International Journal of Learning, Teaching and Educational Research
Vol. 21, No. 8, pp. 21-42, August 2022
https://doi.org/10.26803/ijlter.21.8.2
Received Mar 30, 2022; Revised July 12, 2022; Accepted July 27, 2022

Exploring the Use of Chemistry-based Computer Simulations and Animations Instructional Activities to Support Students' Learning of Science Process Skills

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Abstract. This study aimed at exploring the instructional activities that could support students' learning of science process skills by using chemistry-based computer simulations and animations. A total of 160 students were randomly selected and 20 teachers were purposively selected to participate in the study. Data were gathered in both qualitative and quantitative formats. This was accomplished through the use of a classroom observation checklist as well as a lesson reflection sheet. The qualitative data were analyzed thematically, while the quantitative data were analyzed using percentages. The key findings from the study indicated that chemistry-based computer simulations and animations through instructional activities, particularly formulating hypotheses, planning experiments, identifying variables, developing operational definitions and interpretations, and drawing conclusions, support students in learning science process skills. It was found that during the teaching and learning process, more than 70% of students were able to perform well in the aforementioned types of instructional activities, while 60% performed well in planning experiments. On the other hand, as compared to other instructional activities, planning experiments was least observed among students and teachers. Students can be engaged in knowledge construction while learning science process skills through the use of chemistry-based computer simulations and animations instructional activities. Therefore, the current study strongly recommends the use of chemistry-based computer simulations and animations by teachers to facilitate students' learning of chemistry concepts in Tanzanian secondary schools.

Keywords: chemistry-based computer simulations; instructional activities; science process skills

1. Introduction

The possibility of involving students in the acquisition of knowledge and scientific skills, particularly science process skills (SPSs), has grown in importance in chemistry curricula globally (Aydm, 2013; Bete, 2020). This is owing to the science process skills' alignment with students' learning and application in everyday life. As a result, different countries' chemistry curricula include science process skills in both basic and integrated SPSs. Basic SPSs includes observing, classifying, measuring, calculating, inferring, and communicating. Integrated SPSs include formulating hypotheses, identifying and controlling variables, designing experiments, data recording and interpretation (Abungu et al., 2014; Athuman, 2019; Aydm, 2013). During chemistry teaching and learning, effective instructional strategies that engage students in inquiry activities are essential for the development of science process skills. Therefore, inquiry-based approaches to teaching and learning, such as practical work and hands-on activities, are critical for engaging students in active learning (Abungu et al., 2014; Irwanto et al., 2018; & Seetee et al., 2016).

Chemistry includes abstract concepts such as chemical kinetics, equilibrium and energetics which students find difficult to learn (Lati et al., 2012). Along the same line, teacher-centeredness dominates chemistry teaching and learning in Tanzanian classrooms, with the teacher remaining the primary source of information through the chalk-and-talk technique. Moreover, inquiry learning tasks such as observations, hypotheses, testing, data collection, interpretations, discourse, and conclusions are similarly restricted in the learning process (Kalolo, 2015; Kinyota, 2020). Consequently, memorization learning persists, and there is little effort to support learners with science process skills (Mkimbili et al., 2018; Kinyota, 2020; Semali & Mehta, 2012). In this regard, inappropriate teaching strategies which rely on teacher-centeredness and occasional practical work, shortages of laboratories and teaching aids, as well as large class size, are among the contributing causes (Mkimbili et al., 2018; Semali & Mehta, 2012).

Chemistry-based computer simulations and animations are examples of an information and communication technology (ICT) invention that has been explored and used as alternative teaching and learning resources in classrooms globally. Computer simulations are computational models of real or hypothesized situations or natural phenomena that allow users to explore the implications by manipulating or changing parameters within them (Nkemakolam et al., 2018). In addition, animations are dynamic displays of graphics, images, and colors that are used to create certain visual effects over a series of frames (Trindade et al., 2002). Computer simulations and animations include virtual laboratories and visualizations of phenomena. Further, the interactivity feature of computer simulations in involving students in hands-on activities has promoted their importance as they are essential for inquiry learning and a learner-centered environment in the classroom (Moore et al., 2014; Plass et al., 2012). Based on the significance of ICT, the competence-based curriculum in Tanzania recommends the availability and use of ICT, including computer simulations and animations. This is to ensure smooth teaching and learning as well as giving learners real-world experience in learning (MoEST, 2015; MoEST, 2019).

Despite Tanzania's government's initiatives to integrate ICT into classrooms, little is known about how chemistry content may be presented effectively in an inquiry-based setting (Ngeze, 2017). ICT uses encompasses specific instructional strategies that support students in learning science process skills through inquiry learning in the chemistry classroom. This follows the fact that blending proper instructional activities when using computer simulations is an important factor in engaging students in learning chemistry concepts and specific science process skills (Çelik, 2022). The reviewed literature (Beichumila et al., 2022; Çelik, 2022; Moore et al., 2014) advocates the use of computer simulations and animations in chemistry learning to improve students' acquisition of science process skills.

In the above regard, Çelik (2022) and Sreelekha (2018) emphasize teaching strategies for students to acquire science process skills through computer simulations and animations. In such a learning context, little is known about instructional strategies that support the learning of these integrated science process skills through computer simulations and animations. Therefore, the goal of this study was to investigate the chemistry-based computer instructional activities used to engage students in building integrated science process skills during chemistry teaching and learning. The study sought to address the following research question: What are the chemistry-based computer simulation and animation instructional activities used to engage students in building integrated science process skills during chemistry teaching and learning?

