Computer-based Simulation and its Effects on Student's Knowledge and Interest in Chemistry

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Abstract

Central to learning Chemistry is the development of fluency across various representations such as symbolic-, macroscopic-, and particulate-levels. "Simulations that support multi-representational fluency are considered critical (Moore, Chamberlain, Parson, & Perkins, 2014)" because of the inherent difficulty of Chemistry as a subject matter. This action research, aimed at analyzing the effects of computer simulation on students' knowledge and interest in Chemistry, used a quasi-experimental research design. The participants of the study were three intact classes from different learning groups in a male boarding school in Southern Tagalog province. Four Physics Education Technology (PhET) interactive simulations were used in teaching the concepts of chemical reaction for three weeks.

Pre- and post-test scores of the students showed that there is an increase in students' knowledge and is highest in the advance group. The result of the interest survey showed that advance and proficient students were highly interested while students approaching proficiency were moderately interested in learning Chemistry using simulation. Students revealed that they enjoyed using the computer-based simulation while learning Chemistry because (1) of the stars that they virtually receive and the challenges posed in the game levels, (2) the material is easy to manipulate, (3) they perform the activity with minimal supervision, thus making them feel independent, and (4) the material contains practice exercises and a game after the topic introduction. The computer-based simulation is recommended to be employed in classroom instruction to increase students' knowledge and interest in Chemistry.

Keywords: *Computer-based simulation, knowledge, interest, learning groups*

Introduction

The Enhanced Basic Education Act of 2013 in the Philippine Basic Education Curriculum is a solution to create opportunities that will help all children from the time they enter the classroom until they join the workforce (McCleary, 2012). However, our educational system encourages most of the students to be extrinsically motivated for attendance, for a grade or for requirements purposes (Dichev et al., 2014). According to the 2013 Functional Literacy, Education and Mass Media Survey (FLEMMS) (Philippine Statistics Authority, 2013) of the nearly 4 million out-of-school children and youth (6-24 years old), 19.1 percent lacks interest in attending school and is higher for males (33.1) compared to females (10.1). The result also showed that the proportion of persons who are out-of-school was higher among the youth (14.5 % to 20.4 %) than among children (1.7 % to 4.9%). Educators face growing challenges on how to increase the student's interest and achievement in learning.Mobile phone content will efficiently address issues such as a universally acceptable language medium, auto-translations, relevance, and the lack of local knowledge.

Chemistry comes with many challenges including balancing equations, understanding a complex chemical language and interpreting atomic-level representations. According to the results released by the National Education Testing and Research Center (2012), fourth-year Filipino students

obtained a mean percentage score of 48.90 in the 2012 National Achievement Test. The mean percentage score in secondary science was reported to be 39.49 percent in the school year 2004-2005, 37.98 percent in the school year 2005-2006 and 40.53 percent in the school year 2011-2012. Although the result manifests an increase in student's achievement compared to previous school years, it is still far from the government's goal which is 75 percent (Macha, et al. 2018). Moreover, out of 45 participating countries in the Trends in International Mathematics and Science Study (TIMSS) in 2003, the Philippines ranked 41st and 42nd in mathematics and science, respectively (Paul & Scriven, 1987). This suggests that Filipino students are weak in terms of mastery level in mathematics and science when they graduate from high school. The performance of Filipino students in Chemistry obtained 30 percent average correct answers in TIMSS which is way below the international average of 45 percent correct answers. In the male boarding school in Southern Tagalog province, the result of the Grade 10 Chemistry quarter exam for the academic year 2017-2018 is 57 percent with an overall mean score of 24.82 out of 50 (SMSAI-Science, 2018) was a shred of evidence that students really find difficulties in learning the subject.

Science teachers were facing problems on how to present concepts in such a way that the students' knowledge and interest would increase. The issue of the performance of students in chemistry has led to several proposals for enhancement. Unfortunately, those proposals revolve around unfitting teaching strategies and insufficient real-world exposure as the main cause of students' poor performance in chemistry. Many students were less than satisfied with the way it has been taught (Cooper & Cunningham, 2010). With the fast rate of technological advancements, the traditional learning style in which the teacher is the center of the learning seems to be no longer enough (Wu et al., 2012). But when students are given the proper level of instructional support, they can use a properly designed simulation to discover scientific concepts (Rieber, 2005). This study was set to analyze the effects of using computer-based simulation on students' knowledge and interest.

