4 Selection of the Content and Instructional Materials

The study focused on the content of chemical kinetics, equilibrium, and energetics for form or level 3 of secondary school education (MoEVT, 2010). This content, according to the curriculum in Tanzania, is about the concepts of chemical kinetics, factors affecting the rate of chemical reaction that is the effect of temperature, surface area, concentration, and catalyst on the rate of reaction. Other aspects were reversible and irreversible reactions, factors affecting chemical equilibrium, and endothermic and exothermic reactions. The content was selected based on the research findings that students face difficulties in understanding concepts and in explaining how various factors affect the chemical rate of reactions and chemical equilibrium in the topic of chemical kinetics and equilibrium (Gegios et al., 2017; Van Driel, 2002). Moreover, Lati et al. (2012) emphasised the need for engaging students in inquiry learning to acquire SPS as learning rates of chemical reactions following their relevance and usefulness in their daily life activities for problem solving.

In regard to difficulties in learning chemical kinetics, equilibrium and energetics; computer simulations and animations for the intervention were accessed from Yenka chemistry (https://www.yenka.com/en/Yenka_Chemistry), which were installed in the schools' computer laboratories in the study area. The copyright and intellectual property requirements were observed between the researcher and Yenka. In addition, Yenka chemistry provides these tools when all necessary agreements are met by the customer. Moreover, one model of PhET simulation of reactions and rates (https://phet.colorado.edu/en/simulations/reactions-and-rates) was also used as supplement. These computer simulations software were used during the intervention for the treatment group to learn the concepts of rate, collision theory, and the effects of temperature, surface area, catalyst, and concentration on the rate of reaction, reversible reactions, irreversible reactions, the effect of temperature on the position of chemical equilibrium, and endothermic and exothermic reactions. The selection of these computer simulations was based on their features and design, which are based on the school curriculum relevance and level of learners (Çelik, 2022; Zendler & Greiner, 2020). On the other hand, conventional materials used in the intervention for the control group are those instructional materials that have been traditionally used to teach. Conventional materials include real materials such as laboratory materials, textbooks, diagrams, pictures, and models to convey concepts (MoEVT, 2010).

3.5 Validity and Reliability

3.5.1 Validity

For content validity of the SPS tests, 4 chemistry teachers were involved during the construction of the tests (pre- and post-test). This helped to improve the tests items by ensuring that the tests covered the chemistry curriculum and the level of learners. Later on, the tests were given to students in two secondary schools which were not part of the main schools in the study. Again, content validity was ensured for focus group discussion guide by four experts in the field.

3.5.2 Reliability

To ensure reliability, Cronbach's Alpha Coefficient of Reliability was calculated using SPSS version 16 (SPSS Inc., 2007). The coefficient of reliability was 0.72 for the pre-test and 0.75 for the post-test, which are both considered as good (Cresswell, 2012). The variance in reliability can be explained by the fact that, as the teaching and learning process progressed, the test items were revised and reviewed for specific content of the chemical kinetics, equilibrium and energetics topic.

3.5.3 Control of Threats to Internal Validity

To control some pedagogical extraneous variables, 5Es inquiry learning model to guide students in inquiry activities in chemical kinetics, equilibrium and energetics were used. The model involves students in inquiry learning process in 5 cyclic stages which are: engage, explore, explain, elaborate, and evaluate (Bybee et al., 2006). We also made sure that teachers involved in the study had met the criteria mentioned in the sampling and sample size section.

3.6 Data Analysis

To compare the findings of pre and post-test, quantitative data were evaluated using means, standard deviations, paired sample t-test, and an independent sample t-test (Pallant, 2020). However, for qualitative data evaluation, thematic analysis was employed and themes were produced from the data.

4. Results

The findings of this study were divided into two main stages:

Stage 1: Pre-test

The results indicate that the mean for the treatment group was 42.26 while the mean for the control group was 41.59. This indicates that almost all students in the treatment group performed equally as students in the control group though there was little marginal difference (Table 1). The independent sample t-test of the pre-test between the two groups indicated that there was no statistically significant difference in their performance.

Table 1: Means Scores in Pre-test for Control andTreatment Groups

	Students' groups	N	Mean scores for Pre-test	Pre-test Std. Deviation
Students' scores	Control group	156	41.59	12.73
	Treatment group	156	42.26	12.16

However, responses from students indicates that curricula content is heavy since they have many materials to cover in a short amount of time. Moreover, there is shortage of teaching resources as the result students learn concepts theoretically. The following quotes were taken from students of the FGDs conducted through this study:

> [*We are required to cover many topics as some were not covered in form two, for example, mole concept and chemical equations, teachers teach many things at once that is hard for us to understand. (FGD, school D)*]

> [*We have normally learned chemistry topics through theory and not practical activities because our laboratories lack chemicals, apparatus and other materials. Practical activities are only conducted by level 4 students who are required to perform National examinations. (FGD, school A & B)*]

Stage 2: Intervention and Post-test

Findings (Tables 2 and 3) reveal that the treatment group students scored better (pre-test, mean= 42.26; standard deviation (sd) = 12.16, post-test, mean = 65.79; sd = 13.45) in the SPS test after being treated with computer simulations and animations than their counterparts in the control groups (pre-test, mean = 41.59; sd = 12.73, post-test, mean = 48.03; sd = 11.72). Furthermore, a statistically significant difference ($p = 0.000$, $\alpha = 0.05$) between the control and treatment groups was discovered using an independent sample t-test on instructional materials.