2. Literature Review

2.1 Chemistry-computer simulations, animations and science process skills development

The interactivity feature of computer simulations and animations has ability to enable students to observe process, events, and activities during learning (Smetana & Bell, 2012). As students interact with computer simulations and animations, they become engaged in the exploration of the world around them through inquiry activities (Moore et al., 2014). In this sense, students get the opportunity to engage in inquiry learning and gather scientific evidence that are important for learning science concepts. Through computer simulations students develop scientific knowledge as well as science process skills (Beichumila et al., 2022; Çelik, 2022; Supriyatman & Sukarino, 2014). However, aspects of inquiry are not the focus in most of the lessons in science classrooms. As a result, instructional strategies as advocated by Yadav and Mishra (2013) in teaching and learning processes are critical towards using any inquiry-based approach, including computer simulations and animations to develop science process skills. Students learn less in terms of science process skills by using computer simulations in a teacher-centered format in which students' complete recipe-type tasks that require them to verify solutions (Çelik, 2022; Smetana & Bell, 2012). Thus, instructional activities for inquiry learning are important.

2.2 The importance of instructional activities and development of science process skills

Instructional activities relate to all activities that support the teaching and learning process (Akdeniz, 2016). These instructional activities are teaching and learning activities and assessment activities that play a significant role in engaging students in the construction of knowledge and the acquisition of skills. Instructional activities that engage teachers in explaining or lecturing students while students are passive listeners do not help students to acquire science process skills. One way to develop the science process skills among students is to use appropriate instructional activities that engage students in inquiry activities (Bete, 2020; Coil et al., 2010; Irwanto et al., 2018; Seok, 2010). Activating students' background knowledge, offering analogies, asking questions, and encouraging students to use alternative forms of representation are some of the teaching strategies. According to Supriyatman and Sukarino, (2014), teachers can use computer simulations to assist students in predictions to generate inquiry.

Furthermore, Brien and Peter (1994) and Jiang and McComas (2015) advocated the need for instructional activities that integrate well into lessons for inquiry learning. The approach allows students to gain a deeper and broader understanding of science content with real-world applications, as well as learning about the scientific inquiry process. This includes developing general investigative skills (such as posing and pursuing open-ended questions, synthesizing information, planning and conducting experiments, analyzing, and presenting results). For example, during classroom lessons, students were engaged in tasks such as making observations and inferences, planning experiments, and generating predictions (Abungu et al., 2014., Chebii et al., 2012, Rauf et al. 2013, Saputri, 2021). As a consequence of involving students in these learning activities, they work collaboratively in groups, interact with each other through discussion and carrying out experiments under the guidance of the teacher. In addition, the instructional activities mentioned develop critical thinking skills and learning curiosity among learners (Higgins & Moeed, 2017; Pradana et al., 2020). Thus, in the Tanzanian context it was important to explore instructional activities that support students' learning of science process skills while using computer simulations and animations to learn chemistry concepts.

2.3 Theoretical Framework

This study was framed within social constructivism theory by Vygotsky (1978) who believed that knowledge construction is an active process conducted through social interaction among learners themselves, learners and teachers or learners and materials. This indicates that scientific knowledge and skills are socially constructed and verified under social constructivism in science learning. As a result, Onwioduokit (2013) suggested that when students are taught science, they should participate in inquiry activities. This becomes possible when learners are encouraged to learn by doing something as a means of learning instead of only listening (Demirci, 2009). In essence, these instructional activities are essential to enable teachers and learners to interact with computer simulations and animations during teaching and learning.

Vygotsky (1978) explained the role of teachers in using instructional activities and learner-centered strategies to enable students to construct knowledge and skills. Therefore, using social constructivism theory, it was believed that it could help to understand instructional activities that engage learners in knowledge construction and learning science process skills as they learn using computer simulations. These are essential learning environments to create a social learning environment that facilitates students' construction of knowledge and skills that can be applied from a classroom context to real life experiences.

3. Methodology

3.1 Participants, sampling and sample size

The study was carried out at four secondary schools from the Dodoma and Singida regions of Tanzania's central part. The area was chosen because students perform poorly in science, including chemistry, and there is a shortage of instructional materials (MoEST, 2019, 2020). The selection of schools was based on the availability of computer laboratories and other ICT equipment or tools such as projectors. The assumption was that by using computer laboratories, students could be subjected to the teaching and learning of chemistry using computer simulations as one way to engage learners in hands-on activities.

The challenging topic of chemical kinetics, equilibrium, and energetics was the focal point of the current study (Beichumila et al., 2022; Lati et al., 2012), which is taught at level three of secondary education in Tanzania (MoEVT, 2010). This served the choice of 160 Form Three students (level 3 of ordinary secondary education), who were rondomly selected to be involved in this study. Furthermore, 20 chemistry teachers were purposely involved in the study based on the criteria that they had prior training in ICT integration in the classroom.

3.2 Research approach and design

The study employed a mixed method through both quantitative and qualitative approaches to collect data. This was done through classroom observations focusing on both teachers' and students' learning activities (Cresswell, 2013; Cresswell & Clark, 2018). In addition, a lesson reflection sheet was used to explore students' insights on lesson instructional activities. The focus was to explore the instructional activities that could support students' learning of science process skills by using chemistry-based computer simulations and animations. This generated information that helped the research team to explore the instructional strategies that could engage students in learning chemistry concepts using computer simulations and animations. The use of both classroom observation and a lesson reflection sheet was considered as triangulation of information (Cohen et al., 2011). The design of the study followed two steps, namely pre-intervention and post-intervention.

