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Simulation-Based Instructional Materials on Central Dogma of Molecular Biology: Basis in Studying Genetics for Grade 12 Learners

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Abstract

The essence of Genetics lies in the understanding of the concepts of Central Dogma of Molecular Biology. Although these ideas are fundamental to the field, they are notoriously difficult to understand and visualize. While simulation-based instructional materials are found to improve the teaching-learning process in science education, little has been done to assess their effectiveness in teaching and learning the concepts of Central Dogma of Molecular Biology. Hence, this study aimed to examine the effectiveness of simulation-based instructional materials towards the learning performance of Grade 12 learners on the concepts of Central Dogma of Molecular Biology. This study utilized a mixed-method approach. Results of the pretest and posttest showed that the learners demonstrated from approaching proficiency to advanced mastery level on the concepts of Central Dogma of Molecular Biology. Furthermore, it was revealed that the pretest and posttest mean scores of the learners on the concepts differed significantly ($p<.05$). The result of the semi-structured interview revealed that the learners were engaged in experiential learning with the use of simulation-based instructional materials. An action plan was designed based on the study to utilize the simulation-based instructional materials in the teaching-learning process.

Introduction

Science is regarded as a vital topic in the Philippine education due to its direct connections to technology and industry. Despite the complexity of its contents and high cost of execution in the curriculum, it still remains a central topic in both primary and secondary schools. Picardal and Pano (2018) posited that the rationale for the inclusion of science in school curricula is to elevate learners' level of "scientific literacy" in order become citizens who can engage successfully in the contemporary society. However, the COVID-19 pandemic crisis has ushered educational institutions across the globe to new technology-based modalities of instructional implementations (Dukes, 2020; Masoud & Bohra, 2020; Mahaffey, 2020). The changes in the educational landscape posed constraints to teachers with the emergence of new technological challenges, and instructional strategies (Sunasee, 2020) in teaching science concepts that have highly abstract mechanisms (Arrieta, Dancel, & Agbisit, 2020; Huang, 2020), such as Genetics.

Genetic education is considered necessary in schools to develop citizens of the society who can understand issues on the applications of Genetic technologies (Change & Anderson, 2020). However, the essence of Genetics lies in understanding the concepts of Central Dogma of Molecular Biology. Understanding this topic at the secondary level is essential and precursor to other higher concepts in biology, and to be able to connect biological processes happening at the cellular and organismal levels (Picardal & Pano, 2018). While this topic is regarded as core to the discipline, many teachers and learners are facing the burden of understanding its highly abstract concepts. Hence, it remains difficult to teach, and least mastered among teachers and learners, respectively (Kate Wright et al., 2014). Many authors conveyed that this is due to the complexity of the topic's underlying concepts that are not available for direct observations (Reddy & Mint, 2017; Picardal & Pano, 2018; Change & Anderson, 2020).

Consequently, the status quo of the Philippine education in the field of science showed a downward trend in the national and international standardized assessments (Adarlo & Jackson, 2017; Department of Education, 2020). The shortcomings in the school curriculum, the teaching learning process, teachers' preparation, instructional resources, and learners' difficulties in interpreting concepts that include complex thoughts and abstract logics are the key reasons that can be cited to account for the poor performance of the Filipino learners in science (Guerrero, 2009; Department of Education, 2020). Moreover, the congested curriculum is also associated with this depressing scenario as learners do not get adequate time on task (Department of Education, 2020). Although there are many identified factors associated in the downward trend of the academic performance in science of Filipino learners, Arrieta, Dancel, and Agbisit (2020) in their literature review on the attitudes of learners on science have argued that, one striking factor is the quality of teaching. They have insisted that science teaching has to be engaging to the learners, and the classroom environment and activities have to be learner-centered in order to raise learners' interest in science.

Although decades of studies have shown that there are various innovative approaches to education that are cited to increase conceptual understanding of difficult topics in science (Novak, 1990; Marbach-Ad et al., 2008; Ross et al., 2008; Barab et al., 2009; Nogaj, 2013; Quillin & Thomas, 2015), Rivera (2017) posited that there is a need to develop robust teaching pedagogies to elevate the country's scientific literacy by devising innovative learner-centered teaching techniques, such as the integration of technology-based instructional tools in the teaching-learning process. Likewise, Huang (2020) pointed out that the use of appropriate technology-based instructional materials to support the teaching-learning process in the COVID-19 pandemic period is deemed necessary to mitigate its constraints in education. These technology-based instructional materials come in many forms such as computer simulations. These tools can be integrated in the experiential learning which is a comprehensive approach designed to engage learners to investigate authentic problems through experience (Treacy et al., 2011).

Simulation-based instructional materials are commonly used in science education to promote active learning. They are found to scaffold learners to learn concepts that require higher abstract thinking by providing linkages between what is heard and what is seen (Olga et al., 2020). More senses are involved, hence learners are engaged in deep learning that empowers understanding as opposed to surface learning. Despite the advantages proffered by simulation-based instructional materials in science education, many teachers are encumbered, and have no bold attempt to integrate these tools in their teaching pedagogies.