Objectives

The main objective of this study was to analyze how computer-based simulation (CBS) affects students' knowledge and their interest in Chemistry. The specific objectives of the study were:

1. To determine the level of knowledge of the students in Chemistry before using the computer-based simulation;
2. To determine the level of knowledge of the students in Chemistry after using the computer-based simulation;
3. To analyze the students' level of knowledge before and after the computer-based simulation in Chemistry;
4. To examine the effect of computer-based simulation on students' interest in Chemistry; and,
5. To recommend activities that would increase students' knowledge and interest in Chemistry.

Conceptual Framework

Gagne (1981) suggested nine events of instruction that may enhance student learning: gain attention, inform learners of objectives, stimulate recall of prior learning, present stimulus, provide learner guidance, elicit performance, provide feedback, assess performance, and enhance retention and transfer. Computer simulation complements the nine events of instruction (Gagne), which is an excellent lens to enhance the teaching and learning process.

Methodology

This study involved 143 students from three chemistry classes who were grouped homogeneously. The general weighted average of the advanced students (Group 1) is 90.94, proficient students' (Group 2) GWA is 88.32 and the GWA of the students who were approaching proficiency (Group 3) are 82.80. The study utilized the Physics Education Technology (PhET), a free resource computer simulation, in learning Chemistry. The setting of this study was in a male boarding school in the Southern Tagalog province. The researcher used a quasi-experimental design in analyzing how the computer-based simulation affects the knowledge and interest of each group of students in Chemistry.

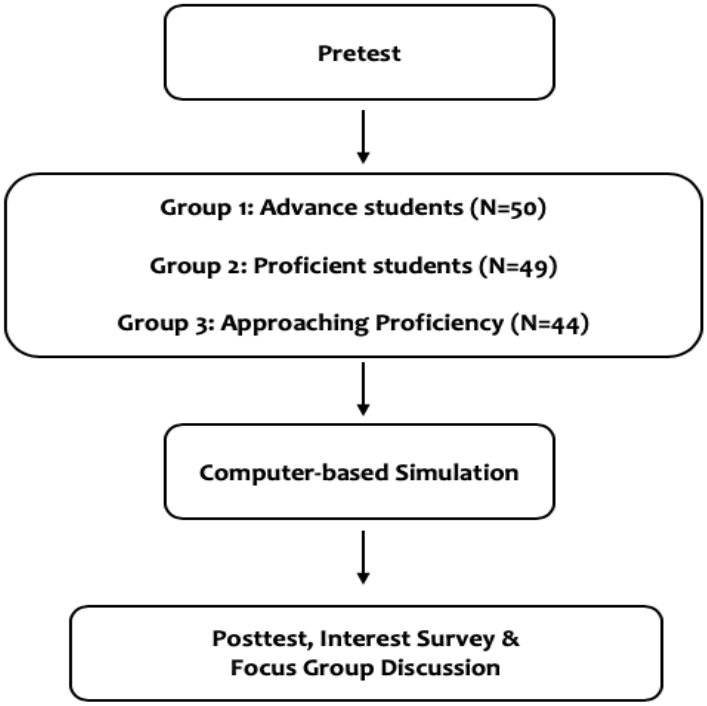

Figure 1. Data Collection Procedure

All of the students took the pretest and then learned the concepts of a chemical reaction using the computer-based simulation. After eleven weeks of instruction, the same students took a posttest and answered an interest survey. There were 6 to 8 students per learning group who participated in the focus group discussion (FGD).

The results from the pre-test and posttest were analyzed descriptively. To determine whether how the computer-based simulation affects the interest of the students in learning Chemistry, the activity perception survey was modified and utilized from the Intrinsic Motivation Inventory developed by Ryan, Mims, and Koestner in 1983. This survey has three subscales: enjoyment, value/usefulness, and perceived choice. Items in this survey were rated with a 7-point Likert scale. The data collected were tabulated in a frequency table. Weighted mean for each item and for each subscale was calculated and interpreted. The 7-point Likert scale was divided into three intervals for ease of interpretation and discussion. The following table served as the basis for interpreting the weighted means.