3.3 Data Collection Procedure

Step 1: Pre-intervention

The first four sessions, which were utilized as a pre-intervention, focused on the topics of chemical kinetics, equilibrium, and energetics, with conducted one lesson per school being conducted. The four lessons in pre-intervention were purposely used to capture an actual picture of instructional activities used by teachers to support students' learning of science process skills through computer simulations. This was a baseline setting. At this stage a classroom observation checklist was used as a data collection tool. The classroom observation checklist was developed by the researcher from existing literature, for example, Chebii et al. (2012). Classroom observation was chosen as the method since it provides first-hand evidence of what the teacher and students perform in class as compared to a questionnaire (Atkinson & Bolt, 2010).

Step 2: Post-intervention
In post-intervention, seven consecutive series of lessons were conducted at school level, making a total of 28 lessons in four secondary schools. Teachers and researchers were involved in the process of lesson planning, classroom teaching, and reflection. During lesson planning, teachers collaborated to prepare a lesson. It was to ensure that the lesson was prepared based on inquiry learning, focusing on achieving science process skills. Classroom teaching involved observations of different instructional activities and how students were learning chemistry concepts as well as science process skills. During lesson reflection, students were given a lesson reflection sheet on which they identified their favorite learning activities from the lesson. This was also time for the research team to reflect on the lesson and plan for the next one. Therefore, in this study, students were required to acquire knowledge as well as to formulate hypothesis, plan experiments, identify variables, define operationally, make interpretations, and draw conclusions. Table 1 indicates the nature of teaching strategies that accompanied the lessons adapted from Jiang and McComas's (2015) framework on inquiry instructional strategies for learning science concepts and process skills in the classroom context. This was to engage students in a more discursive context, as supported by chemistry-based computer simulations and animations in each lesson.

Table 1: Instructional strategies and science process indicators

Item	Instructional strategies in classroom context	Indicators of science process skills
1	Students were required to formulate a hypothesis in relation to the question under investigation	Formulating a hypothesis
2	Students were required to think of scientific procures, plan an investigation, and conduct experiments for the purpose of testing the hypothesis	Identifying procedures and planning for investigation
3	Students were required to identify associated variables of the investigation that could be controlled variables, dependent or independent variables	Identifying variables
4	Students were required to make interpretations of the collected evidence or data through tables, graphs, or words in order to obtain meaningful information and thereafter draw conclusions basing on collected evidence	Making interpretations and conclusions
5	Students were required to develop statements presenting a concrete description of an event that indicates what to observe/do as the evidence towards their observations and conclusion in relation to the question under investigation	Developing operational definitions

Furthermore, computer simulations from Yenka chemistry (https://www.yenka.com/en/Yenka_Chemistry), and one model of PhET simulation of reactions and rates (https://phet.colorado.edu/en/simulations/reactions-and rates) were used during the teaching and learning process in this study. Figures 1 and 2 are samples of these simulations in which students were engaged to learn chemical kinetics, equilibrium and energetics.

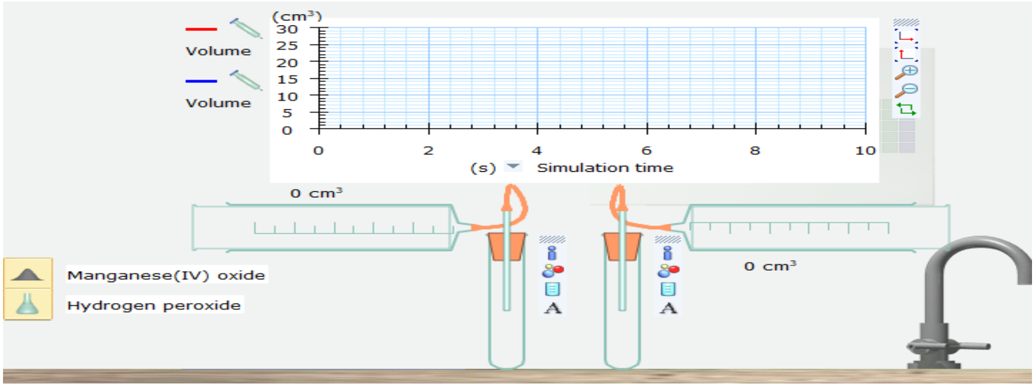


Figure 1: Computer simulation of the effect of a catalyst on the rate of reaction

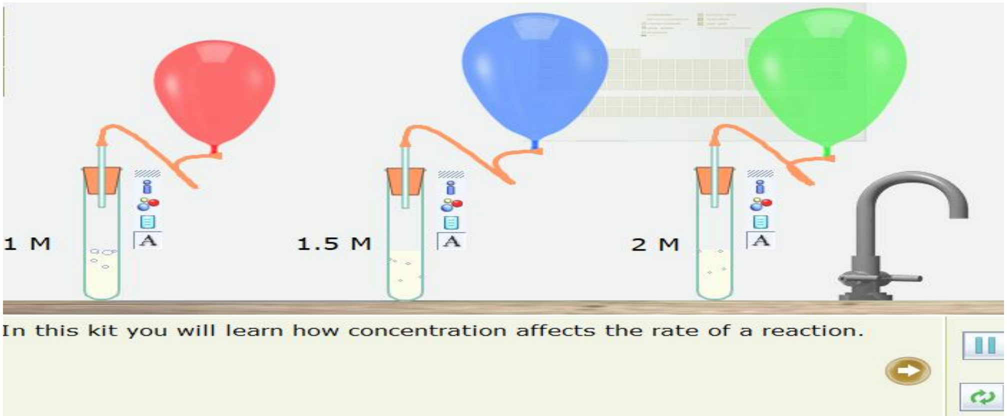


Figure 2: Computer simulation of the effect of concentration on the rate of reaction

3.4 Validity and reliability of data collection tools

In the case of ensuring validity, the classroom observation checklist and reflection sheets were evaluated by three chemistry teachers. Later on, the tools were piloted in two secondary schools that were not part of the selected schools in the study. This helped to identify and remove irrelevant items. In addition, inter-observer reliability which is a measure of consistency between two or more observers of the same construct was calculated (Cohen, 1988). The value of the Kappa coefficient (ka) across three observer pairs was found to be 0.80, 0.78, and 0.79 which are acceptable. The use of three observers (the researcher and two assistant researchers) independently during classroom observation helped to improve the internal reliability of the findings from classroom observation (Cresswell, 2013).

