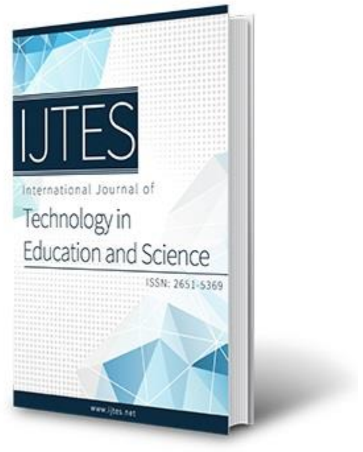

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Abstract

Despite the advantages proffered by technology in science education, little has been done to develop and validate innovative technology-based instructional materials on Central Dogma of Molecular Biology. It is imperative to test any newly generated instructional materials to validate their quality before being widely used. Hence, this study aimed to validate the developed simulation-based instructional materials on Central Dogma of Molecular Biology for Senior High School. This study utilized Research and Development (R&D) design involving 50 Grade 12 STEM learners and 15 Biology education experts chosen through purposive sampling. Results revealed that experts strongly agreed that the developed simulation-based instructional materials on Central Dogma of Molecular Biology have content, technical, and instructional qualities. Meanwhile, the pretest and posttest results revealed that the learners demonstrated significant conceptual improvement from approaching proficiency to advanced mastery level in Central Dogma of Molecular Biology concepts. Further, the learners' pretest and posttest mean scores on the concepts differed significantly ($p<0.05$). Therefore, it is recommended that the developed simulation-based instructional materials be used to complement in teaching Central Dogma of Molecular Biology.

Introduction

The goal of the Department of Education in the Philippines of producing globally competent and life-long learners is impeded by the COVID-19 pandemic. The crisis has dramatically affected the educational systems across the globe, which involved the shifting from the conventional face-to-face teaching practice to distance online learning (Dukes, 2020; Huang, 2020; Masoud & Bohra, 2020; Mahaffey, 2020). To cope with the changing educational landscape, institutions across the globe struggled to obtain computer software and other technology-related items. To fulfill the demands of time and gain mastery of concepts and skills among learners, teachers are encouraged to use technology-based instructional resources, particularly when teaching concepts with complicated processes such as the Central Dogma of Molecular Biology (Arrieta et al., 2020; Huang, 2020; Sunasee, 2020; Cano, 2021).

One of the most important topics in biology is the Central Dogma of Molecular Biology. However, it is replete with concepts involving molecular and cellular mechanisms that are presented as still pictures in textbooks, and the available teaching materials that can promote active learning are underutilized (Picardal & Pano, 2018; Cano, 2021). Although several factors have been linked to the Philippines' poor performance in science (e.g., out-of-school children, socio-economic status, health, and psychological factors) (Adarlo & Jackson, 2017; Department of Education, 2020), Rivera (2017) argued that robust teaching pedagogies are needed to improve the country's science education performance through the development of innovative teaching techniques. According to studies, teachers should utilize proper instructional approaches that are appropriate for the level of comprehension of their learners, and the usage of technology is critical (DeCaporale-Ryan et al., 2016; Olga et al., 2020; Cano, 2021).

As technology continues to pervade the educational system, teachers must develop innovative technology-based teaching materials to address these issues. Consequently, with the Department of Education's shift to online distance learning, schools in the Philippines still have insufficient instructional resources to suit the expanding diversified demands of today's learners (Arrieta et al., 2020). The Department of Education has funded several programs to encourage teachers to create innovative instructional resources to improve the teaching-learning process in an online environment. This endeavor, however, is insufficient to address the country's existing issues. The provision of a more timely solution is imperative.