Table 2: Independent Sample t-test for the Treatment and Control Group

Test	Group	Means	Std. Deviation	t	p-value
Pre-test	Treatment	42.26	12.16	0.473	0.637
	Control	41.59	12.73		
Post-test	Treatment	65.79	13.45	12.436	0.000
	Control	48.03	11.72		

Table 3: Paired Sample t-test for Control and Treatment Groups

Groups	Test	Means	Std. Deviation	t	p-value
Control	Pre-test	41.59	12.73	-18.192	0.000
	Post-test	48.03	11.72		
Treatment	Pre-test	42.26	12.16	-68.990	0.000
	Post-test	65.79	13.45		

Further, there was a high improvement in students' science process kills performance in the post-test for the students taught with computer simulations and animations as compared to the students taught with the conventional instructional materials. The good post-test performance can be explained by the fact that students in the treatment group had previously completed a series of computer-integrated lessons in class at this point.

Moreover, the analysis of students' focus group discussion indicated that the usage of simulations drew their attention to specifics and made the subject easier to grasp than conventional materials. This could be the reason for high scores in the post-test. The following from FGD with students may serve as evidence:

> [*"The lessons were excellent since the teacher taught us using computer simulations which were engaging and easy to follow. We were able to quickly understand the content. (FGD, school B)*]
>
> [*"Chemical kinetics and equilibrium were good since it connected us with daily uses of different activities at home. But we really liked the use of computer simulations and animations from the lessons as they simplied the concepts. (FGD, school C)*]
>
> [*We were able to make predictions of our investigations; for example, we can tell how the concentration of the reacting substance affects the rate of reaction. We were encouraged by the teacher to observe the computer simulation model and make hypothesis, then tested our hypothesis by performing experiment, recording our observations, making interpretations and conclusions. We learned to develop hypothesis, planning experiments, interpretations and conclusions. This was a unique way of learning chemical kinetics, equilibrium and energetics. (FGD, A & D)*]
>
> [*In form one we were taught about scientific procedures such as hypothesis, controlling variables, conclusion but we just claimed the definitions because no experiment was conducted and we did not know their application in scientific investigation. But after using computer simulations we understand that if we are investigating the effect of temperature on rate of a chemical reaction, it means we need to control some variables and manipulate temperature which is the independent variable in order to come up with scientific justification that the effect is as the result of temperature and not other variables. (FGD, school B)*]

Generally, the findings from the study indicated that students taught with computer simulations and animations improved SPS in formulating hypothesis, identifying variables, operational definitions, planning experiments, making interpretations and conclusions in learning chemical kinetics, equilibrium and energetics.

5. Discussion

5.1 Science Process Skills Acquisition in Chemistry

The results in the pre-test showed that students in both treatment and control groups had a very insignificant difference in terms of the science process skills. Moreover, the independent sample t-test indicated that there were no statistically significant differences in SPS performance between the two groups. This finding implies that students' overall level of performance may not be regarded as good performance compared to the emphasis placed on SPS in the chemistry curriculum in Tanzania. The findings are slightly similar to those of Athuman (2019), who assessed the level of SPS in secondary schools in Tanzania and found that students had poor acquisition of SPS. Although the current study could not find a precise reason for the poor performance in SPS before the inclusion of simulations and animations in chemistry, evidence suggests that the amount and level of difficulty of content are one of the reasons. Another reason is the predominant use of lecture methods, which is a common practice in most classrooms in Tanzania (Mkimbili et al., 2017; Kinyota, 2020).

Furthermore, Athuman (2019) suggests, students need to focus on simple learning activities during the teaching and learning process to understand integrated SPS, which resonates with social constructivism principles (Vygotsky, 1978). On the other hand,Germann et al. (1996) asserted that good performance on SPS depended on students' experience and domain-specific learning activities on the skills in prior tasks. Therefore, students were required to learn specific skills to learn chemistry scientifically with the aid of computer-assisted technology, guided by CTML theory.

5.2 Effect of Computer Simulations and Animations on Students' Acquisition of Science Process Skills

Findings from the present study revealed that the treatment group students scored better on the SPS subject to computer simulations and animations than their counterparts in the control groups. Supriyatman and Sukarno (2014) revealed that student-teachers improved basic SPS in observation, prediction, communication and in making conclusions through computer simulations. Nevertheless, Stieff (2011) examined the role of computer simulations and animations in enhancing students' SPS in learning the states of matter among students in secondary schools. It was found that simulations and animations improved students' skills in making observations, predictions, in analysing patterns and making inferences, which are basic SPS. However, the target population was different from the one used in this current study as the research.

Moreover, Çelik (2022) and Guevara (2015) reported that, with computer simulation instruction, students have the opportunity to interact with computer simulation learning environments to develop their science process skills. The mentioned authors' conclusion aligns with the CTML theory, which emphasizes that learners integrate these mental representations with one another and the content through multimedia tools. In a similar vein, the study by Sreelekha (2018) indicated that there was an improvement in students' SPS in measurement, observation, mathematics, drawing, graphing, and inferring skills for students learned through computer simulation instruction. Other studies (Ardac & Sezen, 2002; Saputri, 2021) suggest the positive role played by simulations and animations in helping students acquire relevant SPS in the teaching and learning process.