3.5 Data analysis

For the quantitative data, percentages (Pallant, 2020) were used to show the number of students and teachers in relation to instructional activities and science process skills indicators in the teaching and learning process. The qualitative data generated from classroom observations were thematically analyzed according to Braun and Clarke (2012). Information from the classroom observation and reflection sheet were transcribed and coded after a thorough discussion among the research team. This included notes and comments from observers on specific instructional activities that engaged students to learn science process skills through computer simulations. Finally, the agreed themes were used to conclude specific instructional activities supporting the learning of chemistry concepts with computer simulations and animations.

4. Results and Discussion

The general findings from this study indicate that instructional activities, particularly formulating hypothesis, planning experiments, identifying variables, developing operational definitions, making interpretations, and drawing conclusions, support students in learning integrated science process skills using chemistry-based computer simulations. It was found that during the teaching and learning process, generally more than 70% of students were able to perform the aforementioned activities well while 60% performed well in planning experiments. On the other hand, as compared to other instructional activities, planning experiments was the least observed among students and teachers. Tables 2-6 indicate the findings under each instructional activity.

Formulating hypothesis

The findings from this study indicated that the hypothesis formulation as an instructional activity involved students in predictions skill as 75% of students in post-interventions were able to formulate hypotheses. It was observed that, initially, 70% of students had no idea on how to hypothesize; however, their ability improved as they were involved in this learning activity. The activity helped students to make their predictions that could be scientifically tested. It was found in this study that using chemistry-based computer simulations to learn and understand chemical kinetics, equilibrium, and energetics made students more engaged in the teaching and learning process. Students were more involved in the lesson when they were asked to formulate a hypothesis in relation to the experiment's aim, rather than doing experiments by following predetermined sequence of procedures, as is the case in most science classrooms (Table 2).

Table 2: **Formulating hypothesis**

Teaching activities	Learning activities	Indicators of science process skills in the classroom context
90% of teachers guided students in small groups of 3-5 students through the process of writing down the aim of the experiment to be explored. Then teachers guided students to observe the	Students in small groups of 3-5 students were required to think and write down the question to be investigated and the aim of the experiment. Students discussed in groups what the	Before: The majority of students (70%) were not able to formulate a hypothesis correctly. For example, one of students in school C wrote:

computer simulation models, for example, the simulation that exhibited the effect of temperature and rate of reaction. They began writing down their hypothesis in relation to the question being investigated. For example, investigating how the temperature affect the rate of reaction.	hypothesis could be in relation to the aim of the experiment they determined by observing the computer simulations.	"*Surface area and rate of reaction are related*". After: 75% of students could formulate a hypothesis. Captured sentences from students formulating a hypothesis: "*The higher the temperature, the higher the rate of a chemical reaction*" In another group: "*The higher the temperature, the fast the chemical reaction*" "*Temperature affects the rate of a chemical reaction*" Another group in another lesson: "*The presence of catalyst will speed up the decomposition of hydrogen peroxide*" Observations from students: "*Increasing the rate of a reaction means increasing the number of fruitful collisions between particles, therefore increasing the temperature will increase the rate of reaction*".
The teacher used probing questions to help students use their prior knowledge to understand how they could formulate the hypothesis before further activity, for example: "*From the collision theory what do you think will happen if the temperature is lower or high in the reaction of calcium carbonate and hydrochloric acid*?"	The majority of students (75%) were able to think and discuss in their small groups how collision theory relates with temperature and rate of any chemical reaction.	

The findings from this study support Seok (2010), who found that engaging students in formulating a hypothesis on the question to be investigated in the science classroom helps develop this science process skill. Moreover, the findings indicated that through this instructional activity students developed a sense of collaboration and ownership of the lesson. This was revealed through learning from each other and arguing to reach a conclusion on the kind of hypothesis being formulated. This helped students to construct knowledge while at the same time developing a hypothesis-formulation skill. Darus and Saat (2014) found that teaching strategies that could be used by teachers to help students in hypothesis formulation to generate inquiry include activating students' background knowledge, providing analogies, questioning, and encouraging students to use alternative forms of representation. Thus, hypothesizing as learning with computer simulations in science classroom is one way to promote active learning and reasoning among students (Moore et al., 2014; Sreelekha, 2018).

Furthermore, collaboration is discussed under social-constructivism theory as one of the essential elements in the learning process as it changes the dynamics of the classroom by encouraging discussion among the learners. Vygotsky (1978) further explained that collaboration impacts students' learning. As a result, one of active learning strategies that promote students' curiosity in learning chemistry is their ability to make predictions. As has been suggested in the literature, students' interest in the subject matter contributes significantly to their ability to learn the subject when they are exposed to a social learning environment through active learning activities (Anderhag et al., 2015; Higgins & Moeed, 2017).