Table 1. Intervals used for interpreting the computed weighted means

Interval	Interpretation
4.67 to 7	High
2.34 to 4.66	Moderate
0 to 2.33	Low

Results and Discussion

Results of the pre and posttest showed that there is an increase in the mean difference across all groups. In group 1, there were no students who passed the pretest but during the posttest, there were 49 students who passed in the test. In group 2, there were 5 students who passed in the pretest but all of them passed in the posttest. In group 3, there were no students who passed the pretest but during the posttest, there were 6 students who passed the exam. Looking at the passing percentage per group, Group 2 has the greatest number of test passers among the three groups. Using the mean difference, there was an increase of scores by 10.980 (group 1); 10.490 (group 2); and 4.614 (group 3) making computer-based simulation effective in all learning groups.

Table 2. Mean Difference

	Group 1	Group 2	Group 3
Pretest (sd)	11.54 (3.032)	12.73(2.978)	8.30 (2.163)
Posttest (sd)	22.52 (3.621)	12.73 (2.978)	12.91 (4.414)
Mean difference (sd)	10.980 (4.447)	10.490 (3.447)	4.614 (4.914)

In the focus group discussion, some respondents coming from the advance group shared that they have questions or questions about the topic which was supposed to be addressed right away if the teacher conducted a lecture. They further reasoned that "nakakalimutan po naming magtanong kasi baka maubos na din po yung time sa pag gamit po ng PhET simulation tapos na realize nalang naming nung lumabas sa exam." Group 2 has the highest mean in each of the tests but the greatest increase in knowledge was posted by Group 1. There was an increase in knowledge in Group 3 but using their posttest scores, most of the students failed in the exam.

The computer-based simulation includes affordances, productive constraints, analogies, and representations of phenomena that allow students to construct an understanding of science topics (Podolefsky, Perkins & Adams, 2010). In a related study conducted by Estipular and Roleda (2018) in the Philippines, the pre- and posttests scores of the students showed that there is a significant improvement in the students' conceptual understanding of science topics. However, there are also other factors that explain the increase in students' scores in the posttest. Pretest to posttest gains can be confounded by factors outside of instruction (Marsden & Torgerson, 2012). Natural trends in students' growth and maturation sometimes can account for improvements in scores.

Results of the interest survey showed that advance and proficient students posted a high interest in Chemistry while the lone near proficient rated their interest as moderate. Advanced students posted an overall weighted mean average of 5.55 (high) from the three subscales: enjoyment (rating = 5.83); value/usefulness (rating = 5.86); and perceived choice (rating = 4.97). For the proficient students (group 2), it got an overall weighted mean average of 5.35 (high) from the three subscales: enjoyment (rating = 5.69); value/usefulness (rating = 5.74); and perceived choice (rating = 4.63). For students approaching proficiency (group 3), it got an overall weighted mean average of 4.25 (moderate) from the three subscales: enjoyment (rating = 5.10); value/usefulness (rating = 5.35); and perceived choice (rating = 2.31).

Table 3. Interest survey summary

Interest	Group 1	Group 2	Group 3
Enjoyment	High (5.83)	High (5.69)	High (5.10)
Value/Usefulness	High (5.86)	High (5.74)	High (5.35)
Perceived Choices	High (4.97)	Moderate (4.63)	Low (2.31)
Average	High (5.55)	High (5.53)	Moderate (4.25)

Students revealed that they enjoyed (see figure 2) using the computer-based simulation while learning the Chemistry concept because of the following reasons: (1) due to the stars that they virtually receive and the game levels were challenging;(2) it is easy to manipulate; (3) they were able to do the activity with minimal supervision, thus making them feel independent; and, (4) it always has a practice and a game after the topic introduction that comes in different levels.