Currently, there is a growing interest in validating technology-based instructional materials for authentic learning due to the proliferation of online computer simulations. However, there is limited literature that discusses the appropriate tool to measure the validity of these materials. According to Olga et al. (2020), computer simulations may play an essential role in science education. They may progressively educate learners to understand topics that need more abstract thinking by preparing them intellectually using computer-based teaching methodologies that encourage learners to employ more senses. Furthermore, they engage learners in deep learning, which promotes comprehension rather than surface learning, which focuses only on memorization (DeCaporale-Ryan et al., 2016; Gunda & Dongeni, 2017; Olga et al., 2020). Despite the benefits of computer simulation tools in teaching, many teachers have no bold attempt to integrate them into their teaching pedagogies (Anoba & Cahapay, 2020; Cano, 2021). Therefore, these available computer simulations are not maximized. Accordingly, there is a limited study on developing and validating innovative educational resources on Central Dogma of Molecular Biology. Hence, this prompted the researcher to conduct this study to provide teachers with a responsive strategy for promoting learners' learning that is tailored to their needs and the demands of the new normal in education.

This study aimed to develop and validate the simulation-based instructional materials on Central Dogma of Molecular Biology. Specifically, it sought to: (1) design session plans integrated with computer simulations as instructional materials on Central Dogma of Molecular Biology, (2) validate the simulation-based instructional materials through experts' evaluation, (3) and assess the effectiveness of the developed simulation-based instructional materials on students' mastery level in Central Dogma of Molecular Biology concepts.

Method

Research Design

This study utilized the Research and Development (R & D) design, which involves the process of developing and validating the simulation-based instructional materials on Central Dogma of Molecular Biology (see Figure 1).