Planning experiment

The findings revealed that students (60%) learned to plan experiments through interaction with their peers during the investigation process since students could brainstorm with each other and work cooperatively in their small group to ensure that they come up with a good procedure to test their hypothesis. For example, when investigating how a catalyst affects the rate of reaction, a student told his group members that they needed to use the same amount of hydrogen peroxide in both test tubes, but one test tube needed to be added with a catalyst while the other did not, so that they could observe the difference. This is because some students understand the procedures more easily than others. Therefore, it was observed that this process helped students to share their ideas in the lesson which was also another way of being aware of the procedures and important related aspects such as materials, variables to consider and how to conduct their experiment (Table 3).

Table 3: Planning experiment

<table>
<tr><th>Teaching activities</th><th>Learning activities</th><th>Indicators of science process skills in the classroom context</th></tr>
<tr><td>60% of teachers guided students in groups of 3-4 to devise procedures to investigate the scientific question being explored to test their hypotheses/predictions. For instance, in a scientific question where students were to investigate how the catalyst affects the rate of a chemical reaction,
teachers guided students to use their plans and computer simulations to conduct simple experiments, make observations, record data and write simple reports.</td><td>60% of students in groups of 3-4 students were able to discuss and critically think of the best plan they could use for the procedure to test their hypothesis with the computer simulation.</td><td rowspan="2">Evidence from students' work in one of the groups:
"We have to put the same amount of hydrogen peroxide in two test tubes, then in one of the test tubes put certain amount of catalyst manganese (IV) oxide, then we will start the reaction and observe the time taken for the reaction between the two test tubes to complete."

In another group
"We will put 25mls of hydrogen peroxide (H_2O_2) in two test tubes, then we will add 2g of manganese (IV) oxide (catalyst) and</td></tr>
<tr><td>The majority of teachers were insisting students use specific measurements to obtain justifiable scientific</td><td>Students were able to discuss and decide the amount of solution or solute to be used in their</td></tr>
</table>

conclusions, for example one of the teachers: “*Do you think if you use a different amount of hydrogen peroxide in the two test tubes and a different amount of catalyst you will come up with a good scientific conclusion*?”	experiment to come up with scientific conclusion.	*observe the reaction in both test tubes.”* Observations from students’ group discussion “*… no, we need to take the same amount of hydrogen peroxide in both test tubes and measure specific amount of catalyst to be added in one of the test tubes*”. Another student: “*Yes, this is good, let us use 2g of manganese (IV) oxide as a catalyst*.”
60% of teachers used probing questions to help students understand how to plan scientific investigation/experiments by relating various concepts of kinetics in daily life activities in their homes.	Students were listening to teacher’s questions and trying to think of and give examples of short plans for scientific investigation or experiments from daily life experiences in society.	Observations from students: “*We can scientifically investigate a good soap to remove stains on clothes if we use same amount and types of water, the same clothes but we vary the soaps.”*

It was found that planning and performing experiments as an instructional activity enabled students to use concrete activities through computer simulations to test their hypotheses and come up with evidence. Students could learn other skills such as measuring substances, knowing when to mix chemicals and start the reaction, making observations, keeping records on what they observed, either in tables or in words and making relevant decisions. Irwanto et al. (2018) and Seetee et al. (2016) suggested that students’ experimenting skill is developed when a science teacher guides them to write out detailed steps to their procedure and determine the variables, including what needs to be controlled, and thinking of the data to be collected. The capacity to design an experiment is essential for comprehending the scientific process and developing critical thinking abilities (Pradana et al., 2020).

In addition, experimentation, a process which engages students directly with the physical world has been found to be effective in developing various students’ science process skills (Chebii et al., 2012). Moreover, the study mentioned did not explain the students’ abilities to plan experiments based on their own experience and understanding rather than following predetermined procedures. The use of these instructional procedures during practical activities is teacher-centered and does not match directly with social-constructivist theory as used in the context of the present study. As a result, the current study has revealed that experimentation instructional activity through computer simulations is one way to enable students to think critically and devise procedures to test their hypotheses. As students engage in these learning activities, they learn to reason and think critically.

According to Coil et al. (2010) and Pradana et al. (2020), this encompasses designing experimental skills that involve students in critical thinking and reasoning abilities.

Identifying and controlling variables
It was observed that initially, the majority of students (80%) were not able to identify variables. The findings in post-interventions from this study indicated that using the instructional activity of identifying variables involved students in learning to understand concepts of variables in scientific investigations. Therefore, it was observed that 70% of students could identify variables that can affect an experimental outcome, keeping variables constant while manipulating only the independent variables. Students could explain the independent variables as they manipulated computer simulations. For example, when learning the effect of concentration on reaction rate, one of the students explained that the concentration of acid was an independent variable since it was the one that was manipulated, whereas the rate of a chemical reaction was a dependent variable because it was the one that was measured. Table 4 provides more specific examples.

Table 4: Identifying and controlling variables

Teaching activities	Learning activities	Indicators of science process skills in the classroom context
Teachers were guiding students to be aware of variables associated with the investigation they were conducting. For example, teachers were guiding students to identify the variables through probing questions. For instance, where students were investing the effect of concentration on the rate of chemical reaction with computer simulation, the teacher asked what the controlled variables or factors in the experiment were as well as what the dependent and independent variables were.	Students, in their small groups of 3-4, were able to discuss and identify the variables as they were observing the computer simulations.	Before intervention: 80% of students had wrong answers. For example, one student in school A said: *"…the controlled variable in our experiment is time because in every test tube time taken for the reaction to complete was different"* After intervention: One of the student's words from school A: *"…in this experiment amount of calcium carbonate and temperature are the controlled variables because in all three test tubes there is 0.6g of calcium carbonate and temperature is 25⁰c in all test tubes but there are different concentrations of hydrochloric acid which is 1M, 1.5M and 2M. Concentration of hydrochloric acid in this*
Again, some teachers through probing questions techniques guided	The majority of students (70%) were able to brainstorm in their groups	