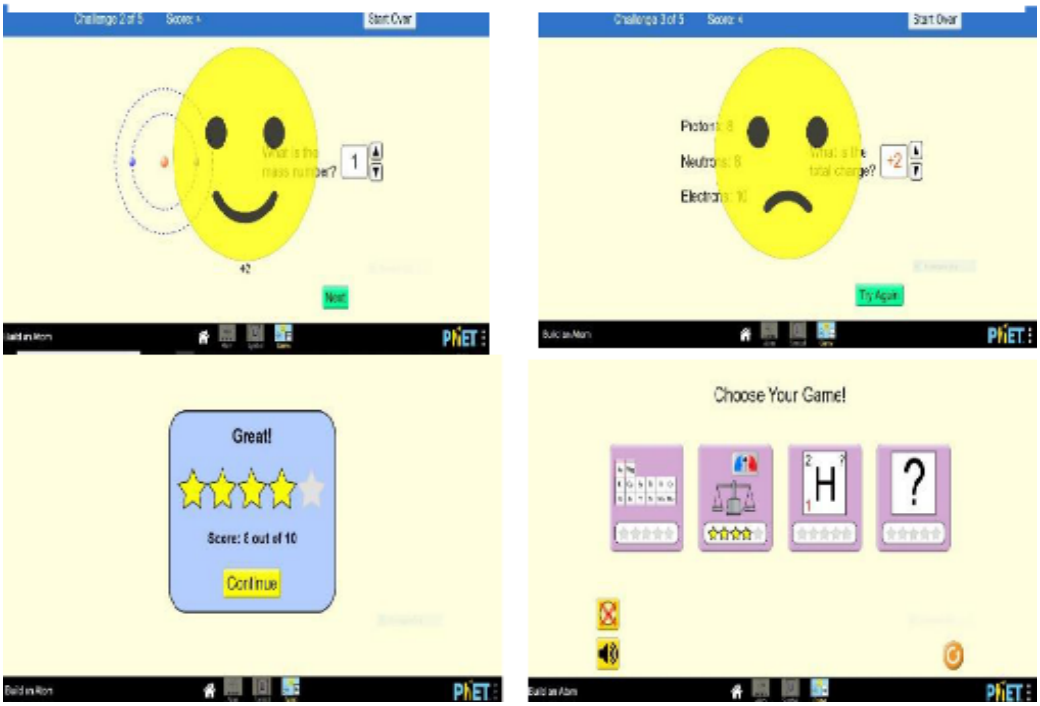

Figure 2. Leveling up your game

In a study conducted by Kuhn (2006), it also showed that learners knew how to build models to explore larger or smaller complex problems and were able to model them independently; they were able to construct meaningful representations and had little or no difficulties using the tool

and the devices used in PhET simulation. Another respondent also enjoys it because he gets to share strategies with his other friends taking the same subject. It was also enjoyable because according to them, students were given the chance to explore in the different computer-based simulations to choose among the topic introduction (see Figure 3), practice or the game.

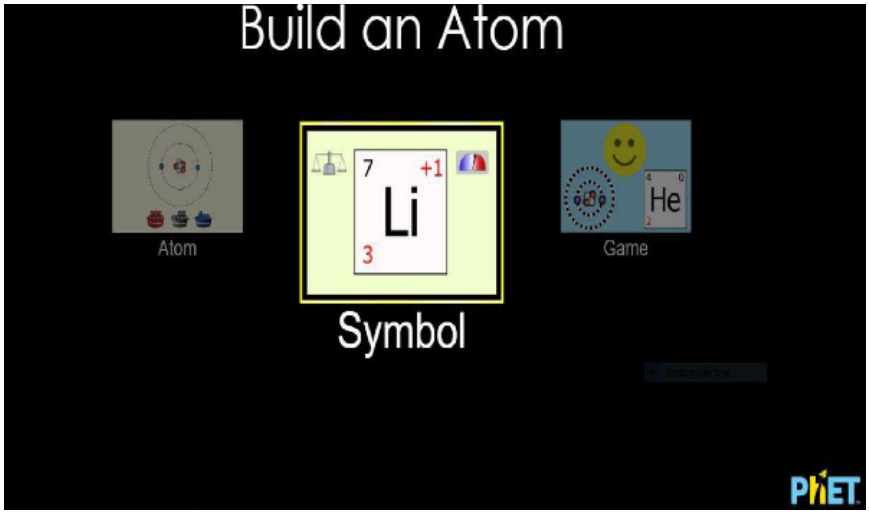

Figure 3. Choose your activity

This result is in line with Gagne's sixth level of instruction. The desired performance is elicited from the learner which in turn could build performance confidence and self-esteem and master target skills and encourage further knowledge acquisition (Gagne, Briggs, & Wager, 1992, cited in Faculty Development and Instructional Design Center, n.d).

Students shared that computer-based simulation is useful in (1) visualizing Chemistry concepts, (2) making the students curious, (3) making the students interested in Chemistry, (4) allowing the students to commit mistakes as he learns the topic and (5) challenging the students.