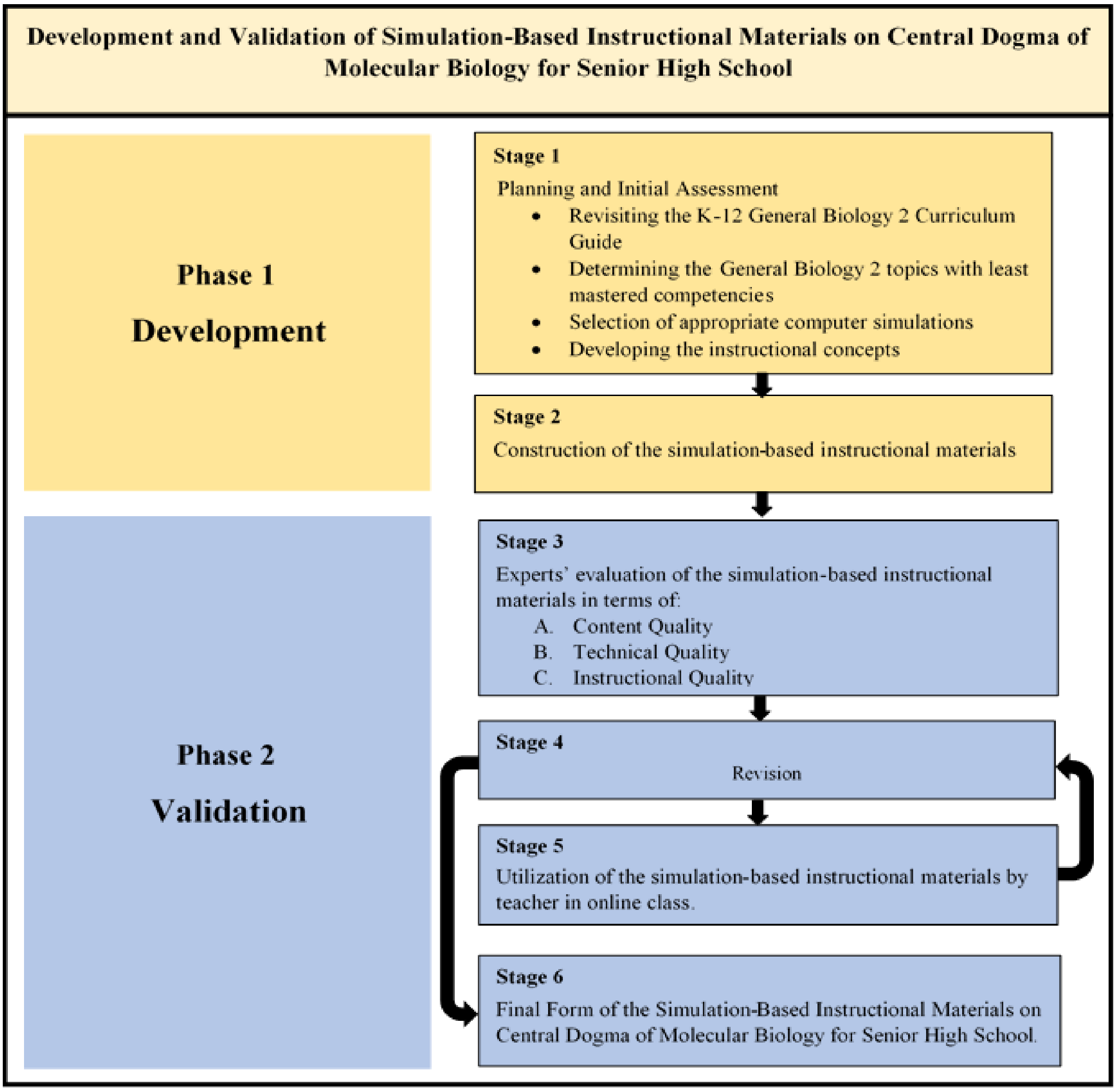

Figure 1. Research Design of the Study

Participants of the Study

One (1) section of Grade 12 STEM learners of Notre Dame of Marbel University-Integrated Basic Education Department Senior High School was purposively selected as the participants of the study. This is for the reason that the researcher is their subject teacher in General Biology 2 and has direct supervision over them. This is to minimize the disruption of classes and other problems that might arise in the course of the study.

Research Instruments

In gathering data relevant to this study, the researcher employed the following research instruments: (a) Experts' Evaluation Tool; and (b) Pretest-Posttest Questionnaire.

Experts' Evaluation Tool

The evaluation tool adapted from the study of Cano (2021) was used to validate the materials. The tool contains three main criteria: (a) content quality, (b) technical quality, and (c) instructional quality. All of the criteria contain nine indicators. A 5-point Likert scale shown in Table 1 was used to describe and interpret the validation results of the developed instructional materials. The means were calculated to evaluate the developed materials in terms of its content, technical, and instructional qualities. Based on the results of the evaluation, the draft was revised.

Table 1. Rating Scale for the Developed Materials Validation

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

Note. Adapted from Cano (2021)

Pretest-Posttest Questionnaire

Pretest-Posttest Questionnaire adapted from the study of Newman et al. (2016) was used to assess the mastery level of the learners on the concepts Central Dogma of Molecular Biology. The questionnaire was comprised of forty (40) – multiple-choice items covering the following sub-topics: a) DNA Replication with sixteen (16) items; b) Transcription with eight (8) items; and c) Translation with sixteen (16) items. The multiple-choice items in the questionnaire have different levels of difficulty based on the designed Table of Specifications considering the cognitive levels of Revised Bloom's Taxonomy (Anderson & Krathwohl, 2001).

Table 2. 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. Andamon, J. and Tan, D. (2018)

The questionnaire was pilot-tested among forty-five (45) senior high school learners. The split-half method was used to assess the reliability of the questionnaire. The analysis of the data revealed that the Pretest-Posttest Questionnaire has a Guttman Split Half coefficient of 0.992. This indicates that the questionnaire scale had a high level of internal consistency (DeVillis, 2003; Kline, 2005). The learners' mastery level scores in the pretest and posttest on the concepts of Central Dogma of Molecular Biology were described using the scale in Table 2.