students to understand the logic behind these variables and their role in scientific investigations. For instance, in an investigation of how the temperature affect the rate of reaction, one of the teachers asked "*Why do you think i) the amount of calcium carbonate was maintained or kept constant in both test tubes?"* *ii) "…the temperature in both the test tubes was varied?"*	why some factors were kept constant while some were varied in their experiments.	*experiment is independent variable because it is the one being varied. The rate of reaction is dependent variable as it depends on the concentration of the acid in the rate of reaction"* Observations by from students: *"...because we wanted to know how the temperature affect the rate of a chemical reaction, so we had to vary the temperature only in both reactions while keeping other factors constant like amount of reacting substance in order to come up with scientific evidence that real the temperature affect the rate of reaction"*. Another observation was that students were also active and eager to ask questions, for example, one student asked "*What will happen if we don't control other variables*?"

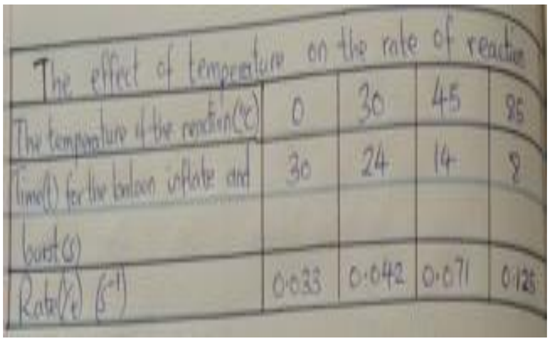
Therefore, the study findings support the teaching and learning methodologies of Athuman (2017) and Irwanto et al. (2018) for the skill of identifying and manipulating variables during the learning process. They include asking learners how they would decide on the set-up of the inquiry that would result in the most complete answer to the problem, as well as leading learners to the conclusion that they will only need to compare one component at a time. This implies that this is the kind of learning that situates students in knowledge construction rather than cramming the concepts. Moreover, Beichumila et al. (2022) and Saat (2004) found that the use of computer simulations-based environment improved students' ability to identify variables. In this case, identifying variables as a teaching and learning activity in chemistry is critical because it exposes students to the reality of these variables and their implications in scientific investigation as recommended in the chemistry competence curriculum.

Even though Ardac and Sezen (2002) and Beichumila et al. (2022) acknowledge the importance of identification and manipulation of variables in learning science, there is much more to be added. This includes the questions around how students are provided with opportunities to explain their understanding of variables in relation to daily life experiences. The focus of the curriculum is on students' understanding of the idea of variables in many situations in everyday life activities so that they may apply what they have learned in chemistry to other contexts (MoEVT, 2010). In this sense, it was critical for the chemistry students in this study to grasp the concepts of variables as they learned chemical kinetics, equilibrium, and energetics, all of which are closely tied to numerous daily activities. Moreover, as students are involved in asking questions and assessing their responses, they use their rational and logical thinking (Harrison, 2014).

Making interpretations and drawing conclusions

From the study findings, students (75%) were able to engage in learning activities such as providing meaning to the obtained data in order to comprehend the patterns and relationships that lead to the formation of conclusions. Students collaborated to organize their information either in tables, words or graphs as they interacted with computer simulations and animations. It was observed that students had an excellent opportunity to discuss in small groups and reach agreement with one another during this teaching and learning activity, and then present their agreed-upon results to the rest of the class. As a result, students learned to develop their own scientific explanations, as opposed to being passive in a teacher-centered classroom where teachers do all the work of explaining and writing notes on the chalkboard. Table 5 provides more insights and examples.

Table 5: Making interpretations and conclusion

<table>
<tr><th>Teaching activities</th><th>Learning activities</th><th>Indicators of science process skills in the classroom context</th></tr>
<tr><td>90% of teachers guided students to make interpretations of the collected data with computer simulations.
Teachers supported students to do it better by probing questions in the data,
for example, "Why do the balloons connected to the test tube with a high concentration of acid inflate faster and burst faster than the rest?"</td><td>75% of students in groups of 3-4 students were able to make interpretations on the observations made by making simple tables to show the pattern of the data, and reading the graphs from the computer simulation experiments. Moreover, explanations given from the observations when performing simple experiments.</td><td>Evidence from students works

The effect of temperature on the rate of reaction
The temperature of the reaction (°C) | 0 | 30 | 45 | 85
Time(t) for the baloon inflate and burst (s) | 30 | 24 | 14 | 8
Rate(1/t) (s⁻¹) | 0.033 | 0.042 | 0.071 | 0.125
Students' observation when explaining the table above: "When the temperature of a reaction increases, the rate of reaction increases. Temperature and rate of reactional are directly proportional."</td></tr>
<tr><td>Teachers were guiding students to make conclusions on their own from their observations in relation to the hypothesis which</td><td>Students in their groups were able to make conclusions based on the collected evidence or observations made.</td><td>Observations from students:
"The rate of the reaction increases as the temperature increases, hence the temperature affects the rate of a chemical reaction".

Another student observation:</td></tr>
</table>

was also presented to the whole class		*"The higher the temperature, the fast the reaction; the lower the temperature, the slow the reaction. Hence temperature affects the rate of reaction".*

Therefore, the findings have revealed the role of interpretation and conclusion as an instructional activity for students learning to interpret the collected information and constructing the meaning from them. The findings support the views of Coil et al. (2010) and Rauf et al. (2013), namely that the central part of the teacher's role in developing interpreting and conclusion skills is to ensure that results are used, and that students do not rush from one activity to another without discussing and thinking through what the results mean, for example, communicating the units such as centigrade, seconds per time, molarity, grams as they report what they did, observed and found. It was also an opportunity for students learning to read tables and graphs for them to interpret these more easily depending on the patterns.

