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Development of RNA-DNA kit as instructional material in teaching Biology

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Abstract

The study was designed to develop a simple but functional instructional material for Biology instruction. The RNA-DNA kit was developed aligned with the constructs of providing scaffold towards better delivery of difficult lessons in Genetics. The instructional material was conceptualized based on the low performance of BSFT students in Microbial Genetics, thus bringing inside the classroom the model of the ribonucleic acid (RNA) and the deoxyribonucleic acid (DNA) though puzzle chips manipulatives which could help to clearly facilitate their understanding of the Central Dogma of Molecular Biology and to increase their science performance. The material was useful in various topics in Biology including base pairing, Chargaff's rule, translation, and transcription that are paired with a manual which serves as a guide for students and teachers on how to use the kit. The simplicity and the originality of the designs of RNA-DNA chips which are made of used matchboxes passed the ocular evaluation and strict suggestions and recommendations of experts in Biology. Further, the use of recyclable materials in the kit has a potential for income generation. A quantitative method utilizing questionnaire checklist and twenty item summative tests were also employed to determine how the RNA-DNA kit affects students' learning. Also, considered is the acceptability of the material for Biology instruction through subjecting to selected group of respondents who are purposively pre-identified MAT-Science students in Technological University of the Philippines and University of Rizal System. Results showed that the material was much acceptable and effective in teaching biology as revealed by the performance of the students which shows significant difference on the level of their performance with the average score of 18.15 verbally interpreted as "High Average" from the 20-item multiple choice type of test given to the respondents. The findings revealed that the utilization of RNA-DNA kit helped to increase Science performance of the students as well as reducing waste in our environment.

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Introduction

Biology education, an integral component of scientific education, helps train future biologists, healthcare professionals, technologists, environmentalists, and researchers. Molecular genetics and genomics advancements in Biology result in the need for innovative and effective instructional materials to help students understand challenging biological concepts. This can be achieved by incorporating interactive and inquiry-based classroom activities (Bogar, 2019; Brederode, 2020; Simamora *et al.*, 2023) into biology instruction to achieve quality science education.

The Philippines consistently ranks lower on the 2018 Programme for International Assessment (PISA) for junior high school students and the 2019 Third International Mathematics and Science Studies (TIMSS) for fourth graders (Schleicher, 2019; Mullis *et al.*, 2020). This type of performance is still visible at the tertiary level, particularly when students take board exams, which serve as a mirror of the university or college to which they belong. The Technological University of the Philippines (TUP) earned 27.78% in the Professional Regulation Commission (PRC) Board Exam for Food Technologists in 2023 (PRC, 2023), which is below the national passing standards. This alarming situation prompted the researcher to conduct a study and examine the least mastered competency of Bachelor of Science in Food Technologists (BSFT) students in one of their major subjects, General Microbiology, with Microbial Genetics identified as one of the concepts that requires more focus and attention.

In Genetics, RNA-DNA interactions are vital in regulating gene expression, hence understanding them is essential to molecular biology particularly in modelling it like a jigsaw puzzle (Liu *et al.*, 2014). The development and validation of an instructive RNA-DNA kit offers a compelling way to bridge theoretical and practical biology education. A kit like this can help students understand biological concepts by letting them explore with RNA-DNA interactions like Chargaff's rule for base pairing, transcription, and translation. The study examined the biology teaching effectiveness utilizing the RNA-DNA kit particularly its potential to improve students' molecular biology knowledge and to understand RNA-DNA model interactions. The researcher aimed to prove the kit's usefulness in encouraging biology students' active learning, critical thinking, and scientific curiosity through rigorous validation and assessment, thus improving their Science performance.

Several studies have been conducted on the development of instructional materials to supplement digital literacy (Asrizal *et al.*, 2018; Manuel Área Moreira *et al.*, 2023; Tang and Chaw, 2016) and to bridge distance learning (Altawalbeh and Al-Ajlouni, 2022; Rizwan and Masrur, 2018; Sutton, 2020; Yilmaz and Korur, 2020) in Science education. The current study, however, considers the development of a material that is readily available, recyclable and can supplement both traditional and modular classroom settings using RNA-DNA kit which is made of by used match boxes as puzzle chips and used cheese cloth for ribosome representation to model the complex process of the Central Dogma of Molecular Biology.