Data Collection

Development Phase

Planning and an initial assessment were conducted prior to the development of simulation-based instructional materials. Before the conduct of the study, the researcher ensured the following: (a) revisiting the K-12 General Biology 2 Curriculum Guide; (b) identifying the topics with the least mastered competencies; (c) identification of appropriate simulation-based instructional materials anchored to the topic and curriculum; (d) review of resource materials and instruments to ensure the competencies were consistent with the Department of Education – Curriculum Guide; and (d) the development of the session plans.

Biology textbooks, General Biology 2 curriculum map of Notre Dame of Marbel University-Integrated Basic Education Department Senior High School, and K-12 Curriculum Guide in General Biology 2 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. A decade of studies cited that this particular topic remains difficult for teachers and learners to teach and learn, respectively (Lewis, 2000; Kozma et al., 2000; Knippels et al., 2005; Reddy & Mint, 2017; Cano, 2021). Furthermore, the following were also considered in the selection of the topic: (a) the experience of the researcher provided information that this was the topic found most complex and least mastered competencies among senior high school learners; and (b) this topic involves DNA and RNA structures that are tedious to visualize and analyze but can be aided with computer-simulation materials.

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 (2008), Rinehart and Winston, were identified and selected as appropriate computer simulations to be integrated in the session plans in order to deliver the intended learning outcomes in the Central Dogma of Molecular Biology. All the interactive simulation tools are adapted into English. The PhET® simulation software is set up so that learners may complete the exercises in a virtual environment on their own. The materials and tools necessary for the activity can be chosen on the different tool menus; necessary controls and varieties can be easily manipulated using the tools.

The LabXchange® simulation is also arranged systematically where learners can easily learn and trace on how the genetic information is replicated and expressed to form proteins. Videos and articles are also incorporated in the series of simulations. The DNA Interactive® simulation presents the timeline for significant and relevant scientific discoveries on DNA. It also presents the information in a sequence where learners can easily understand and manipulate the variables. Moreover, the Holt's® simulations present the processes of DNA replication, transcription, and translation. The simulations are user-friendly, and the users can easily understand and manipulate the variables and options. After selecting the topic and identifying the computer simulations appropriate to the topic and curriculum, the researcher developed the simulation-based instructional materials on Central Dogma of Molecular Biology.

Validation Phase

Fifteen (15) experts evaluated the developed simulation-based instructional materials on Central Dogma of Molecular Biology. Three (3) evaluators are with a doctorate degree in Biology and curriculum developers, four (4) evaluators are associate professors of a private university with a master's degree in Biology, one (1) evaluator is a Science Program Coordinator with a master's degree in Biology, and seven (7) secondary educators are with master's degree in Biology.

One sample pretest-posttest design (Knapp, 2016) was employed to determine the effectiveness of the simulation-based instructional materials. This design is employed on a single (1) sample group only, and samples are measured before and after the procedure is applied (Fraenkel & Wallen, 2000). The 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 simulation-based instructional materials.

Furthermore, the participants 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 researcher delivered the instructions, methods, and instructional materials to prevent bias and external factors. The delivery of instructions using the simulation-based instructional materials lasted for two (2) weeks. The same set of questions in the Pretest-Posttest Questionnaire was administered for the posttest. Time limits were employed in the conduct of the tests. Based on the researcher's experience on the utilization of the simulation-based instructional materials in the online class, the draft was further revised to produce the final form of the product.

Ethical Consideration

The researcher conducted this study in complete accordance with established research protocols. The researcher ensured that the participants and their parents approved the computerized informed consent form. The participants were informed that their participation would be voluntary, private, and confidential and that their identities would remain anonymous. Additionally, participants were informed that the data gathered would be utilized solely for academic purposes and would be kept with the utmost confidentiality.

Data Analysis

To conduct an objective analysis of the gathered data, the researcher used descriptive statistics such as weighted mean to examine the:

(a) content quality;

(b) technical quality;

(c) and instructional quality of the developed instructional materials on Central Dogma of Molecular Biology.