Furthermore, the use of computer simulations and animations affects students' acquisition of SPS in learning chemical kinetics, equilibrium and energetics. It can be argued that students taught with computer simulations have more opportunities to interact, observe, discuss and make interpretations in the teaching and learning process. It is the view of the findings of this study that computer simulations and animations favored more learner-centered learning, which provided more opportunities for students to be involved in inquiry learning as compared to students learning with traditional instructional materials.

This practice supports the claim put forward by the Tanzania competence-based science curriculum (2010) that the use of an inquiry-based approach could be effective for engaging students in developing SPS. From the social constructivism view, learning occurs through inquiring and classroom discourse which opens to active participation in the learning process (Demirci, 2009).

Nonethless, the findings from the present study indicate that learning chemistry concepts, particularly chemical kinetics, equilibrium and energetics in inquiry using computer simulations and animations, provides an opportunity for students to forecast (make hypothesis), test their ideas through hands-on activities, observe and make relevant interpretations. Through inquiry learning activities, students construct knowledge along with the acquisition of associated SPS. This can be explained further by the fact that using interactive computer simulations and animations enables students to see abstract concepts that cannot be displayed or shown on real laboratory equipment, charts, and diagrams (Çelik, 2022; Guevara, 2015; Haryadi & Pujiastuti, 2020). Also, learning with computer simulations shortens the time of practicum and provides an opportunity for students to repeat experiments for more observations and interpretations. Nevertheless, students have more time for classroom interaction through classroom discussions and communicating the results based on collected evidence contrary to those students who learn through the conventional materials such as real equipment, charts, or diagrams (Seputri, 2021; Supriyatman & Sukarno, 2014).

6. Limitations

Regarding the limitations, this study was limited to only public secondary schools. It can be expanded further in private secondary schools to lay the extended groundwork for CSA implementation. The findings of this study clearly indicate that students' science process skills improve when they are exposed to hands-on activities via computer simulations as compared to conventional materials. As a result, a fascinating avenue for further research would be to investigate the relationship between science process skills acquisition and academic achievement when using computer simulations and animations in chemistry teaching and learning.

7. Conclusion

Generally, it can be stated that students score better on the science process skills test when exposed to computer simulations and animations than their counterparts in conventional materials.

Every student should learn the SPS because it is useful in everyday life. Therefore, the current study recommends the use of computer simulations and animations in the teaching and learning of chemistry in Tanzanian secondary schools as a viable alternative instructional resource**.**

8. Recommendations

The use of computer simulations and animations should be given priority by chemistry teachers in secondary schools with similar contexts because of their interactivity. Our findings indicate that CSA can improve students’ acquisition of science process skills as opposed to conventional materials. Therefore, we suggest that chemistry teachers employ computer simulations and animations to support students’ science process skills in secondary schools.

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Appendix 1: Science Process Skills Test (Pre-test)

School code…………Student class………Time: 50 minutes Date…………….

Instructions: This test comprises 25 multiple choice test Items. Read all questions carefully and circle an alphabetical letter indicating the *correct* answer of your choice in each question.

1. Tunda was investigating the effect of temperature on the dissolving common salt, Sodium chloride. She dissolved 0.5g of sodium chloride in 25mls of cold water and then another 0.5g of salt sodium chloride in 25mls of hot water. How dissolving ability of the salt could be determined or measured?
   a) Measuring the particles of salt in cold and hot water
   b) Measuring the time, it takes for salt to dissolve in cold and hot water
   c) Noting the particles of salt remained in cold and hot water after dissolving
   d) Noting the particles of salt remained in cold and hot water before dissolving
2. Students were surprised to see a candle continue burning when exposed to air. They hypothesize that air containing oxygen supports combustion. How could students plan their experiment to test their hypothesis?
   a) Light two candles and cover all lighted candles with hard glass beakers, then make an observation
   b) Light two candles and cover one lighted candle with a hard glass beaker while leaving the other lighted candle uncovered and make an observation
   c) Light two candles and leave all lighted candles uncovered, then make an observation
   d) Light one candle and leave it uncovered, then make an observation
3. Students carried out experiments to determine the efficiency of liquid and solid fuels. The efficiency of fuel depends on the amount of heat produced per a specific mass of fuel. 500g of kerosene produced 75,600 Jmol-1 of heat, while 500g of charcoal produced 58,800 Jmol-1 of heat. What conclusion can you make from the experiment results?
   a) Solid charcoal fuel is more efficient than kerosene fuel.
   b) Kerosene liquid fuel is more efficient than solid charcoal fuel.
   c) Kerosene fuel and charcoal fuel are equally efficient.
   d) Liquid fuel is less efficient than solid fuel.
4. Students wanted to investigate the efficiency of water in extinguishing fires from flammable and non-flammable substances. They hypothesized that water extinguishes fire more efficiently from non-flammable substances than from flammable substances. Which plan students should choose to test their hypothesis;
   a) Apply water to extinguish a fire from flammable substances.
   b) Apply water to extinguish fires from both flammable and non-flammable substances.
   c) Apply water to extinguish fire from non-flammable substances.
   d) Apply water to extinguish fires from different substances.