The purpose of the study is to design, to develop and to test the acceptability of RNA-DNA kit as instructional material in teaching Biology.

Development of RNA-DNA kits

The RNA-DNA kit is designed to provide students with hands-on experience in exploring RNA-DNA interactions, which are fundamental to gene expression and understanding the central dogma of molecular biology. The development process involves the creation of puzzle chips and an activity manual to facilitate significant biological processes like DNA replication, transcription, and translation. Pioneering work by researchers like Beltramini *et al.* (2006) and Newman *et al.* (2018) highlighted the importance of developing instructional materials like model kits and simulation (Cano *et al.*, 2022) to facilitate the teaching of RNA-DNA biology and Genetics. Their study presented a comprehensive testing of their

developed instructional materials and demonstrated their utility in a classroom setting.

Development and improvisation of instructional materials for Biology instruction

Instructional materials include various tools such as textbooks, digital resources, and hands-on manipulatives. According to Olayinka (2016), these materials facilitate the transmission of information, encourage active participation, and promote enhanced comprehension. They play an essential role in guiding instruction and enabling educators to reach diverse learners. The development of RNA-DNA kit for Biology instruction is timely and relevant to supplement traditional textbooks and online simulations (Alvarez, 2021; Cano, 2021; Cano *et al.*, 2022), thus maximizing the access and ensuring the quality of academic instruction. Fowler (2018) emphasized that the quality of Science instruction could be achieved if significant changes in academic performance of the students are both quantitatively and qualitatively observed as well as its context (Darling-Hammond *et al.*, 2019). This gave bearing to the current study by developing instructional material designed to bridge the difficult concepts in the Central Dogma of Molecular Biology and a foundation in understanding Microbial Genetics for the college students which was validated though their Science performance test and evaluation of the developed material by the experts that includes MAT-Science Graduate Students in the field.

Improvisation of instructional materials resolves the scarcity of resources in a traditional classroom setting (Thasmai Dhurumraj and Zainul Moola, 2023). Mushimiyimana *et al.* (2022) and Esezi *et al.* (2019) highlight the significance of employing improvised instructional materials in chemistry and social sciences as well as Cruz and Rivera (2022) in using validated project-based module in Biology to enhance learner engagement, inclusivity, and participation. With the aid of utilizing used match boxes for RNA-DNA puzzle chips, used cheese cloth for ribosomal representation, used newspapers and used shoe box as container kit, the developed RNA-DNA kit could be easily replicated at low cost, thus responding for the scarcity of learning materials. Jeremake (2023) developed the “make-roscope” key chain which is an alternative to sophisticated microscopes contained in school laboratories. It’s handy feature and magnifying power enable it to be useful to bridge distance learning at the height of the pandemic particularly in facilitating laboratory activities where the use of microscopy is highly needed. Since DNA and RNA requires high powered microscopes to be clearly examined, the development of RNA-DNA kit will be useful in modelling these structures and explaining the difficult concepts governing it, thus strict evaluation in terms of its usefulness, quality, safety, and maintenance were also considered.

Conceptual framework

The conceptual model on the next page was based on Coombs' Systems Approach, which includes input, process, and output. The first box, the input phase, refers to the various resources and components required for the process to function, which includes the respondents, the MAT graduate students, and BSFT students, components of Biology Education that includes the RNA-DNA concepts and various types of RNA-DNA puzzle chips kit, the materials such as the used match boxes, shape patterns, acrylic paint, cutter used box and newspaper and the questionnaire checklist with respect to usability, quality, and safety and maintenance.

The second box, the process phase, entails the designing, development of an RNA-DNA kit and data through the preparation and validation of a questionnaire checklist and item analysis of test questions about the acceptance and effectiveness of the RNA-DNA kit as instructional material in teaching Biology through data analysis. The final box, the output phase, comprises the study's findings, which include the acceptance and effectiveness of the RNA - DNA kit as instructional material in Biology class. The arrow from the first box across the second box and leading to the third box represents the

study's principal tool or technique in establishing the appropriateness of developing an RNA-DNA kit as an instructional material in teaching Biology.