Anoba and Cahapay (2020) pointed out that the lack of accessibility to resources, competence, and confidence on the proper utilization of technology are among the reasons. Hence, these available simulation-based instructional materials are not maximized, and little has been done to assess their effectiveness in teaching and learning the concepts of Central Dogma of Molecular Biology. This prompted the researchers to conduct a study to assess the effectiveness of simulation-based instructional materials on the learning performance of Grade 12 learners in Central Dogma of Molecular Biology. Specifically, this study sought to determine the mean mastery level scores of the learners in Central Dogma of Molecular Biology concepts before and after the conduct of the study. Furthermore, this investigation determined the attitudes of the learners exposed to simulation-based instructional materials, and the plan of action that will be implemented to utilize the materials.

Methods

Research Design

This study utilized a mixed method approach (Creswell & Plano-Clark, 2011) to assess the effectiveness of simulation-based instructional materials towards the learning performance of Grade 12 learners on the Central Dogma of Molecular Biology concepts. The quantitative phase of the study used pretest and posttest design to determine the mastery level of the learners before and after the simulation-based instructional materials were applied. For the qualitative phase of the study, semi-structured interviews were carried out in order to reveal the attitudes of the learners towards the simulation-based instructional materials. This is to examine and strengthen the quantitative data gathered on the effects and significant differences on the pretest and posttest scores of the sample group. One sample pretest-posttest design (Knapp, 2016) was specifically employed in this study. The characteristic feature of this research design is that the study is conducted in one (1) sample group only, and the measurements of the samples were taken both before and after the method was applied (Fraenkel & Wallen, 2000).

This research design is shown in the diagram below:

Sample Group O1 x O2/SSI

where,

O1 referred to the pretest scores of the sample group

O2/SSI referred to the posttest scores of the sample group and semi-structured interview (SSI)

x referred to the use of simulation-based instructional materials in the sample group

Locale of the Study

The study was conducted at Notre Dame of Marbel University-Integrated Basic Education Department Senior High School in Brgy. Sto. Nino, City of Koronadal, South Cotabato, Philippines. It is a Marist institution that strives for the formation of holistically developed learners through Marist Quality Education. The school is owned and managed by Marist Brothers Congregation of the Philippines. NDMU-IBED SHS is a new department created in compliance with the implementation of the K-12 Program in the Philippines. It was established in the year 2016.

Participants of the Study

The participants of this study were the learners from one (1) section of Grade 12 STEM strand of Notre Dame of Marbel University-Integrated Basic Education Department Senior High School. To ensure the containment of the data, and to avoid contamination and inconsistencies in the results of the study, the following inclusion criteria in selecting the participants were employed: (1) the participants must be enrolled in the Grade 12 STEM strand in the second semester of school year 2020-2021, (2) any gender with no age restrictions were recognized as participants, and (3) currently taking General Biology 2 subject.

Sampling Technique

The participants of this study were mainly selected based on purposive sampling technique. It was a non-probability sampling technique in which the researcher carefully selected the sample while ensuring the purpose of the study, with the assumption that each participant will be able to provide specific and rich data that are important to the study. One (1) section of Grade 12 STEM learners of Notre Dame of Marbel University-Integrated Basic Education Department Senior High School was chosen as the participants of the study. This was for the reason that the researchers had direct supervision on them. This was done to minimize the disruption of classes and other conflicts that might arise in the conduct of the study.

Research Instrument

For the gathering of quantitative data, the study used a Pretest-Posttest Questionnaire. The questionnaire was adapted from the study of Newman, D.L., Snyder, C.W., Fisk, J.N., and Wright, L.K. (2016), and was used to assess the mastery level of the learners on the concepts Central Dogma of Molecular Biology. The questionnaire consisted of forty (40) – multiple choice items covering the following sub-topics: a) DNA Replication with 16 items, b) Transcription with 8 items, and c) Translation with 16 items. The multiple choice items in the questionnaire had different levels of difficulty based on the designed Table of Specifications considering the cognitive levels of Revised Bloom's Taxonomy (Anderson & Krathwohl, 2001).

The reliability of the questionnaire was assessed by using the split-half method. Right answers were given 1 point, and wrong answers were given 0 points. The analysis of the data revealed that the Pretest-Posttest Questionnaire had a Guttman Split Half coefficient of 0.992. This indicated that the questionnaire scale had a high level of internal consistency (DeVillis, 2003; Kline, 2005). The mastery level scores in the pretest and posttest of the learners on the concepts of Central Dogma of Molecular Biology were described using the scale in Table 1.