A chemistry teacher and his students in chemistry laboratory were interested in investigating the efficiency of solid and liquid fuels. They planned their investigation by taking 500g of charcoal and filing it in a charcoal burner, lighting the charcoal until it burned red hot. They placed 400mls of pure water in a hard glass beaker and recorded its initial temperature, then placed the water on hot charcoal burner and started the stopwatch. Students recorded the temperature raise after 5 minutes interval. They also took a kerosene burner filled with 500mls of kerosene, lighted the burner. They placed 400mls in a hard glass beaker and recorded the initial temperature. Then the water was immediately placed on the blue flame kerosene burner and started the stop watch. Students recorded temperature raise after a 5 minutes interval.

5. What variables were kept constant during this experiment;
   a) Kerosene and charcoal burners
   b) The amount of water and the temperature of the water
   c) The amount of fuel, amount of water used and the type of beaker
   d) Temperature, beakers and amount of water used
6. Which variables were changed or manipulated in the experiment?
   a) Mass of charcoal and kerosene
   b) Charcoal and kerosene burner
   c) Water and beakers used
   d) Temperature of water and beakers
7. Students investigated the strength of hydrochloric acid depending on its concentration. The following were the results;

Concentration of hydrochloric acid	pH value
0.02M	5
0.05M	4.7
1.5M	2.8
3.0M	2

What conclusion can you make?
   a) The lower the concentration of HCl, the lower the pH value.
   b) The higher the concentration of HCl, the higher the pH value.
   c) The higher the concentration of HCl, the lower the pH value.
   d) The concentration of HCl is equal to the pH value.
8. Kamau planned his experiment by adding 2 tea spoons of sugar to a cup of cold water, and another 2 tea spoons of sugar were added to a cup of hot water. He then observed that sugar in a cup with hot water dissolved more quickly than sugar in a cup with cold water. What is a suitable hypothesis for this experiment;
   a) Cup affects sugar's dissolving
   b) Cold water affects sugar dissolving
   c) Temperature affects sugar dissolving
   d) Hot water affects sugar dissolving

A study was done to see if the temperature applied to salts has an effect on salt solubility. Salts were placed in 3 beakers of the same size. The first beaker had 0.2g of NaCl, second beaker had 0.2g of NaCl and the third beaker had 0.2g of NaCl and 5mls of water were added in each beaker and placed at different temperature; 0^{o}c, 20^{o}c and 75^{o}c respectively.

9. What is the hypothesis being tested?
   a) Temperature affects salt solubility.
   b) The size of the beaker used affects salt solubility.
   c) The amount of salt affects its solubility.
   d) The number of beakers affect salt solubility.
10. What variable was kept constant in this experiment;
   a) Both the temperature and amount of salt
   b) An amount of salt and water
   c) Temperature applied
   d) Beakers and temperatures
11. What is the responding variable?
   a) Temperature applied
   b) Amount of salt
   c) Both the temperature and solubility of salt
   d) Solubility of salt
12. What is the manipulated (changed) variable?
   a) The mount of salt in each beaker
   b) The amount of water in each beaker
   c) Temperature
   d) Number of beakers
13. Maunda hypothesized that neutral soil would produce more tomatoes. How Mounda can plan experiment to test her hypothesis;
   a) Planting different tomato plants in buckets with acidic soil, basic soil and neutral soil then counting amount of tomatoes produced in each bucket.
   b) Planting same tomato plants in buckets with acidic soil, basic soil and neutral soil then counting amount of tomatoes produced in each bucket.
   c) Planting same tomato plants in buckets with neutral soil then counting amount of tomatoes produced.
   d) Planting tomato plant in different buckets with acidic soil and basic soil then counting amount of tomatoes produced in each bucket.
14. Students investigated the characteristics of different solutions made from acids and bases. The table below indicates what they found out;

Solution	**pH value**	**Strength**
Diluted battery acid	1	Strong
Lemon juice	5	Weak
Vinegar	5.7	Weak
Sodium chloride	7	Neutral
Sodium hydroxide	13	Strong
Sodium carbonate	10	Weak

Which conclusion can you make from the information above?
   a) Solutions with a high pH value are strong acids, while solutions with a low pH value are strong bases.
   b) Solutions with a low pH value are both strong acids, while solutions with a high pH value are strong bases.

c) Solutions with a low pH value are strong acids, while solutions with a high pH value are strong bases.
d) Solutions with a low pH values are neutral, while solutions with a high pH values are weak.

15. Students wanted to learn how to change the ice cubes into a liquid state. They designed an investigation where ice-cubes are placed at different temperatures. In this investigation which of the following could be a hypothesis;
    a) Ice-cubes are converted to water liquid when pressure is increased.
    b) Ice-cubes are converted to water liquids when the temperature is increased.
    c) Ice-cubes are converted to water liquid and gaseous when the temperature is decreased.
    d) Ice-cubes are converted to liquid water when their size is small and temperature is decreased.
16. A carpenter found his nails rusted after leaving them outside over the whole night. He wanted to know whether the oxygen and moisture the nails were exposed to were the causes. Which of the hypotheses could he test;
    a) Keeping the nails away from water and moisture prevents the nails from rusting.
    b) Keeping the nails away from oxygen prevents the nails from rusting.
    c) Keeping the nails away from oxygen and moisture prevents the nails from rusting.
    d) Keeping the nails away from water prevents them from rusting.
17. Kibo wanted to determine the effect of boiling on removing the hardness of water. He was told that the hardness of the water had been removed from the leather, making it easy to clean with soap. He took water from two different sources and boiled the water. Then, after cooling, the boiled water with soap solution was removed. How could Kibo determine the extent to which the hardness of water has been removed?
    a) Time it takes for the water to boil and the soap to lather
    b) Amount of water remained after boiling.
    c) Observe the amount of leather formed with water after boiling.
    d) Observe the amount of leather formed with water before boiling.
18. Juma thinks that the smaller the size of salt particles, the more soluble the salt substance is. To investigate this hypothesis, he prepared salt particles and water. How should Juma test his hypothesis?
    a) Dissolve salt particles of the same size with a different amount of water.
    b) Dissolve different salt particle sizes with the same amount of water.
    c) Dissolve the same salt particle size with the same amount of water.
    d) Dissolve different salt particle sizes with different amounts of water.
19. Students noticed that sometimes water used to wash clothes does not form lather with soap, while other times water used forms lather easily. Students wanted to find out what caused lather formation. They planned their investigation by reacting to different kinds of water with the same amount of soap in a small basin. What best hypothesis could be tested;
    a) Soft water can wash clothes.