Meanwhile, the paired-samples t-test was utilized to assess the significant difference between the pretest and posttest scores on the participants' mastery level scores in Central Dogma of Molecular Biology concepts.

Results

Designed Simulation-Based Instructional Materials

This study sought to design session plans integrated with computer simulations as instructional materials on Central Dogma of Molecular. To address this problem, careful planning was made to determine what are to be included in the session plans. After the conceptualization of what are to be included and how the computer simulations should be incorporated, the researcher started the development of the simulation-based instructional materials. The developed simulation-based instructional materials are composed of the following parts: (a) title page; (b) preface; (c) parts of the session plans; (d) table of contents; (e) curriculum instruction delivery alignment map; and (f) the different session plans with specific topics. Ten (10) session plans (see Table 3) were developed to achieve the subject outcome requirement on the topic Central Dogma of Molecular Biology.

Table 3. Central Dogma of Molecular Biology Topics

Session Plans	Topics
1	DNA: Searching for the Genetic Material
2	DNA Structure, Composition, and Function
3	Discovering the Structure of DNA
4	DNA Replication
5	Prokaryotic and Eukaryotic Replication
6	RNA and Gene Expression
7	Transcription: Reading the Gene
8	Transcription: Regulating Gene Expression
9	Translation: RNA to Proteins
10	The Mechanisms of Central Dogma

Every session plan consists of the following sections: (a) content standard; (b) learning competencies; (c) specific learning objectives; (d) lesson outline; (f) introduction; (g) motivation; (h) instruction; (i) generalization; (j) evaluation; and (k) references.

Validation of the Simulation-Based Instructional Materials

The validation of the simulation-based instructional materials on Central Dogma of Molecular Biology was done in two (2) ways. First is the evaluation of the materials by the experts. Fifteen (15) Biology education experts were asked to evaluate the developed instructional materials' validity, appropriateness, and usefulness. The criteria for evaluation include the following: (a) content quality (Table 4); (b) technical quality (Table 5); and (c) instructional quality (see Table 6).

As shown in Table 4, experts strongly agreed that the developed instructional materials have content quality (M = 4.78 ± 0.36). Likewise, experts strongly agreed on the instructional materials' technical quality (M = 4.88 ± 0.18), which is presented in Table 5.

Table 4. Validation Result on Content Quality

I. CONTENT QUALITY INDICATORS	**WEIGHTED MEAN ± SD**	**DESCRIPTION**
1. The content is scientifically adequate and accurate.	4.50 ± 0.58	SA
2. It emphasizes active learning.	4.75 ± 0.50	SA
3. It is well organized.	4.75 ± 0.50	SA
4. The contents of the session plan are relevant to the learning objectives	5.00 ±` 0.00	SA
5. The session plan is supported by instructional materials (illustrations and tasks) suited to the level of the learners.	4.75 ± 0.50	SA
6. It evaluates student-learning as stated in the objectives.	4.75 ± 0.50	SA
7. It allows development of multiple intelligences.	4.75 ± 0.50	SA
8. The session plan is aligned to the curriculum.	5.00 ± 0.00	SA
9. The content is free of ethics, gender, and other stereotypes.	5.00 ± 0.00	SA
OVERALL MEAN	**4.78 ± 0.36**	**SA**

Note. 1.00–1.49 = Not Applicable (NA); 3.50 –4.49 = Agree (A); 1.50 –2.49 = Strongly Disagree (SD); 4.50-5.00 = Strongly Agree (SA); 2.50–3.49 = Disagree (D)

Table 5. Validation Result on Technical Quality

II. TECHNICAL QUALITY INDICATORS	**WEIGHTED MEAN ± SD**	**DESCRIPTION**
1. The session plan is easy to understand.	5.00 ± 0.00	SA
2. The session plan allows teachers to control pace of teaching.	4.75 ± 0.50	SA
3. The graphics are excellent.	4.75 ± 0.50	SA
4. The layout and design are attractive.	4.75 ± 0.50	SA
5. Intend users can easily and independently use the session plan.	5.00 ± 0.00	SA
6. The language used is clear, concise, and motivating.	5.00 ± 0.00	SA
7. The session plan is aesthetically pleasing.	5.00 ± 0.00	SA
8. The symbols used are well-defined.	4.75 ± 0.50	SA
9. Topics in the session plan are presented in a logical and sequential order.	4.75 ± 0.50	SA
OVERALL MEAN	**4.88 ± 0.18**	**SA**