The majority of the students enjoyed and find the activity useful in learning Chemistry. A respondent from group 3 shared that they have to do the activity for them to be given another chance to use the computer. Various studies suggest that the most effective factor contributing to students' decisions to study science is their interest in the subject (Milner, Ben-Zvi, & Hofstein, 1987; Lindahl et al., 2003). Respondents shared that computer-based simulation is very useful in understanding the movements of atoms and molecules and it helped them understand the concept in a simpler and faster way. One respondent said, "*It is very hard to imagine what happens to molecules when temperature or other factors affecting reaction is increased or what molecules look like*," but using the simulation (see Figure 4), visualisation is real time.

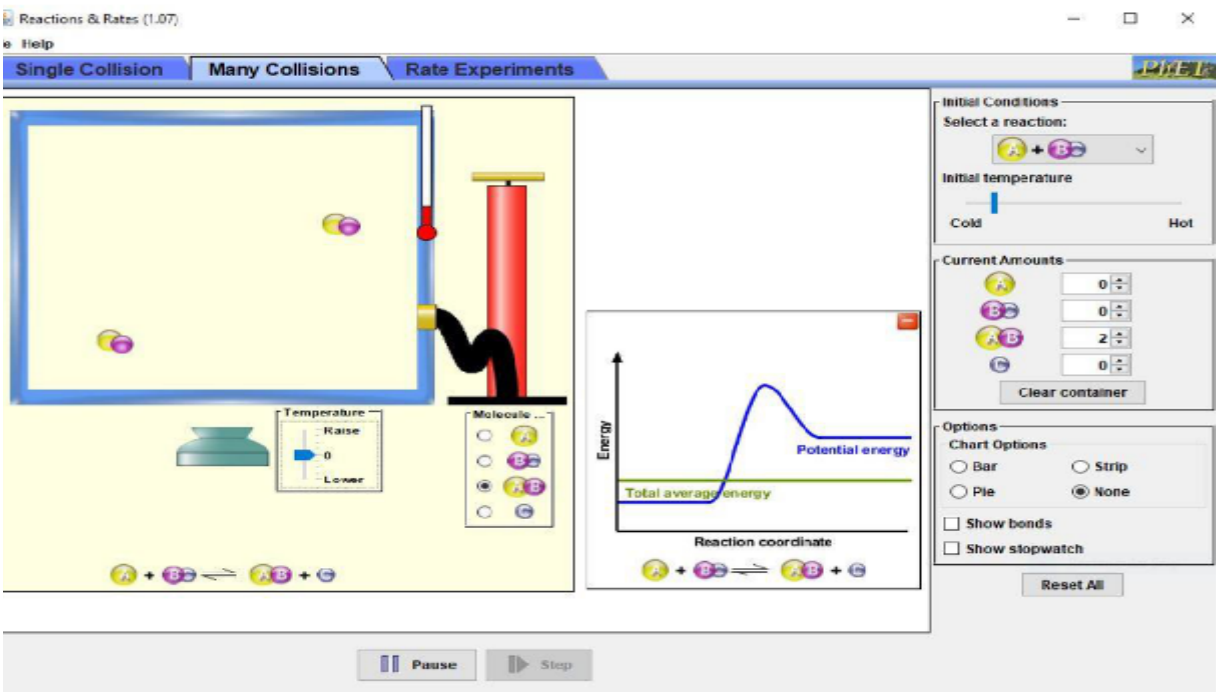

Figure 4. Reaction & Rates

It also challenges them because they had to learn the concept at their own pace and can check whether they really understand the concepts through the different game levels, thus making them feel independent. In Gagne's first level of instruction, the attention of most individuals is easily gained and maintained through a learning experience (Bill, 2003) . The speed of the simulation is manipulated by the individual, therefore faster learners are not bored and slower learners maintain control for their own optimum rate of knowledge acquisition. The respondents said that they got mistakes especially in balancing the chemical equation (see Figure 5) but while they are committing mistakes, they learn how to balance equations properly (see Figure 6). They thought that balancing equations was a hard topic but the computer-based simulation makes them realized that one just had to adjust the coefficients and it must be always equal in both reactants and products side.