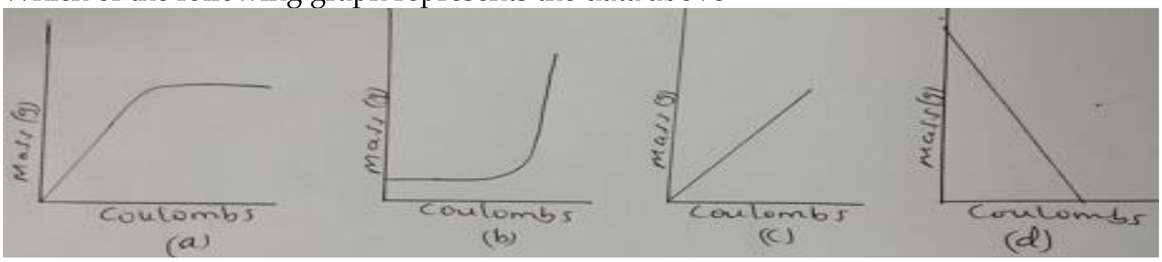
b) Soft water forms lather more easily than hard water.
c) Hard water does not wash clothes easily.
d) Water forms leather easily.

20. Mpho wants to know what determines the time it takes for water to boil. He pours the same amount of water into three containers of different sizes, made of clay, steel, and aluminium. He applies the same amount of heat to the containers and measures the time it takes the water in each container to boil. Which one of the following could affect the time it takes for water to boil in this investigation?
a) The shape of the container and the amount of water used.
b) The amount of water in the container and the amount of heat used.
c) The size and type of the container employed.
d) The type of container and the amount of heat used.

21. Form three students investigated the relationship between the quantity of electricity supplied and the masses of the products formed during electrolysis. The following kind of data were collected;

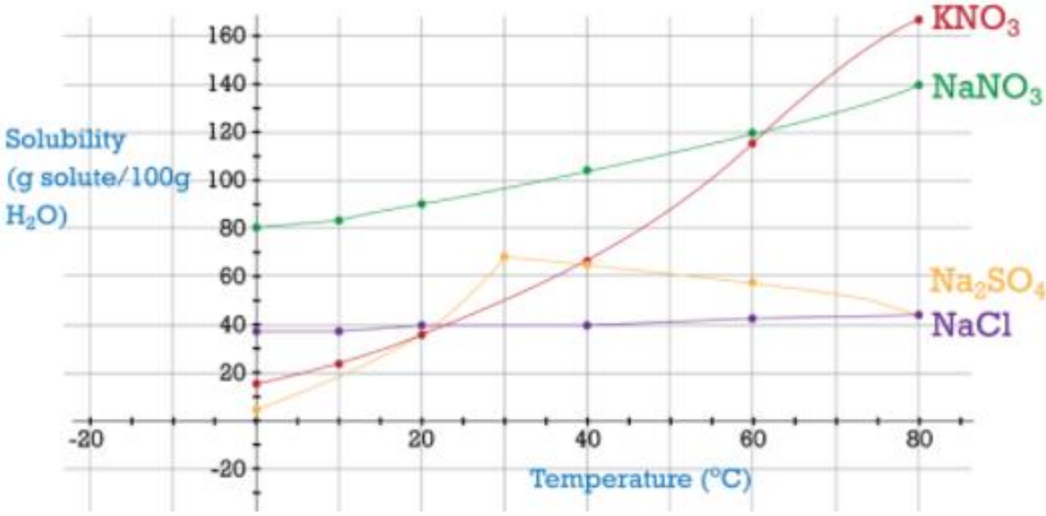
Quantity of electricity (coulombs)	Mass of Copper (g) corrode from anode
189	0.060
378	0.12
567	0.19
756	0.25

Which of the following graph represents the data above



22. Some students are considering variables that might affect the time it takes sugar to dissolve in water. They identify the temperature of the water, the amount of sugar, and the amount of water as variables to consider. What is a hypothesis the students could test about the time it takes for sugar to dissolve in water?
a) The more sugar there is, the more water is needed to dissolve it.
b) The colder the water, the faster it has to be stirred to dissolve.
c) The warmer the water, the more sugar that will dissolve.
d) The warmer the water, the more time it takes the sugar to dissolve.