Furthermore, it was found that discussing their results involved students in meaningful learning as they interacted with real activities, the teacher, and the learners themselves. It was therefore observed that students discussing and making conclusions on their own is very important in the teaching and learning process. It enables students to communicate their results but also to improve their communicative skills in interpreting what they have observed through words, graphs, or tables and drawing their own conclusions depending on the patterns or relationship of their results. In addition, Rauf et al. (2013) and Saputri (2021) explained that when students are involved in a discursive process, their science process skills become more developed. However, the studies are based on biological and physics phenomena rather than the current, which is based on chemistry, particularly chemical kinetics, equilibrium, and energetics. The common link between the previous mentioned studies and the present study is that both agree on the role of a teaching strategy that involves students in making relevant interpretations through words, graphs, or tables to make meaning. This supports social-constructivism theory as employed in this study that involving students in discursive processes promotes student interaction.

Making operational definitions

From the findings (Table 6), it was found that defining operationally is one of the instructional activities that involves students (70%) in learning. This includes what to observe or measure when conducting a scientific investigation. During scientific investigations, students are encouraged to use logic and critical thinking, and to participate in knowledge construction. Table 6 gives more evidence.

Table 6: **Making operational definitions**

Teaching activities	Learning activities	Indicators of science process skills in the classroom context
80% of teachers were able to guide students to make operational definitions which engaged students in critical thinking on the	70% of students were able to make operational definitions of their observations to justify their	The observation of one of the students answering the question: *"The time taken for the green balloon to inflate and burst,*

observations made as they performed experiments. Teachers used probing questions. For example: *"How do you know that the rate of reaction was fast or slow?"*	conclusions to answer the questions. For example, students were recording the time for each reaction to be completed, observing the color changes, the differences in chemical reactions, the formation and disappearance of bubbles as they mixed chemicals through computer simulations.	*which was placed at the reaction with a high temperature, was very short compared to the red balloon placed at the reaction with a low temperature."* Another student indicated: *"Because the green balloon took less time to fill and burst (8 seconds) than the red balloon, the green balloon's reaction was fast, but the red balloon's reaction was delayed".*

Athuman (2017) and Ngozi (2021) claimed that by providing a variety of materials and resources to aid students' investigations, posing thoughtful questions, encouraging dialogue among students and with the teacher, and maintaining students' natural curiosity throughout the process students' development of science process skills can be promoted. In addition, Athuman (2019) explained that involving students directly to develop understanding could deflect them from cramming information. Instead, they are involved in the process of understanding what is happening.

Furthermore, similar findings from students' lesson reflection sheets (Figures 3 and 4) indicated that learning using a chemistry-based computer strategy exposes students to instructional activities. This implies that the instructional activities are important in helping students to learn the associated science process skills.

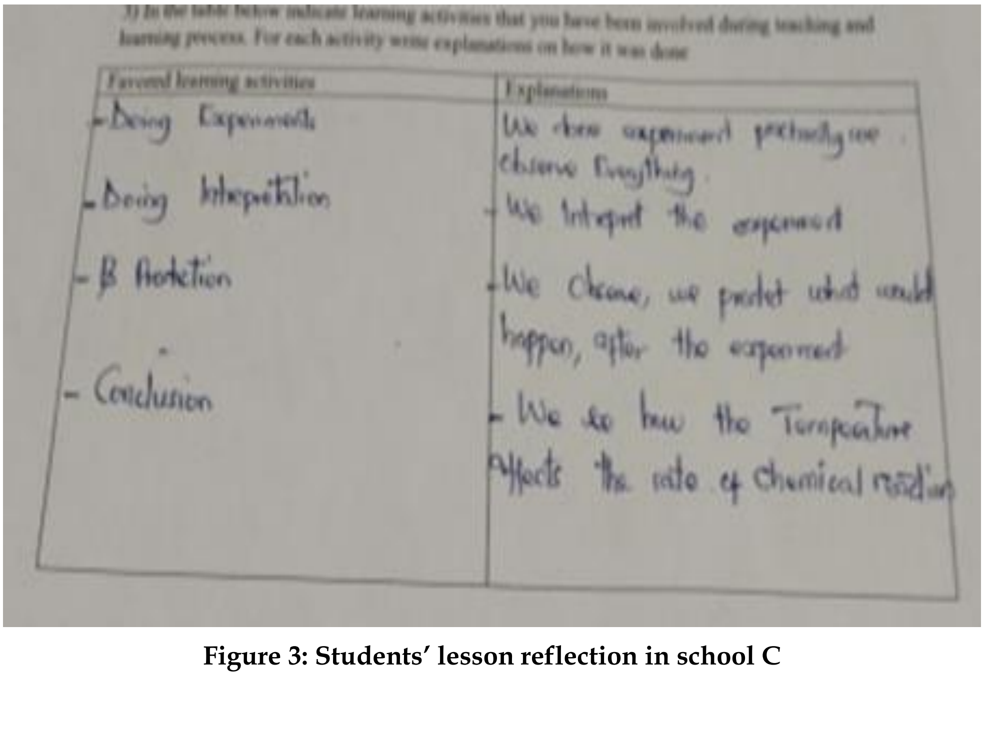
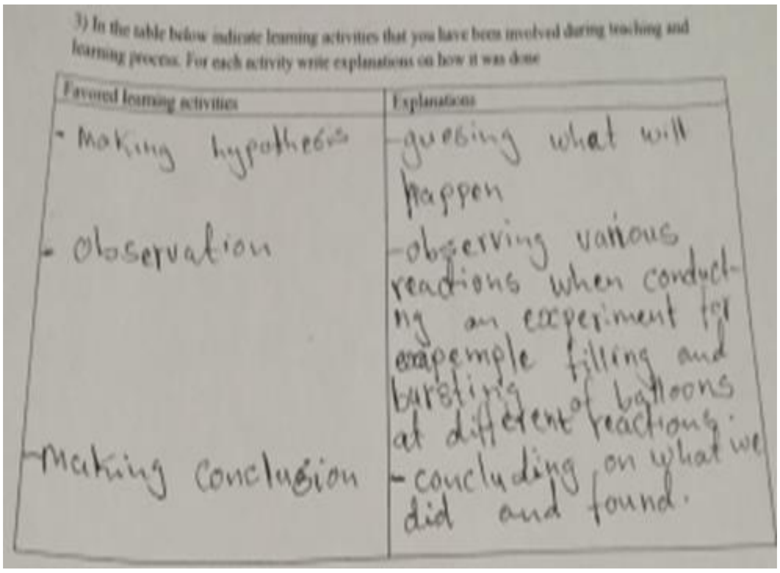