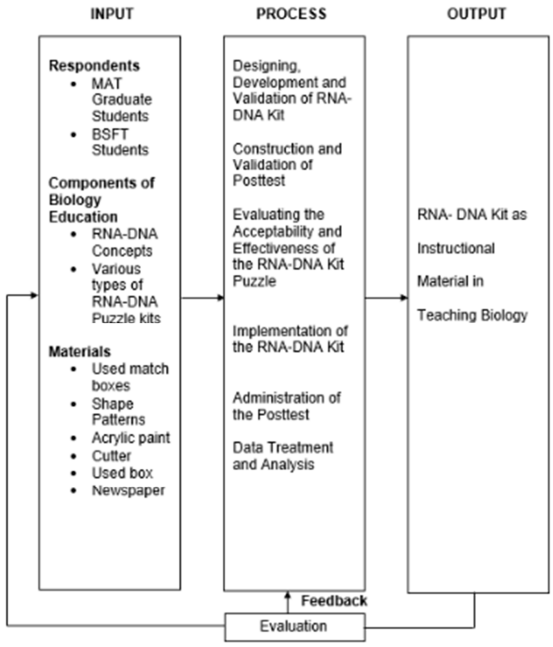

Fig. 1. Conceptual model showing the development, acceptability, and effectiveness of RBNA-DNA kit as instructional material in teaching Biology

Materials and methods

Research design

A two-group posttest-only randomized experimental design was employed in the course of the study. In a two-group posttest design, one group receives the program intervention or treatment, while the other group, the comparison group, does not (Trochim, 2023). This type of design should be applied only when the researcher can precisely describe the value of the mean that would be seen in the absence of the treatment (Kirk, 2013). In the case of the study, whether or not the students use the developed RNA-DNA kit, the effect of the teacher's academic instruction will certainly have an effect on their performance. As a result, during the course of the investigation, the researcher only considered the posttest result. The researcher adopted this sort of research design to investigate the causal influence of using the produced kit as instructional material on the students' Microbial Genetics summative test. The study's participants were BSFT students who were purposefully chosen by the researcher due to his direct supervision over the class and the availability of the subject offered for the given semester. The participants were split into two groups and chosen at random using an add-even procedure. The experimental group consists of twenty (20) students who were exposed to the usage of an RNA-DNA kit in the classroom, whereas the control group consists of twenty (20) students who were subjected to traditional class instruction. Qualitative and quantitative methods were also employed to determine how the RNA-DNA Kit affects students' learning. Further, this study discussed problems and opportunities in integrating innovative instructional resources into the curriculum.

Participants

This study included undergraduate students from one (1) section of the Bachelor of Science in Food Technology (BSFT) from Technological University of the Philippines. To maintain data containment and to avoid contamination and discrepancies in the study's outcomes, the following inclusion criteria were used in choosing participants: (1) Participants must be regular students in the second semester of the school year 2022-2023, (2) any gender with no age limitations, and (3) currently enrolled in General Microbiology. Another group of respondents were ten (10) Master of Arts in Teaching- Science graduate students who evaluated the acceptability of the developed kit for instruction.

Procedure of the study

1. Defining the constructs: The first step is to define, specialize and characterize the construct that must be measured. In the case of the study, the researcher analyzed the previous summative result for School Year 2021-2022 and found out that Microbial Genetics is one of the least mastered. Thus, a need for the development of instructional material particularly about the Central Dogma of Molecular Biology as its fundamental pre-requisites was conceptualized.
2. Construction of the table of specifications (TOS): The test is constructed using the two-way Table of Specifications (TOS) considering the Revised Bloom Taxonomy to identify the number of items for every topic respectively.