23. The following curve shows the graph of solubility of some salts against temperature. Which interpretation is correct;



a) Solubility of KNO_3, NaCl and $NaNO_3$ increases, as temperature increases while solubility of Na_2SO4 increases and then decreases as temperature increases.
b) Solubility of KNO_3 and NaNO3 increases as temperature increases, while solubility of Na_2SO4 increases and then decreases as temperature increases.
c) Temperature increases the solubility of KNO_3, Na_2SO_4, NaCl and $NaNO_3$
d) The solubility of KNO_3 and $NaSO_4$ increases as temperature increases, while the solubility of NaCl increases and then decreases as temperature increases.

24. Students wanted to determine the convention of chemical energy in kerosene into heat energy. A kerosene burner was used to heat pure water in a beaker. How was the convention of chemical energy in kerosene converted into heat energy measured?
a) Using a thermometer to verify any change in the temperature of water
b) Observing the light produced in the kerosene burner
c) Measuring the amount of water being heated
d) Observing the heat produced in pure water

25. Lisa wants to measure the amount of heat energy a flame will produce in a certain amount of time. A burner will be used to heat a beaker containing a liter of cold water for ten minutes. How will Lisa measure the amount of heat energy produced by the flame?
a) Note the change in the water temperature after ten minutes
b) Measuring the volume of water after ten minutes
c) Measuring the temperature of the flame after ten minutes
d) Calculate the time it takes for the liter of water to boil

Appendix 2: Science Process skills Test (Post-test)
School code………Student class……..Examination time: 50 minutes Date…………
Test instructions: This test comprises 25 multiple choice test Items. Read all questions carefully and circle an alphabetical letter indicating the correct answer of your choice in each question.

1. Mbagau wants to find a good way to increase the rate of reaction at which hydrogen is produced between magnesium wire and hydrochloric acid. He was thinking that the concentration of hydrochloric acid used could affect the rate of hydrogen produced. Which of the following is a good procedure to test the hypothesis;
   a) Using magnesium wire of different sizes while using different concentrations of hydrochloric acid
   b) Using magnesium wire pieces of the same size while varying the concentration of hydrochloric acid
   c) Using magnesium wire of different sizes while using the same concentration of hydrochloric acid
   d) Use the same amount of magnesium wire while using the same concentration of hydrochloric acid.
2. In an experiment, the teacher investigated the effect of different concentrations of acetic acid on the rate of carbon dioxide gas produced. He hypothesized that the higher the concentration of acetic acid, the higher the rate of carbon dioxide gas produced. In this experiment, what is the independent or causing variable?
   a) Concentrations of acetic acid used
   b) Both the concentration of acetic acid and the rate of carbon dioxide produced
   c) The rate of carbon dioxide produced
   d) All the above
3. In Dekaus's village, people use white and black seeds from local mbuni trees as soap detergents to remove stains from their clothes. Dekau wanted to investigate the effectiveness of seeds in removing stains from clothes. She hypothesizes that black seeds remove stains more effectively than white seeds. Which procedure should he choose to test his hypothesis?
   a) Wash clothes with same equal amount of white seeds. Then observe the time taken for the stains to be removed from the clothes
   b) Wash clothes with an equal amount of black seeds. Observe the time taken for the stains to be removed from the clothes.
   c) Wash clothes with an equal amount of black seeds and white seeds. Thereafter, observe the time taken for the stains to be removed from the clothes.
   d) Wash clothes with an equal amount of mbuni tree seeds. Then observe the time taken for the stains to be removed from the clothes.
4. A student wants to know the effect of acid rain, upon a fish population. He takes two jars and fills each of the jars with the same amount of water. He adds fifty drops of vinegar (acid) to one jar and adds nothing extra to

the other. He then puts 10 similar fish in each jar. Both groups of fish are cared for (oxygen, food) in identical fashion. After observing the behavior of the fish for a week, he draws his conclusions. What would you suggest to improve this experiment?

a) Prepare more jars with different amounts of vinegar.
b) Add more fish to the two jars already used.
c) Add more jars with different kinds of fish and different amounts of vinegar to each jar.
d) Add more vinegar to the jars already in use.

5. Five different size of magnesium wire is used to produce hydrogen gas in the industry. The same wire is used for each production. The following table shows the results of an investigation that was done on the amount of hydrogen gas produced in each reaction.

Size (diameter) of magnesium (mm)	Amount of hydrogen produced per minute (Litres)
8	1
13	2
20	4
26	7
30	12

Which of the following statements describes the effect of the size of magnesium on the amount of hydrogen per minute?

a) The more the amount of hydrogen produced, the more the time used to produce it.
b) The smaller the diameter of the magnesium wire, the higher the speed at which the hydrogen is produced.
c) The larger the diameter of the magnesium, the more the amount of hydrogen produced.
d) The diameter of the magnesium has less effect on the amount of hydrogen produced

6. Students in the laboratory wanted to conduct an experiment involving solid calcium carbonate and dilute hydrochloric acid to produce carbon dioxide gas. They hypothesize that temperature affects the rate at which carbon dioxide gas is produced. How can students plan their experiment to test their hypothesis?

a) Carrying out a reaction at different temperatures with different amounts of calcium carbonate and the same amount of hydrochloric acid.
b) Performing the same amount of calcium carbonate and hydrochloric acid reaction at different temperatures
c) Carrying out a reaction at different temperatures with the same amount of calcium carbonate and a different amount of hydrochloric acid.
d) At the same temperature, carry out a reaction with varying amounts of calcium carbonate and hydrochloric acid.