Note. 1.00– 1.49 = Not Applicable (NA); 3.50 – 4.49 = Agree (A); 1.50 – 2.49 = Strongly Disagree (SD); 4.50 – 5.00 = Strongly Agree (SA); 2.50 – 3.49 = Disagree (D)

Meanwhile, experts strongly agreed on the instructional quality (M= 4.84 ± 0.16) of the instructional materials, as shown in Table 6. All of the indicators received strongly agree ratings.

Table 6. Validation Result on Instructional Quality

III. INSTRUCTIONAL QUALITY INDICATORS	**WEIGHTED MEAN ± SD**	**DESCRIPTION**
1. It provides an appropriate feedback on the accuracy of student's answer.	4.75 ± 0.50	SA
2. It is of high educational value.	4.75 ± 0.50	SA
3. It is good supplement to the curriculum.	5.00 ± 0.00	SA
4. It addresses the needs and concerns of the intend users.	5.00 ± 0.00	SA
5. The session plan facilitates collaborative and interactive learning.	4.75 ± 0.50	SA
6. It integrates student's previous experience.	5.00 ± 0.00	SA
7. The test items are constructed appropriate to the level of the learner.	4.75 ± 0.50	SA
8. It reflects current trend in Science instruction.	4.75 ± 0.50	SA
9. The graphics, and colors used are appropriate for the instructional objectives.	4.75 ± 0.50	SA
OVERALL MEAN	**4.84 ± 0.16**	**SA**

Note. 1.00– 1.49 = Not Applicable (NA); 3.50 – 4.49 = Agree (A); 1.50 – 2.49 = Strongly Disagree (SD); 4.50 – 5.00 = Strongly Agree (SA); 2.50 – 3.49 = Disagree (D)

On the other hand, Table 7 presents the summary result of the evaluation by the experts on the developed simulation-based instructional materials on Central Dogma of Molecular Biology. As far as the validity of the simulation-based instructional materials is concerned, experts registered an overall grand mean of 4.83 ± 0.23. This indicates that the experts strongly agreed with the developed simulation-based instructional materials' content, technical, and instructional qualities.

Table 7. Summary of the Experts' Validation Results

CRITERIA	**OVER-ALL MEAN ± SD**	**DESCRIPTION**	**RANK**
Content Quality	4.78 ± 0.36	SA	3
Technical Quality	4.88 ± 0.18	SA	1
Instructional Quality	4.84 ± 0.16	SA	2
OVERALL GRAND MEAN	**4.83 ± 0.23**	**SA**	

Note. 1.00– 1.49 = Not Applicable (NA); 3.50 – 4.49 = Agree (A); 1.50 – 2.49 = Strongly Disagree (SD); 4.50 – 5.00 = Strongly Agree (SA); 2.50 – 3.49 = Disagree (D)

The second way of validating the simulation-based instructional materials on Central Dogma of Molecular Biology was done by comparing the mastery level performance of the learners through one sample pretest-posttest design. Table 8 demonstrates the paired-samples t-test of the pretest and posttest mean mastery level scores of the learners in Central Dogma of Molecular Biology concepts.

Table 8. Paired-Samples t-Test of the Learners' 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*
Overall	**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 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. Specifically, a statistically significant increase in the mastery level scores of 3.85, 2.54, and 4.02 on DNA Replication, Transcription, and Translation concepts was observed, respectively. Furthermore, a statistically significant increase in the overall mastery level scores of 10.42 on Central Dogma of Molecular Biology concepts was observed.