Table 1. Descriptive Rating of Learner's Mastery Level Scores

No. of Items			Percentile	Description	Interpretation
8	16	40			
6.41-8.00	12.81-16.00	33-40	81-100	Advanced	Very High
4.81-6.40	9.61-12.80	25-32	61-80	Proficient	High
3.21-4.80	6.41-9.60	17-24	41-60	Approaching Proficiency	Average
1.61-3.20	3.21-6.40	9-16	21-40	Developing	Low
0.00-1.60	0.00-3.20	0-8	0-20	Beginning	Very Low

Note. Adapted from: Andamon, J. and Tan, D. (2018)

For the gathering of qualitative data, the researcher used a semi-structured interview guide questions adopted from the study of Ulukok, S., and Sari, U. (2016) to reveal the attitudes of the participants exposed to the simulation-based instructional materials. The tool contained the five (5) open-ended questions that revolved around the utilization of the instructional materials on Central Dogma of Molecular Biology.

Development and Validation of Session Plans

Biology textbooks, together with the curriculum maps of Notre Dame of Marbel University-IBED Senior High School, and the Curriculum Guide of the Department of Education were considered in preparing the content to be included in the session plans. The topic considered in the study was the Central Dogma of Molecular Biology. This topic was chosen and included in the study for the reason that it was cited to be a difficult topic to teach and learn by the teachers and learners, respectively (Lewis et al., 2000; Kozma et al., 2000; Knippels, Waarlo, & Boersma, 2005; Reddy & Mint, 2017). Furthermore: a) teachers teaching the subject suggested this topic because of more complicated mechanisms involved; b) the experience of the researcher provided information that this was the topic found most difficult and least mastered competencies; and c) this topic involves DNA and RNA structures that were tedious to analyze and draw on the chalkboard and could be provided with a computer-simulation material.

After identifying and selecting the topic, session plans were developed and validated. Four (4) expert-validators: one (1) validator with a doctorate degree, and a curriculum developer; two (2) validators were associate professors of a private university with master's degree in Biology; and one (1) validator was a Science Program Coordinator with master's degree in Biology were asked to validate the developed session plans. The evaluation tool adapted from the study of Guerrero (2009) was used to validate the materials. The tool contains three main criteria: (1) content quality; (2) technical quality; and (3) instructional quality. All of the criteria contained nine (9) indicators. A 5-point Likert scale shown in Table 2 was used to describe and interpret the validation results of the developed session plans. The means were calculated to evaluate the developed materials in terms of its content, technical, and instructional qualities.

Table 2. Rating Scale for the Validation of Session Plans

Rating Scale	Range	Description
1	1.00 – 1.50	Not Applicable
2	1.51 – 2.50	Strongly Disagree
3	2.51 – 3.50	Disagree
4	3.51 – 4.50	Agree
5	4.51 – 5.00	Strongly Agree

The validation result showed that the validators strongly agreed on the content, technical, and instructional qualities of the developed session plans on Central Dogma of Molecular Biology.

Simulation-Based Instructional Materials Used in the Study

The simulation-based instructional materials used in the study were properly incorporated in the developed session plans. The LabXchange® Simulation Package on DNA Replication and Central Dogma developed by the Harvard Faculty of Arts and Sciences and funded through the Amgen Foundation, Gene Expression Simulation developed by Colorado University's Physics Education Technology (PhET®) Project, DNA Interactive Simulation developed by Cold Spring Harbor Laboratory, and Holt's Central Dogma Simulations developed by Holt, Rinehart and Winston, were integrated in the session plans to deliver the intended outcomes in teaching the Central Dogma of Molecular Biology.

All the interactive simulation tools were adapted into English. The PhET® simulation software was arranged in such a way that the learners could do the activities easily by themselves in a virtual environment. The materials and tools necessary for the activity could be chosen in the different tool menu; necessary controls and varieties could be easily manipulated using the tools. The LabXchange® simulation was also arranged systematically where learners could easily learn and trace on how the genetic information was replicated and expressed to form proteins. Videos and articles were also incorporated in the series of simulations. The DNA Interactive® simulation presented the timeline on the significant and relevant scientific discoveries on DNA. It also presented the information in sequence where learners could easily understand and manipulate the variables. Furthermore, the Holt's® simulations presented the processes of DNA replication, transcription, and translation. The simulations were user friendly, and the variables and options could be easily understood and manipulated by the users.

Data Gathering

The following materials were prepared and ensured by the researchers before the conduct of the study; (i) developing and establishing the reliability of the Pretest-Posttest Questionnaire, (ii) identification of appropriate simulation-based instructional materials anchored to the topic and curriculum, (iii) review of resource materials and instruments to ensure the coherence of the competencies with the Department of Education (DepEd) – Curriculum Guide, and (iv) development and validation of the session plans. The researcher initially wrote a permission letter to the School Principal of Notre Dame of Marbel University-Integrated Basic Education Department Senior High School to conduct the study, explaining the purpose and nature of the study. Subsequently, a letter of invitation and informed consent form approved by the Principal were sent to the participants and to their parents to seek for their approval through online. The goal and their participation in the research were also explained to them.