7. In a radio advertisement, it is claimed that Surf produces more foam than other types of powdered soap. Chudwa wanted to confirm this claim. He put the same amount of water in three basins and added 1 cup of a different type of powdered soap (including surf) to each basin. He vigorously stirred the water in each basin and observed the one that produced more foam. Which of the factors below is likely not to affect the production of foam by powdered soap?
   a) The amount of time used to stir the water
   b) The amount of stirring done
   c) The type of basin used
   d) The type of powered soap used

Sarah wanted to know if temperature affects the rate of reaction between magnesium and water substances. One beaker was kept at 0°C, another beaker was kept at 30°C and another beaker was kept at 60°C. The beakers were observed where the time taken for the reaction to take place was recorded.

8. What is the dependent or responding variable in the experiment?
   a) Reaction rate of the reacting substances
   b) Water and magnesium
   c) Temperature used
   d) Total number of beakers used at each temperature
9. What is the independent or causing variable in the experiment?
   a) Reaction rate of the reacting substances
   b) Water and Magnesium
   c) Temperature used
   d) Total number of beakers at each temperature
10. One of the students observed that a reaction involving hydrogen peroxide decomposes slowly to form water and oxygen gas in which effervescence is produced. He was advised that the chemical reaction can be increased when manganese dioxide is used as a catalyst. Which of the following hypotheses is suitable;
    a) Manganise dioxide increases the rate of water formation.
    b) Manganise dioxide increases the rate of reformation of hydrogen peroxide.
    c) Manganise dioxide increases the rate of decomposition of hydrogen peroxide.
    d) Hydrogen peroxide increases the rate of decomposition of manganese dioxide.
11. The efficiency of the catalyst in the rate of decomposing hydrogen peroxide was studied. Two identical test tubes received an equal amount of hydrogen peroxide, but only in one test tube a few drops of catalyst (manganise dioxide) were added. How would Nyambiti measure the rate of reaction?
    a) By measuring the amount of time, it takes for the reaction to complete
    b) By measuring the mass of hydrogen peroxide decomposed
    c) By measuring the amount of manganese dioxide remained after the reaction
    d) By measuring the amount of water formed after the decomposition of hydrogen peroxide

12. Observe the following table below showing the results of investigation made by students. The results show that;

Time (min)	0	1	2	3	4	5
Volume of gas produced (cm^3)	0	34	42	48	50	50

a) The reaction had stopped at three minutes as the gas was not increasing.
b) The reaction had finished by four minutes, as no more gas was produced after that.
c) The rate of reaction was high as more gas was produced throughout the reaction.
d) The rate of reaction was high at the beginning of the reaction and at the end of the reaction.

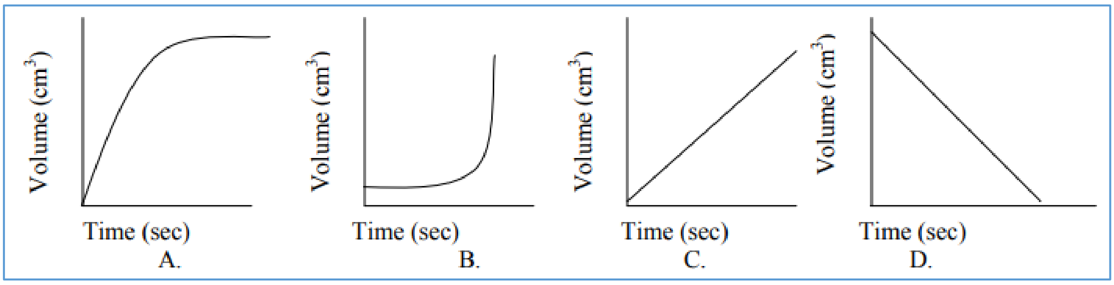
13. Students added 0.5M of dilute hydrochloric acid to 0.2g of magnesium metal in flask A. As they added more 1M of dilute hydrochloric acid to 0.2g of magnesium metal in flask B students noted the increase of rate of reaction between magnesium metal and dilute hydrochloric acid. What could be the hypotheses being tested;
a) The rate of chemical reaction increases as the concentration of hydrochloric acid increases.
b) The rate of chemical reaction increases as the concentration of hydrochloric acid decreases.
c) The higher the concentration of hydrochloric acid, the higher the difference in the rate of chemical reaction.
d) The concentration of hydrochloric acid decreases the chemical reaction between magnesium metal and acid.

14. Monde noticed that the steel wool that she uses to clean her pots rusts quickly if exposed to air after using it. She also noticed that it takes a longer time for it to rust if it is left in water. She wondered whether it was the water or the air that caused the wet, exposed steel wool to rust. Which of the following statements could be tested to answer Monde's concern?
a) Steel wool cleans pots better if it is exposed to air.
b) Steel wool takes a longer time to rust if it is left in water.
c) Water is necessary for steel wool to rust.
d) Oxygen can react with steel wool.

15. Sandile carried out an investigation in which she reacted magnesium with dilute hydrochloric acid. She recorded the volume of the hydrogen gas produced from the reaction. The results are shown below;

Time (seconds)	0	10	20	30	40	50	60	70
Volume (cm^3)	0	14	23	31	38	40	40	40

Table above shows the volume of hydrogen gas produced per second. Which of the following graphs show these results correctly?