3. Developing an item pool: After defining the construct and topics the researcher constructed more items than necessary, the researcher had one hundred fifty (50) items though he needs only twenty (20) items referring to various indicating behavior in the three major topics.
4. Validation of the test material: The twenty (20) item test was face and content validated by the three Ph. D. major in Science Education students who are enrolled in a private autonomous university and a state university in Manila. They were considered by the researcher to validate the material because of their expertise in the field of Science education.
5. Test try-out 1: The twenty (20) item teacher-made test was administered to the previous students who took General Microbiology subject on the previous school year.
6. Item Analysis: The fifty (50) item teacher-made test was item analyzed in which case twenty eight (28) items were retained. The instrument coefficient of the test is 0.86 which means that the teacher made test possesses consistency of the items with the test as a whole.
7. Selection of Test Items: There were twenty (20) items selected in the finalized teacher-made test which is consisted of seven (7) items for DNA replication, seven (7) items for Transcription and six items (6) items for Translation as reflected to the Table of Specifications (TOS) made by the researcher. The items were selected according to difficulty and discrimination index of the items.
8. RNA-DNA Kit Acceptability: Using an adopted questionnaire, the questionnaire was given to selected MAT-Science students together with the developed kit. Further, the teacher introduced to the students the process of making a portfolio. Then, they were grouped randomly using odd-even technique using their grades in the prelim term as reference for ranking and grouping to determine who will be using the RNA-DNA kit and those who will be exposed to traditional classroom instruction.
9. Test try-out 2: The finalized twenty (20) item teacher-made test was tried out to both the control and experimental groups of BSFT students as form of their summative test.

Table 1. Likert scale for the evaluation of the acceptability of RNA-DNA kit

Scale value	Verbal interpretation	Range of mean
5	Very much accepted	4.20 - 5.00
4	Much accepted	3.60 - 4.19
3	Moderately acceptable	2.60 - 3.59
2	Acceptable	1.80 - 2.59
1	Not acceptable	1.00 - 1.79

Table 2. Descriptive rating of learners' mastery level scores

No. of items			Percentile	Verbal interpretation
6	7	20		
5.91-6.00	6.90-7.00	19.70-20.00	98.50-100.00	Excellent
5.73-5.90	6.69-6.89	19.10-19.69	95.50-98.49	Very superior
5.55-5.72	6.48-6.68	18.50-19.09	92.50-95.49	Superior
5.37-5.54	6.27-6.47	17.90-18.49	89.50-92.49	High average
5.19-5.36	6.06-6.46	17.30-17.89	86.50-89.49	Average
5.01-5.18	5.85-6.05	16.70-17.29	83.50-86.49	Low average
4.83-5.00	5.64-5.84	16.10-16.69	80.50-83.49	Satisfactory
4.65-4.82	5.43-5.63	15.50-16.09	77.50-80.49	Fair
4.47-4.64	5.22-5.42	14.90-15.40	74.50-77.49	Passed
4.46 and below	5.21 and below	14.89 and below	74.49 and below	Failed

Note: Adopted from Andamon and Tan, (2018) and Percentile from TUP Student Handbook, (2013)

Sources of data

The researcher-made test was used as the main instrument in determining the performance of student respondents in central dogma of molecular biology under Microbial Genetics and the adopted questionnaire to determine the level of its acceptability as perceived by the MAT-Science Graduate Students.

To determine the level of performance of the students using the researcher-made test the following mean range on the next page were used (Table 1 and 2).

Ethical considerations

The researcher had made certain that the informed consent form had been authorized by both the subjects and their parents. Participants were informed that their participation would be secret, confidential, and voluntary, and that their identities would be concealed. It was also stressed to the participants that the data acquired from the semi-structured interview would be utilized solely for academic purposes and would be kept strictly confidential.

Procedure of RNA-DNA kit construction

In constructing the RNA – DNA pattern, the researchers dealt with different steps. As an initial step, the researcher searched different shapes and patterns in the internet and existing studies and modified this. Then, he looked for the necessary tools and materials needed in the construction of RNA – DNA pattern and RNA – DNA list and purchased them to develop the output. In constructing the RNA – DNA pattern, the researcher drew the modified shape with specific measurement and traced them on the match boxes board. Then he finished the RNA – DNA pattern by applying it with acrylic paint for chip classification and identification. The researchers himself constructed the RNA – DNA pattern to test whether the develop kit is really effective and acceptable following this procedure.