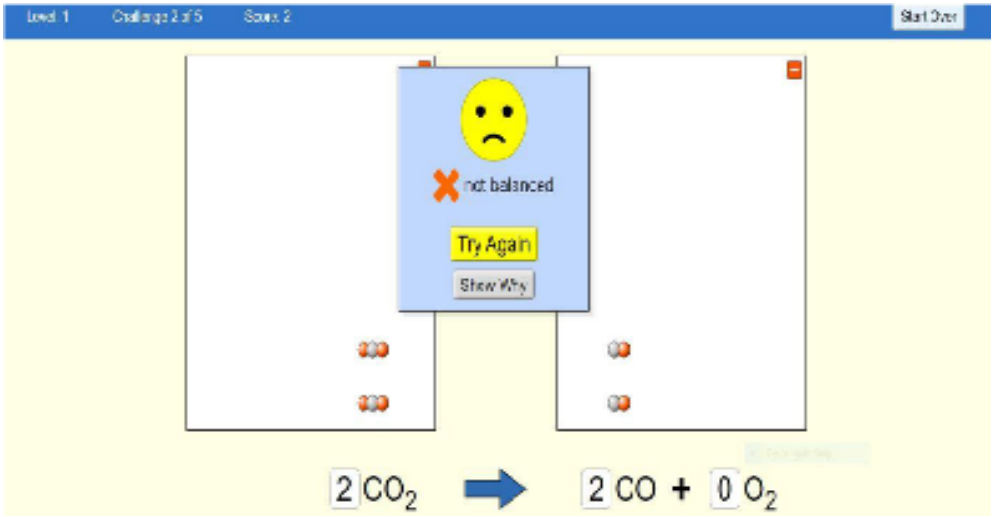

Figure 5. Balancing equations (x)

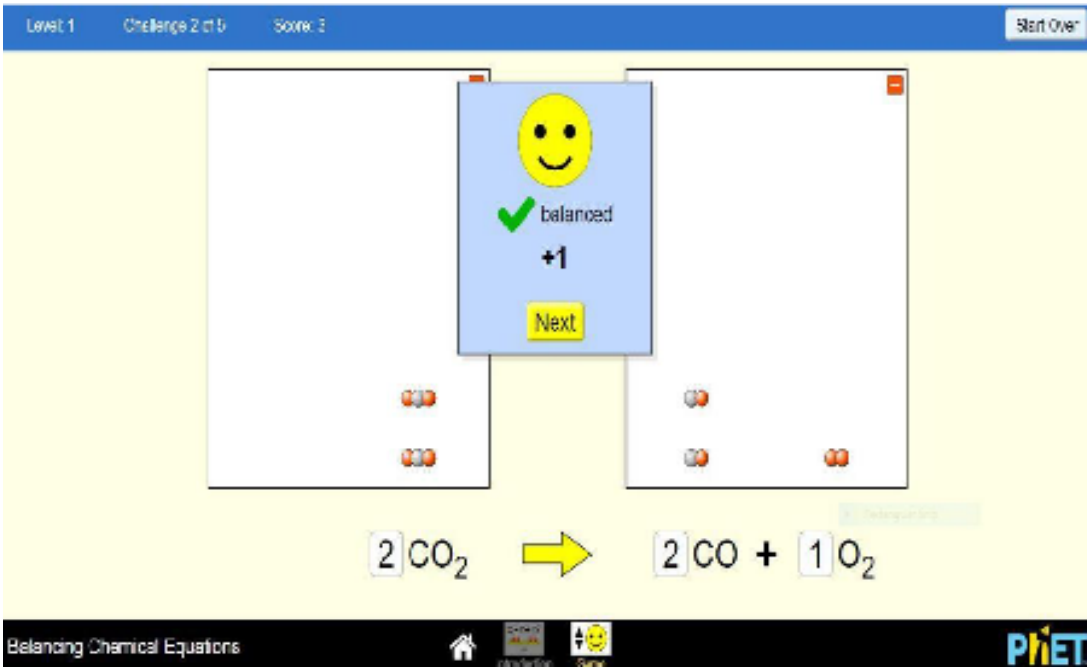

Figure 6. Balancing equations (/)

According to Gagne's eight-level instruction (Kruse, 2009), the safe environment affords the individual an opportunity to learn by making mistakes and receive additional information in the form of instructive feedback. This type of assessment also provides the learner with information pertaining to her progress towards the mastery of skills set forth in the learning objectives.