16. Amina wanted to determine if there was any difference in the amount of carbon dioxide produced in chemical reaction between calcium carbonate and dilute hydrochloric acid when different sizes of calcium carbonate are used. Ahmad put different size of calcium carbonate in different test tubes with hydrochloric acid. Which of the following variables would be the most important to be controlled in this experiment;
    a) The weight of the hydrochloric acid used
    b) time of the day the experiment is conducted
    c) The amount of hydrochloric acid used in two test tubes
    d) The number of reactions made during the experiments
17. Okwino placed 10g of ammonium chloride in a flask that was connected to another flask. He applied heat of 498^{0}C to the flask containing ammonium chloride. After the reaction was completed, he measured the weight of products which were collected in the second flask and found 10g of ammonium chloride. What conclusion can you make;
    a) Products are recombined to form the reactants.
    b) The reaction remained at equilibrium.
    c) The reaction involved decomposition.
    d) The reaction fevered the forward reaction.

Thobiso is worried about how the hot winter will affect the growth of bacteria on the bread he produces. He decided to investigate the effect of temperature on the growth rate of bacteria in breads. He packed the same bread in three identical containers and placed them at different temperatures of -10^{0}C, 30^{0}C and 80^{0}C. The growth rate of bacteria on bread was observed at the end of 5 days. Use this to answer question 18-20 below;

18. What could be the hypothesis in the above experiment;
    a) The winter is not conducive for bread production.
    b) Containers affect the growth rate of bacteria on breads.
    c) The temperature affects the growth rate of bacteria on breads.
    d) The differences in bacteria growth are associated with containers at each temperature
19. What is the dependent (responding) variable in this investigation?
    a) Changes in temperature
    b) The growth rate of bacteria in breads.
    c) The three containers used
    d) Breads in three identical containers
20. What variables were kept constant in this investigation?
    a) Bacteria
    b) The growth rate of bacteria in breads.

c) Changes in temperature
d) Bread and containers

21. A chemistry teacher heated hydrated copper sulphate in the flask. Then the teacher observed the colour changing from blue to white powder. After allowing the white power to cool, the teacher added a few drops of water, and the colour changed from white to blue. What is the most reasonable conclusion can you make;
    a) The reaction was irreversible.
    b) The reaction is reversible.
    c) The reaction was at equilibrium.
    d) The reactant only reacts to form products.
22. The teacher wanted to show students' whether increasing the concentration of hydrochloric acid with zinc granules increased the rate of production of hydrogen gas. How the teacher and students would determine that the rate of reaction has increased?
    a) By measuring the time used to decompose zinc granules
    b) By measuring the volume of hydrogen gas produced
    c) By measuring the amount of acid used in the reaction
    d) By measuring the amount of zinc used in the reaction
23. Kwandu was studying the effect of homo soap on removing stains from white clothes. He hypothesizes that the homo soap removes stains easily. He used different soaps including homo to wash white clothes. How could the rate of removing stains be measured?
    a) Note the time taken for stains to be removed from the clothes
    b) The number of stains removed from each piece of clothing washed with a different detergent.
    c) Note the time taken to complete washing clothes
    d) The amount of soap used to wash clothes
24. Thabo wanted to show his friend that the size of a container affects the rate of water loss, when water is boiled. He poured the same amount of water into containers of different sizes but made of the same material. He applied the same amount of heat to all the containers. After 30 minutes, he measured the amount of water remaining in each container. How was the rate of water loss measured in this investigation?
    a) By measuring the amount of water in each container after heating it.
    b) By using different sizes of the containers to boil the water for 30 minutes.
    c) By determining the time taken for the water to boil in each of the containers.
    d) At a given time, by determining the difference between the initial and final amounts of water

25. Students investigated the effect of catalyst on the rate of reaction and the following data were recorded;

Time (s)	0	15	30	45	60	75	90	120	150	180	195
Volume of O_2 cm^3 using 1g of MnO_2	0	9	18	26	35	44	50	71	76	80	80
Volume of O2 using 3g of MnO2	0	15	29	42	53	64	75	80	80	80	80

The results show that;

a) When 1 gram of manganese (IV) oxide is used, more oxygen gas is collected in a shorter period of time than when 3 g of manganese (IV) oxide is used.
b) The volume of oxygen gas collected at each specific time of interval is less when 3g of manganese (IV) Oxide is used than the corresponding volume of oxygen when 1g of manganese (IV) is used.
c) When 1g of Manganese (IV) Oxide is added, the reaction proceeds very fast and a lot of oxygen is collected in a short time.
d) The volume of oxygen gas collected at each specific time interval is greater when 3g of manganese (IV) Oxide is used than the corresponding volume of oxygen when 1g of manganese (IV) is used.

Appendix 3: Focus Group Discussion with Students (before intervention)
School code: ……………………………

Dear students,

The following discussion aims at looking at your general feelings and experience in learning chemistry concepts during teaching and learning. Please be free to give your contributions. The information given will only be used for the purpose of this study and not otherwise.

1. How do you learn chemistry concepts?
2. How do teachers engage you to learn through science process skills when learning chemistry concepts?

Appendix 4: Focus Group Discussion with Students (After intervention)
School code: ……………………………

Dear students,

The following discussion aim at exploring your general feelings and opinions on the use of computer simulations and animations used during teaching and learning. Please be free to give your contributions. The information given will only be used for the purpose of this study and not otherwise.

1. How have computer simulations and animations in teaching facilitated your learning of chemistry concepts?
2. Can you explain how the use of computer simulations and animations has engaged you in learning science process skills when learning chemistry concepts?