In the conduct of the study, the identified participants were asked to answer the pretest using the Pretest-Posttest Questionnaire. The pretest was administered through Schoology® - the official learning management system of the school. The participants answered the test synchronously for one (1) hour. The test was given to gauge the mastery level of the learners in Central Dogma of Molecular Biology before the application of the simulation-based instructional materials. The sample group went through ten (10) online teaching sessions based on the developed session plans. The official learning management system of the school - Schoology® was used as the platform. The simulation-based instructional materials from LabXchange®, PhET®, DNA Interactive®, and Holt's® Simulations were used during the online teaching sessions. The researchers delivered the instructions, methods, and instructional materials to prevent external factors and bias. The delivery of instructions using the simulation-based instructional materials run for one week. Two (2) hours of online teaching was administered per day, and one session was administered per hour. The same set of questions in the Pretest-Posttest Questionnaire was administered for the posttest. To maintain the objectivity, and to avoid bias in the posttest results, the different items in the 40-item questionnaire were distributed across ten (10) online teaching sessions based on the lessons that the questions were anchored. Time limits were employed in the conduct of the tests. The researchers administered the tests through online.

The semi-structured interview was employed to nine (9) identified participants from the sample group. These were the top three (3), middle three (3), and lowest three (3) performers based on the posttest scores. The participants were asked to answer five (5) questions through semi-structured interview through online. This was to examine and strengthen the quantitative data gathered on the effects and significant differences on the pretest and posttest scores of the participants. The date and time of the interview were scheduled based on the participants' convenience. The participants' responses were recorded, transcribed, and were subjected to thematic content analysis. The participants were coded as S1 to S9 to keep their identities confidential.

Ethical Consideration

The researcher strictly followed interview protocols before conducting the semi-structured interview. Hence, the researcher had ensured that the electronic informed consent form was approved by the participants and their parents. The participants were assured that their participation would be private, confidential, voluntary, and that their identity would remain anonymous. It was also emphasized to the participants that the data being gathered from the semi-structured interview will be used purely for academic purposes only, and shall be treated with utmost confidentiality.

Data Analysis

The mean and percentage were used to determine the mastery level scores of the participants before and after the conduct of the study on the concepts of Central Dogma of Molecular Biology. The paired-samples t-test was used to determine the significant difference in the pretest and posttest scores on the mastery level of the participants on the concepts of Central Dogma of Molecular Biology. Meanwhile, the data and information gathered from the semi-structured interview were subjected into Thematic Content Analysis to reveal the attitudes of the learners exposed to simulation-based instructional materials. Verbatim data from the interviews were transcribed. Subsequently, the transcripts were analyzed to classify relevant sentences for further coding, which may involve sentences, terms, or long statements. (Factor, Mateinzo & de Guzman, 2017). The reliability of the qualitative data was ensured by sending back to the participants the initial codes together with the significant statements for checking. This is to ensure that the codes generated resonate the real experiences of the participants (Birt, Scott, Caverns, Campbell & Walter, 2016). Related codes were clustered into categories (Saldana, 2009). Consequently, categories were synthesized in an overarching theme which later became instrumental in revealing the attitudes of the learners exposed to the simulation-based instructional materials.

Results

Pretest and Posttest Scores of the Learners

This study sought to determine the mean mastery level scores of the learners in Central Dogma of Molecular Biology concepts before and after the conduct of the study. The mean and percentage of the pretest scores of the learners on the Central Dogma of Molecular Biology concepts were computed. Based on the percentage values, descriptions were offered. The pretest mean mastery level scores of the learners on the concepts of Central Dogma of Molecular Biology are presented in Table 3.

Table 3. Learners' Pretest Mean Mastery Level Scores

Concepts	No. of Items	Mean ± SD	Percentage	Description
A. DNA Replication	16	10.17 ± 2.46	63.54	Proficient
B. Transcription	8	3.81 ± 1.00	47.66	Approaching Proficiency
C. Translation	16	9.04 ± 3.15	56.51	Approaching Proficiency
Over-all	**40**	**23.02 ± 5.82**	**57.55**	**Approaching Proficiency**

Note. 0%-20% = Beginning; 21%-40% = Developing; 41%-60% = Approaching Proficiency; 61%-80% = Proficient; 81%-100% = Advanced

The pretest result showed that, out of 16 items on the concept of DNA Replication, the learners obtained a mean mastery level score of 10.17 ± 2.46 or 63.54%. This implied that the learners were "proficient" on the concept of DNA Replication. On the other hand, out of 8 items on the concept of Transcription, the learners obtained a mean mastery level score of 3.81 ± 1.00 or 47.66%. This suggested that the learners were "approaching proficiency" on the concept of Transcription. Likewise, out of 16 items on the concept of Translation, the learners obtained a mean mastery level score of 9.04 ± 3.15 or 56.51%. This indicated that the learners were "approaching proficiency" on the concept of Translation. Nevertheless, out of the total 40 items on the concepts of Central Dogma of Molecular Biology, the learners registered an over-all mean mastery level score of 23.02 ± 5.82 or 57.55%. This revealed that the learners were generally "approaching proficiency" on the concepts of Central Dogma of Molecular Biology before the conduct of the study.