Discussion

In designing the simulation-based instructional materials on Central Dogma of Molecular Biology, the following were highly scrutinized and taken into consideration to ensure that the instructional materials are appropriately organized: (a) computer simulations; (b) appropriate teaching strategies; (c) alignment to the curriculum; (c) content quality; (d) technical quality; and (e) instructional quality. According to Liu et al. (2008), when all the components of teaching pedagogies are highly considered in designing an instructional material, it results in an effective teaching and learning process.

Likewise, Fong et al. (2010) maintain that a good combination of skills and expertise are necessary for the production of effective instructional materials; hence, fifteen (15) Biology education experts evaluated the validity, appropriateness, and usefulness of the developed simulation-based instructional materials on the content, technical, and instructional qualities. The experts strongly agreed that the developed instructional materials have content quality (M = 4.78 ± 0.36) (see Table 4). Apparently, all of the indicators received a strongly agree rating which reveals that the contents of the session plans are well organized, scientifically adequate and accurate, and emphasize active learning. Accordingly, the contents evaluate learners' learning as stated in the objectives and promote the development of multiple intelligences. The experts' comments support this: the contents of the session plans are highly organized, adequate, and promotes the critical thinking of the learners.

Nevertheless, three (3) indicators received a perfect rating (M= 5.00 ± 0.00) (see Table 4) which highly emphasizes that the contents of the instructional materials are relevant to the learning objectives, aligned to the curriculum, and are free of any form of stereotypes. This is supported by the experts' comments: the lessons are well-crafted to suit the K-12 curriculum and very detailed, and of great help to K to 12 learners. Efe and Efe (2011) and Lameras et al. (2016) pointed out that the success in the teaching and learning process greatly depends on the compatibility of the instructional materials with the curricula.

Meanwhile, the experts strongly agreed that the instructional materials possessed technical quality ($M = 4.88 \pm 0.18$) (see Table 5). All of the indicators received a strongly agree rating. Moreover, four (4) indicators received a perfect rating ($M = 5.00 \pm 0.00$) which signifies that the session plans are aesthetically pleasing, easy to understand, and can easily and independently be used by the teachers. Namasaka et al. (2017) emphasized that instructional materials that can be easily used, suited to the level of the learners, and have a good quality of layout can improve the teaching-learning process.

Likewise, the experts strongly agreed on the instructional materials' instructional quality ($M= 4.84 \pm 0.16$) (see Table 6). All of the indicators received a strongly agree rating. Moreover, three (3) indicators received a perfect rating ($M = 5.00 \pm 0.00$) from the experts, which implies that the developed sessions plans are a good supplement to the curriculum, they integrate learner's previous experience, and they address the needs of the concerns of the intended users which is the primary purpose of developing these instructional materials.

The summary result of the evaluation by the experts on the developed simulation-based instructional materials on Central Dogma of Molecular Biology showed that the technical quality has the highest overall rating ($M = 4.88 \pm 0.18$) (see Table 7), which indicates that this is the most vital point among the three parts of the developed simulation-based instructional materials. This is supported by the comments of the experts to wit: the lesson is presented logically thus, it can easily be understood. This is followed by instructional quality with an overall mean of 4.84 ± 0.16. On the other hand, the content quality has registered the lowest overall mean of 4.78 ± 0.36 among the different parts of the instructional materials. Although this still falls under the "strongly agree" category, there is still a need to improve this part of the instructional materials. This is supported by the comments of the experts to wit: the antiparallel orientation of the DNA strands could be incorporated; it would be better if the choices that will be deduced by the learners is in terms of adenine-thymine and guanine-cytosine percent base composition to support the idea of base pairing rules; and error rates in the crucial processes of Central Dogma could be incorporated. According to Lameras et al. (2016), the teaching process must be coupled with appropriate selection and use of instructional resources and teaching strategies. It must be planned consciously using appropriate and effective teaching styles and instructional materials to optimize the teaching-learning process. Likewise, these instructional materials can provide ideas and help teachers achieve their goals that could not or would not be accomplished on their own (Mceneaney, 2016). When properly designed and used, these instructional materials can profoundly increase the power of self-direction, retention, skill in fundamental processes, reasoning ability, and solving problems of the learners, and enable teachers to deliver better lessons (DeCaporale-Ryan et al., 2016).