A longer time for computer-based simulation helped them learn the concept independently. Respondents find it boring to learn a concept in the classroom especially those that are hard to visualize and concepts which they cannot relate in their daily life. According to Gagne's first level of instruction, the use of multiple media enables the learner's senses to be heightened and primed to receive information (Gagne, Briggs, & Wager, 1992, cited in Faculty Development and Instructional Design Center, n.d). The majority of the respondents said that even though they behave well in using the computer due to a variety of reasons, the majority of them also said that they enjoyed and were challenged to learn the topic on their own. The graphics, stars, and the game level make it enjoyable and challenging. The majority of them also shared that they prefer computer-based simulation as a reinforcement activity, that is, the teacher should present first the necessary concepts. By doing this, it will save time and all students can relate in the simulation because they already have a background on the topic.

Based on the available data, computer-based simulation should be used in learning a concept most especially in topics that are hard to visualize and unsafe to perform in the laboratory. The teacher should entertain questions related to the lesson, especially during the session. For example, an advance student shared in the focus group discussion that he had questions that do not address right away because he was so much into the simulation. Students across all learning groups should be monitored because of the issues that need to be identified and resolved when individual differences are considered. A participant in the focus group discussion said that "hindi ako masyado ma computer kaya nag a-adjust po ako." It is important that the design of learning activities be given a higher level of priority than the use of instructional technology when employing computer simulations in the classroom. Participants from group 3 shared that they

were having a hard time understanding the worksheets due to the language barrier. Students who were approaching proficiency suggested that they want the computer-based simulation activities to be reinforcement rather than the strategy to present the topic. They will prefer that the teacher will present all the related concepts first for them to have a better background and to not waste time. The researcher recommends that students should be allowed to fully and or will not fully engage in computer-assisted activities to cater to different learning styles.

Conclusion

Using the result of the pre and posttest, it was found out that the use of computer-based simulation increases the knowledge of all learning groups. There was an increase in the pre and posttest mean scores and is highest in the advance group. This is similar to the result of the study conducted by Estipular and Roleda (2018) in the Philippines, the pre- and posttests scores of the students showed that there is an improvement in the students' conceptual understanding of science topics. Proficient students have the greatest number of test passers among the three groups while the advance students posted the highest increase in knowledge.

Using the activity perception survey, the results of the survey showed that the enjoyment subscale posted a high rating in all learning groups. Students revealed that they enjoyed using the computer-based simulation while learning the Chemistry concept because (1) of the stars that they virtually receive and the game levels were challenging and (2) it is easy to manipulate, (3) they were able to do the activity with minimal supervision, thus making them feel independent and (4) it always has a practice and a game after the topic introduction that comes in different levels. This study also found out that students believed that computer-based simulation has a high value or use in learning Chemistry concepts. Students shared that computer-based simulation is useful in (1) visualizing Chemistry concepts, (2) making the students curious, (3) making the students interested in Chemistry, (4) allowing the students to commit mistakes as he learns the topic and (5) challenging the students. On the perceived choice, the advance students rated it high. Respondents from this group shared that they performed the activity because they want to earn all the stars and achieve the maximum level and are always looking forward to using computer-based simulation in learning a concept. Proficient students rate it as moderate. The majority of the respondents from this group wants minimal supervision from the teacher. On the other hand, students approaching proficiency posted a low rating and shared that they have to do the activity for them to be given another chance to use the computer. Overall, the interest of the students in learning Chemistry while using computer simulation was moderate to high. Students from this group suggested that computer-based simulation activities should be a reinforcement activity to avoid waste of time and to help students be aware of the topic's background.

Based on the findings of the study, using computer-based simulation increases the knowledge and interest in Chemistry of advanced, proficient, and even to students who were approaching proficiency. The computer-based simulation is recommended to be employed in teaching and learning Science concepts, particularly in Chemistry.

Recommendations

The researcher highly recommends that science module developers should include the use of computer-based simulation in science teaching and learning guides because this study revealed

that it can increase students' knowledge and interest in Chemistry. The computer-based simulation is recommended to be employed for classroom instruction even on other topics of Chemistry and other branches of Sciences.

Further research must be made to investigate its effects when students are allowed to fully and or will not fully engage in computer-assisted activities.
While integrating the emerging new technology that can potentially help students in learning, considerable continuing research needs to be done because there are always issues that need to be identified and resolved when individual differences are considered. The use of technology in teaching and learning solves the barriers in education and promotes inclusivity. Meanwhile, it is important that the design of learning activities and the use of instructional technology must be given a priority when employing computer simulations.

The researcher also recommends that further studies to groups of developing and beginning students should be made to analyze its effects when this is employed to other learning groups. Research should also be conducted to heterogeneous groups so that there will be a control and treatment group for comparison purposes.

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