On the other hand, the mean and percentage of the posttest scores of the learners on the Central Dogma of Molecular Biology concepts were computed. Based on the percentage values, descriptions were offered. The posttest mean mastery level scores of the learners on the concepts of Central Dogma of Molecular Biology were presented in Table 4. The posttest result showed that, out of 16 items on the concept of DNA Replication, the learners obtained a mean mastery level score of 14.02 ± 1.44 or 87.63%. This suggested that the learners were "advanced" on the concept of DNA Replication. On the other hand, out of 8 items on the concept of Transcription, the learners obtained a mean mastery level score of 6.35 ± 0.98 or 79.43%. This indicated that the learners were "proficient" on the concept of Transcription. Nevertheless, out of 16 items on the concept of Translation, the learners obtained a mean mastery level score of 13.06 ± 1.33 or 81.64%. This indicated that the learners were "advanced" on the concept of Translation. Meanwhile, it could also be deduced in Table 4 that, out of the total 40 items on the concepts of Central Dogma of Molecular Biology, the learners registered an over-all mean mastery level score of 33.44 ± 2.94 or 83.59%. This revealed that the learners were "advanced" on the concepts of Central Dogma of Molecular Biology after the conduct of the study.

Table 4. Learners' Posttest Mean Mastery Level Scores

Concepts	No. of Items	Mean ± SD	Percentage	Description
A. DNA Replication	16	14.02 ± 1.44	87.63	Advanced
B. Transcription	8	6.35 ± 0.98	79.43	Proficient
C. Translation	16	13.06 ± 1.33	81.64	Advanced
Over-all	**40**	**33.44 ± 2.94**	**83.59**	**Advanced**

Note. 0%-20% = Beginning; 21%-40% = Developing; 41%-60% = Approaching Proficiency; 61%-80% = Proficient; 81%-100% = Advanced

To determine if there was a difference between the mean mastery level scores of the learners on the Central Dogma of Molecular Biology concepts before the conduct of the study, and the learners' mean mastery level scores after the simulations-based instructional materials were employed, a paired-samples t-test was utilized. Exploratory data analysis revealed that were no outliers in the distribution. The pretest and posttest scores distributions were normally distributed as assessed by the Shapiro-Wilk's test with p=0.313 and p=0.260, respectively. Table 5 demonstrated the paired-samples t-test of the pretest and posttest mean mastery level scores of the learners on the Central Dogma of Molecular Biology concepts.

Table 5. Paired-Samples T-Test of the Learners' Pretest and Posttest Mean Mastery Level Scores

Concepts	Pretest Mean ± SD	Posttest Mean ± SD	Mean Difference
A. DNA Replication	10.17 ± 2.46	14.02 ± 1.44	3.85*
B. Transcription	3.81 ± 1.00	6.35 ± 0.98	2.54*
C. Translation	9.04 ± 3.15	13.06 ± 1.33	4.02*
Over-all	**23.02 ± 5.82**	**33.44 ± 2.94**	**10.42***

Note. *significant at 0.05 level of significance

The result of the paired-samples t-test revealed that there was a statistically significant difference ($p<0.05$) between the pretest and posttest mean mastery level scores of the learners on the concepts of DNA Replication, Transcription, and Translation. Likewise, a statistically significant increase in the mastery level scores of 3.85, 2.54, and 4.02 on the concepts of DNA Replication, Transcription, and Translation were observed, respectively. Furthermore, it could be observed in Table 5 that there was a statistically significant difference ($p<0.05$) between the over-all pretest (23.02 ± 5.82) and posttest (33.43 ± 2.94) mean mastery level scores of the learners. Accordingly, a statistically significant increase in the over-all mastery level scores of 10.41 on the concepts of Central Dogma of Molecular Biology was observed.

Discussion

The low pretest mean mastery level score of the learners on the concepts of Central Dogma of Molecular Biology connotes less prior knowledge, and misconceptions of the concepts as they need the prerequisite knowledge on cell division and reproduction to be able to correctly explain the process of gene transmission. This finding supported the argument of Change and Anderson (2020) and Picardal and Pano (2018) that there was a lack of basic knowledge on Genetics and Genetics technologies by the learners, and widespread misconceptions at various levels. Meanwhile, the significant increase in the posttest mean mastery level score of the learners signified the pronounced effect of the simulation-based instructional materials to the learners' learning on the concepts of Central Dogma of Molecular Biology. This indicated that learners had developed a conceptual understanding on the mechanisms of DNA Replication, Transcription, and Translation. Computer simulations were proven to develop learners' thinking and interpretation skills, thus, resulting into the development of higher-order thinking skills (Efe & Efe, 2011). The present study conformed to the different research findings that the use of computer simulations in teaching resulted in a better learning outcomes of the learners (DeCaporale-Ryan, Dadiz, & Peyre, 2016; Mceneaney, 2016; Gunda & Dongeni, 2017; Olga et al., 2020).