Figure 3: Students' lesson reflection in school C


3) In the table below indicate learning activities that you have been involved during teaching and learning process. For each activity write explanations on how it was done

Favored learning activities	Explanations
- Making hypothesis	- guessing what will happen
- Observation	- observing various reactions when conducting an experiment for exapemple filling and bursting of balloons at different reactions;
- Making conclusion	- concluding on what we did and found.

Figure 4: Students' lesson reflection in school A

Because chemistry is so closely connected to our daily lives, learning these science process skills makes it a meaningful subject. Students get the opportunity to discuss and evaluate their solutions with classmates and teachers while acquiring these science process skills. Students utilize their logical and reasonable thinking while encouraging higher order thinking skills in the act of generating assessments and discourse (Harrison, 2014; Pradana et al., 2020). Although, the current study has demonstrated that students can be engaged in the process of the learning science process to some extent, more work needs to be done on the exploration and development of chemistry computer simulations and animations.

5. Limitations of the study

The findings of this study revealed that instructional activities such as formulating hypotheses, planning experiments, identifying variables, compiling operational definitions, making interpretations, and drawing conclusions can support students in learning integrated science process skills. However, the study was limited to the exploration of the chemistry-based computer simulations and animations instructional activities supporting science process skills learning. To extend the scope beyond this sudy, further studies may be conducted on students' perceptions towards the use of computer simulations and animations in chemistry teaching and learning at secondary school level.

6. Conclusion

The study revealed that during the teaching and learning process, instructional activities as used in this study can support students in learning integrated science process skills using chemistry-based computer simulations and animations. This implies that instructional activities that focus not only on scientific content but also on transferable skills such as hypothesis formulation, designing experiments, identifying variables, interpreting results, and drawing conclusions are needed to prepare students more effectively to apply chemistry concepts in daily life. The same activities are essential in students' daily lives as they need to observe or predict different phenomena they come across. Furthermore, the use of chemistry-based computer simulations is one way to engage students in active teaching and learning processes, which creates a favorable learning environment for students to construct knowledge in the classroom at the same time that they acquire science process skills.

7. Recommendations

The findings of this study suggest that chemistry-based computer simulation instructional strategies that focus on engaging students in both scientific content and process skills such as formulating hypotheses, designing experiments, identifying variables, interpreting information, and drawing conclusions are essential in the learning process. Therefore, teachers need to consider the use of these instructional activities through chemistry-based computer simulations to facilitate students' learning of chemistry concepts in secondary schools.

Acknowledgement

The authors would like to thank the management of the African Centre of Excellence for Innovative Teaching and Learning Mathematics and Science (ACEITLMS) at the University of Rwanda, College of Education, which provided the funding for the entire study. We also acknowledge the participation of all the teachers, students, and the researchers’ team.

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9. Appendix A

Classroom observation checklist

Directions: In each item below, place a tick (√) depending on what you will observe by using the given scales. Also indicate any supporting evidence or comments depending on your observation.

Item no	Teachers' and students' teaching and learning activities	Never (1)	Rarely (2)	Sometime but not clear (3)	Sometimes but clear (4)	Almost always and clearly (5)	Comment/ any evidence as observed
1	Teacher guides students to make predictions or hypothesis of an investigation						
2	Teacher forms groups for students to work collaboratively during teaching and learning process at different stages of the lesson e.g., to formulate hypotheses, identify procedures, conduct investigations, and interpret and communicate results						
3	Teacher guides students' participation in identifying						

	and writing procedures to conduct a certain investigation	
4	Teacher guide students through questions to identify variables associated with an investigation	
5	Teacher guides students to plan and perform experiments to collect relevant data	
6	Teacher guides students to observe changes taking place in reactions, for example, color changes, formation and disappearance of bubbles, changes in the volume of gases being emitted when performing experiments,	
7	Teacher guides students to record observations and ideas when doing activities	
8	Teacher guides students to develop operational definitions during investigative activities	
9	The teacher provides an opportunity for students to discuss with each other in groups to describe the results of an investigation	
10	Teacher guides students to communicate the results of an investigation using words or graphs through whole class presentation, group presentation or report writing	
11	Students discuss and compare the results of the investigations to predictions/hypothesis made prior to investigations	
12	Others (specify below)………	

10. Appendix B

Students' lesson reflection sheet

1) In the table below, indicate learning activities in which you have been involved during the teaching and learning process. For each activity, write explanations of how it was done.

Favored learning activities	Explanations