On the other hand, the learners' low pretest mean mastery level score on the concepts of Central Dogma of Molecular Biology (see Table 8) indicates that they have less prior knowledge and misconceptions about the concepts, as they need to know about cell division and reproduction to correctly explain the process of gene transmission (Change & Anderson, 2020; Picardal & Pano, 2018). Meanwhile, the learners' posttest mean mastery level score increased significantly, revealing that the simulation-based instructional materials had a substantial impact on their acquisition of the Central Dogma of Molecular Biology concepts. The current study supports previous research findings suggesting that computer simulations in teaching improve learners' learning outcomes (DeCaporale-Ryan et al., 2016; Mceneaney, 2016; Gunda & Dongeni, 2017; Olga et al., 2020).

One of the reasons for the learners' success in the post-test result is probably the fact that simulation-based instructional materials help learners visualize processes that seem abstract and complex. According to Gunda and Dongeni (2017), utilizing visual instructional tools in teaching and learning environments is relevant and highly useful. 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). Likewise, decades of studies have identified a correlation between constructive motivation and a good learning atmosphere using simulation-based instructional materials (Flanagan, 2009; DeCaporale-Ryan et al., 2016; Mceneaney, 2016; Ulukok, 2016; Gunda & Dongeni, 2017; Reddy & Mint, 2017; Olga et al., 2020).

On the contrary, some studies have found that using computers and technology-based instructional resources throughout the teaching-learning process elicits certain negative responses. Greene (2001) stated that digital technology can diminish the interpersonal component of teaching, as the core of teaching is the creation of knowledge through connections with learners to assist them in comprehending topics. Similarly, Bautista (2011) asserts that computers and the internet cannot replicate the art of teaching. While these resources can supplement an already excellent educational experience, it is costly to depend on them exclusively for learning.

Conclusions

Based on the findings, the developed simulation-based instructional materials on Central Dogma of Molecular Biology have content, technical, and instructional qualities. Meanwhile, the pretest and posttest results showed that the learners demonstrated significant improvement ($p<0.05$) from approaching proficiency to advanced mastery on the concepts of Central Dogma of Molecular Biology with the use of the simulation-based instructional materials based on the results of the learners' pretest and posttest mean scores. This signifies the pronounced effect of the simulation-based instructional materials on the learners' learning on Central Dogma of Molecular Biology concepts. The learners learned from the instructional materials with their teacher as the facilitator of learning. With all of this critical information gleaned from the current study, it is sufficient to claim that teachers may be able to redirect the focus of classroom instruction in science education from the conventional approach to technology-based instruction.

Recommendations

In line with the Department of Education's goal of continuously producing learning resources as part of the K-12 Program's implementation in the new normal, the researcher suggests the following: (1) the developed simulation-based instructional materials can be used to supplement the teaching of the Central Dogma of Molecular Biology; (2) the study can be replicated by other researchers by preparing instructional materials for other topics in Biology;

conducting an experimental design to further validate the study's findings; and developing and trying-out the materials using an experimental approach to test their effectiveness; (3) this study was conducted on a small sample size of participants; hence, to conduct further study on a broader scope to improve the effectiveness and practicability of the simulation-based instructional materials is suggested; (4) the computer simulations used in the study were also limited and primarily based on the researchers' preferences; hence, it is suggested that other computer simulation tools and educational software be used in teaching the Central Dogma of Molecular Biology concepts. While the current study may be limited to only a few participants, this study could serve as a baseline for succeeding development of instructional materials in science education.

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