One of the reasons for the success of the learners in the posttest result was probably the fact that simulations help learners to visualize processes that seem abstract and complex such as the structure and composition of DNA, DNA replication, the use of knowledge in DNA to generate messenger RNA (mRNA), and the processing of functional proteins using the mRNA as a template. According to Gunda and Dongeni (2017), utilizing visual instructional tools in teaching and learning environments is relevant and highly useful since it allows learners to envision and explore the implications of the model's rules for a method or system. This, in turn, can aid in the development of the learner's self-confidence, and logical thinking skills (Mceneaney, 2016). There are some benefits of using models to teach the Central Dogma of Molecular Biology. They are both secured and practical to use. They often take less time to manipulate, and can be replayed as many times as possible (Sahin, 2006). In addition to these benefits, experiments in science education have shown that computer simulation-based learning improves academic performance (Efe & Efe, 2011; Gruler et al., 2019; da Silva, Rodrigues, & Leal, 2019). Previous studies have also shown that integrating simulations in learning environments improves learners' ability to learn the concepts (DeCaporale-Ryan, Dadiz, & Peyre, 2016; Mceneaney, 2016; Warren et al., 2016). Furthermore, decades of studies have identified a correlation between constructive motivation and a good learning atmosphere using computer simulations (Flanagan, 2009; DeCaporale-Ryan, Dadiz, & Peyre, 2016; Mceneaney, 2016; Ulokok & Sari, 2016; Gunda & Dongeni, 2017; Reddy & Mint, 2017; Olga et al., 2020).

On the contrary, several studies have demonstrated that the use of computers and technology-based instructional materials in the teaching-learning process is eliciting some negative reactions. Greene (2001) mentioned that digital technology has the potential to reduce the interpersonal component of teaching, since that the essence of teaching is the development of knowledge through relationships with learners in order to help them understand the concepts. The intertwining of emotional and intellectual bonds gives meaning to the teaching-learning process. Similarly, Bautista (2011) asserts that computers and the internet cannot imitate the art of teaching. These resources may enhance an already high-quality educational experience, but relying on them as the sole source of learning is a costly mistake.

Learners' Attitudes on Simulation-Based Instructional Materials

Participants' responses through semi-structured interview were analyzed and synthesized into specific codes. Similar codes were grouped into categories. Consequently, categories were synthesized in an overarching theme. Based on the responses of the participants, one theme emerged. This theme collectively characterized the attitudes of the learners exposed to simulation-based instructional materials: *Engaged in Experiential Learning*.

Engaged in Experiential Learning

The result of the thematic content analysis on the responses of the learners revealed that they were engaged in experiential learning with the use of simulation-based instructional materials. Most of them pointed out that using the computer simulations, they were engaged in better attainment of concepts through experience. They also emphasized that they better understand the concept because they were able to experience the activity first-hand through engaging interactions. The following were some of the responses of the participants:

One participant shared:

> "*… mas lalalong maintindihan yung lesson. Tapos hindi lang yung parang nag iimagine kalang pero parang na eexperience mo talaga. Although simulation lang siya parang na eexperience mo pa rin kung paano ba talaga naga work yung bagay bagay*." [… the lesson was better understood. You do not just imagine, but it seems like you can really experience. Although it is just a simulation, it seems like you can still experience how things work.] (S5)

Another participant also added:

> "*…you can interact and you are the one who is manipulating, and there is a clear picture and view on how the processes are made. You can see it not just read it, and the process is very instructional sir. The way you interact with the simulations it can help you better understand the lesson*." (S4)

S2 commented:

> "*Yung simulation sir… it is useful lalo na kase… interactive at engaging siya at the same time naka visualize. So, mas madali siyang marecall at ma intindihan yung lesson*." [The simulation sir… it is useful, especially that it is interactive and engaging, at the same time it can visualize. So, it is easier to recall and understand the lesson.]

From the gathered data, it can also be noted that learners were able to better understand the concepts using the simulation-based instructional materials because they were able to visualize the information, giving them a concrete experience of what is happening in the processes. Some of the responses of the participants were the following:

One participant emphasized:

> "*… kung i-compare ko siya sa usual na lessons, more on presentations lang na usual, hindi ko kaayo ma grasp ang mga ideas and hindi ko ma follow ang instructions properly. Whereas kung may simulation, makita ko siya properly at mas maintindihan kung ano ang nangyayari sa process mismo*." […if I were to compare it to the usual lessons, more on the usual presentation, I cannot really grasp the ideas and I cannot follow the instructions properly. Whereas if there is simulation, I can see it properly and I can really better understand what is happening in the process.] (S6)

S5 shared:

> "*… makita po namin kung paano nagawork yung DNA. Hindi lang po imagination namin parang navivisualize rin po namin kung ano po talaga yung nangyayari sa loob. Mas na iintindihan po namin yung processes*." [… we can see how the DNA works. We do not just imagine, but we can really visualize what is happening inside. We can really understand better the processes.]

Meanwhile, the learners also pointed out that the simulation-based instructional materials engaged them in evaluative thinking. They emphasized that using the computer simulations, they were able to evaluate the consequences of their actions. The following were some of the responses:

One participant shared:

> "… it can give me chance to evaluate the consequences of my actions and the importance of minimizing my errors, sir." (S8)

S4 also added:

> "…we think of the process like we also question ourselves how did it get to this, like…we always asked questions how and why instead of just simply defining."

The results of the study presented collectively revealed that computer simulations engaged learners to better understand the concepts through experiential learning. According to Juan et al. (2017), experiential learning such as simulation is commonly used in teaching to engage learners' in critical and evaluative thinking, and self-directed learning (Pugh et al., 2020). It allows learners to immediately apply things that they have learned to real-world experiences. In the study conducted by Hakeem (2001), learners engaged in experiential learning have a greater understanding of their subject matter than learners in a traditional lecture class. Furthermore, DeCaporale-Ryan, Dadiz, & Peyre (2016) posited that computer simulations can enhance learning by engaging learners to create models of dynamic systems by combining words with pictures. This also conforms to the study of Gunda and Dongeni (2017) that computer simulations can engage learners to visualize and investigate the consequences of the rules of the model for a system, and develop conceptual understanding that can reveal learners' thoughts, ideas and experiences (Isiaka & Mudasiru, 2016).

Similarly, the data collected revealed that learners are actively involved in the learning process through interacting in practical, dynamic, complex, and evaluative contexts. According to Abelsson (2017), active participation in learning entails evaluating what happens before and after an operation. When learners use an evaluative method focused on a hypothesis or personal interactions, they develop their analytical reasoning and have a deeper comprehension of concepts (Cant & Cooper, 2017). Furthermore, several authors emphasized the effectiveness of using computer simulations in creating scenario-based environments in which learners can interact and apply their knowledge and skills to solve real-world problems, improve their learning and thinking power, and evaluative thinking (Mceneaney, 2016; Gunda & Dongeni, 2017; Olga et al., 2020). According to Kolb's experiential learning theory, the learner can learn through a circle of understanding, beginning with the direct experience of perception, progressing to a more complex conceptualization and, finally, active experimentation (Reshmad'sa & Vijaya Kumari, 2017). As a result, learners' learning can improve by problem solving and achieve a higher level of understanding of the concepts. On the other hand, Pugh et al. (2020) stressed that the human learning method can involve a variety of time periods based on what is to be processed and how rigorous the process is.

Plan of Action to Utilize the Simulation-Based Instructional Materials

To utilize the simulation-based instructional materials on Central Dogma of Molecular Biology, an action plan based on the study was designed. The Plan-Do-Check-Act (PDCA) framework (Realyvásquez-Vargas, et al., 2018) was utilized to develop the action plan. It involves four primary phases: planning, doing, checking, and acting. The framework employed is practical, and it is consistent with many standard curricular approaches. Table 6 demonstrated the action plan to utilize the simulation-based instructional materials.

Table 6. Action Plan to Utilize the Simulation-Based Instructional Materials

Phases and Time frames	Actions	Key Participants	Expected Outputs
Phase 1 - Plan **Time frame:** Before the start of the School Year	Examine the current curriculum on the topic Central Dogma of Molecular Biology with the field experts for the possible curricular updates and changes in the contents and methods.	Science teachers, academic coordinator, and field experts	Enhanced curriculum contents and methods on the topic Central Dogma of Molecular Biology
	Examine the school's available instructional materials (e.g. computer laboratories with internet connection, and teachers' and learners' resources on the topic Central Dogma of Molecular Biology.	Science teachers, and school administrators	List of available instructional materials
	Determine how the simulation-based instructional materials could be integrated into the existing curriculum structure on the topic Central Dogma of Molecular Biology.	Science teachers	Enhanced curriculum structure on the topic Central Dogma of Molecular Biology
	Develop the session plans on Central Dogma of Molecular Biology integrated with simulation-based instructional tools.	Science teachers	Session plans on Central Dogma of Molecular Biology integrated with simulation-based instructional tools
	Validate the session plans in terms of content, technical, and instructional qualities.	Science teachers, and field experts	Validation results on the developed session plans
	Develop evaluation methods and tools, and commence collecting pre-interventional data through pretest.	Science teachers	Evaluation methods and tools, and pretest result
Phase 2 - Do **Time frame:** 3rd Quarter	Utilize the developed session plans in teaching Central Dogma of Molecular Biology.	Science teachers	Learners' learning performance
Phase 3 - Check **Time frame:** End of the 3rd Quarter	Evaluate the effectiveness of the developed session plans through posttest, and conduct semi-structured interview to the learners.	Science teachers	Posttest result, comparison of the pretest and posttest data, and analysed data on the participants' responses
Phase 4 - Act **Time frame:** End of the School Year	Revise and improve the developed session plans accordingly.	Science teachers	Enhanced session plans on Central Dogma of Molecular Biology

As shown in the table, one should gain an understanding of the current curriculum during the planning phase. One way to do this is to examine the current curriculum on the Central Dogma of Molecular Biology. This may also include discussion on the content and method components of the curriculum with the field experts for the possible curricular updates and changes, especially those related to curricular methods such as transition from the traditional model to a problem-based learning model. In this phase, particular teaching models, curriculum evaluation methods, and where the simulation-based instructional materials can be integrated into the curriculum must be determined and clearly described. According to Realyvásquez-Vargas, et al. (2018), using this needs assessment approach can result in an easier development of curriculum materials to address curricular concerns. Accordingly, once there is already an overall understanding of the curriculum, school's available instructional materials such as the availability of the computer laboratories with internet connection, teachers' resources on Central Dogma of Molecular Biology (e.g. simulation-based instructional materials, existing lesson plans), as well as the available learners' resources (e.g. textbooks, and other learning references) related to the topic must also be examined. Namasaka, Mondoh, and Wasike (2017) posited that knowledge of the available resources can help in designing appropriate instructional materials.

Likewise, careful planning should be made in order to determine what is to be incorporated in the curriculum structure. Conceptualization of what is to be included, and how the simulation-based instructional materials should be incorporated must be taken into consideration (Efe & Efe, 2011; Lameras et al., 2016). Once content-relevant instructional materials and strategies are identified, the session plans can now be developed. The available computer simulations, appropriate teaching strategies, alignment to the curriculum, content, technical, and instructional qualities must be highly scrutinized to ensure that the contents and simulation-based instructional materials are properly organized and incorporated to achieve the intended learning outcomes (Lameras, et al., 2016). Similarly, every session plan must contain the essential instructional components such as content standard, learning competencies, specific learning objectives, lesson outline, introduction, motivation, instruction, generalization, evaluation, and references. Liu, et al., (2008) emphasized that when all the components of teaching pedagogies are highly considered in designing an instructional material, it results into an effective teaching-learning process. Consequently, the validity, appropriateness, and usefulness of the developed session plans in terms of content, instructional, and technical qualities must be evaluated by the field experts. Fong et al. (2010) maintain that a good combination of skills, expertise, and continuous evaluation of instructional materials are necessary for the production of effective curricular instruments.

Once session plans are developed and validated, evaluation methods and tools must be described. Evaluation methods and tools should match the overall instructional objectives. Deshpande (2010) suggests that sophisticated multiple-choice questions that test problem solving and application are found to be better evaluation methods.

In the second phase of the action plan, it is necessary that teachers are aware of the proper utilization of the simulation-based instructional materials. Thus, there may need to train the teachers on how to maximize the use of the instructional materials in the teaching-learning process. On the other hand, all curricular interventions need to be regularly evaluated (Phase 3), revised, and improved (Phase 4). Since the instructional and curricular materials may change, flexibility and the development of alternative strategies based on the evaluation results are important (Carague, 2013).

According to Lameras et al. (2016), to optimize the teaching process, it must be planned consciously with the use of appropriate and effective teaching styles, and instructional materials. These materials can provide teachers with ideas and help them in achieving their goals that could not or would not be accomplished on their own (Brown, 2009). Likewise, Gray (2007) posited that when these materials are properly designed, incorporated in the curriculum, and used, they can have profound effects in increasing the power of self-direction, retention, skill in fundamental processes, reasoning ability and solving problems of the learners, and enable teachers to better deliver the lessons.

Conclusions

The learners were proficient on the concept DNA Replication, and approaching proficiency on the concepts of Transcription and Translation before the conduct of the study. On the other hand, the learners demonstrated advanced on the concepts of DNA Replication and Translation, and proficient on the concept of Transcription after the conduct of the study. Furthermore, there was a significant difference ($p<0.05$) in the mean mastery level scores of the learners on the concepts of Central Dogma of Molecular Biology before and after the conduct of the study. The learners were engaged in experiential learning with the use simulation-based instructional materials. An action plan on the utilization of simulation-based instructional materials in the teaching-learning process was designed based on the study.

Recommendations

In the light of the findings from the data, the researchers recommended to assess the potential problems on the utilization of the simulation-based instructional materials to further validate their usefulness; conduct further study on a wider scope to improve the effectiveness and practicability of the simulation-based instructional materials; use other computer-aided simulations tools and educational software in teaching the concepts of Central Dogma of Molecular Biology, and assess their effectiveness towards learners' learning performance; utilize the designed action plan to incorporate the simulation-based instructional materials in the curriculum; and utilize the developed session plans in teaching the concepts of Central Dogma of Molecular Biology.

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