First, draft the foundation pattern on match boxes. Second, cut the chips according to their proper color and cut it using the cutter. Third, place the chips on the kit according to their parts. Fourth, prepare the developed kit for the evaluation of the chosen respondents.

Data analysis

The following statistical treatments were used to evaluate and answer the sub problems.

1. To determine the level of acceptability of the RNA-DNA Kit as evaluated by respondents, mean and standard deviation was applied.
2. To determine the level of performance of the respondents in Microbial Genetics (Central Dogma of Molecular Biology) as revealed by the posttest results with respect to the different lessons, mean and standard deviation were used.
3. To determine the significant difference on the level of performance of the two groups of respondents as revealed by the posttest results with respect to different lessons, t-test was used.

Results and discussion

Fig. 2 shows the actual DNA model from the kit while Table 3 presents the composite table on the level of acceptability of the developed RNA-DNA kit as in instructional material in teaching Biology with respect to different aspects.

Fig 2. The DNA Model was formed using the puzzle chips from the kit

It can be seen from the Table 3 that the over-all mean is 4.10 and verbally interpreted as “Much Acceptable”.

Between the three items, aspect number 1 "usefulness" has the highest, general mean of 4.30 and verbally interpreted as "Very Much Acceptable". Followed by safety and maintenance with the general mean of 4.10. Last is the "quality" with a general mean of 4.0. Both aspects are verbally interpreted as "Much Acceptable".

This implies that from the result of the evaluation of the respondents the output is useful, and it has features that may be used in laboratory works for both instructors and students. It supports the study of Newman *et al.* (2018), wherein the usage of three-dimensional RNA-DNA model is relatively important in bridging the abstract concepts in the central dogma of molecular biology. Though the developed puzzle chips in the study are two-dimensional in nature, it utilizes used match boxes which promote recycling and economically friendly for its reproduction at low cost.

Table 3. Composite table on the level of acceptability of the developed RNA-DNA kit as instructional material in teaching biology with respect to different aspects

Aspect	Mean ± SD	Verbal interpretation
1. Usefulness	4.30 ± 0.35	Very much acceptable
2. Quality of the output	4.00 ± 0.18	Much acceptable
3. Safety and maintenance of the output	4.10 ± 0.30	Much acceptable
Over-all mean	4.10 ± 0.28	Much acceptable

Table 4. The experimental group of learners' mastery level scores

Concepts	No. of items	Mean ± SD	Percentage	Verbal interpretation
A. DNA Replication	7	6.80 ± 0.41	97.14	Very superior
B. Transcription	7	6.30 ± 0.80	90.00	High average
C. Translation	6	5.05 ± 0.88	84.17	Low average
Over-all	20	18.15 ± 1.46	90.75	High average

Table 5. The control group of learners' mastery level scores

Concepts	No. of items	Mean ± SD	Percentage	Verbal interpretation
A. DNA Replication	7	6.50 ± 0.69	92.86	Very superior
B. Transcription	7	5.95 ± 0.89	85.00	Low average
C. Translation	6	3.95 ± 1.54	65.83	Failed
Over-all	20	16.40 ± 1.43	82.00	Satisfactory

Table 4 presents the experimental group of learners' mastery level after using the RNA-DNA Kit as instructional material in teaching the central dogma of molecular biology as part of Microbial Genetics.

It can be gleaned on the table that the experimental group of BSFT learners exposed to RNA-DNA kit shows a very superior performance in DNA replication, high performance in transcription and low average in translation with the means of 6.80, 6.30 and 5.05 respectively with standard deviation of 0.41, 0.80 and 0.88. The average score of 18.15 out of 20 shows a high degree of mastery on average. This shows that the RNA-DNA Kit was effective as an educational material in fostering an in-depth understanding of the biological principles covered in the study. It confirms the study of Cano et al (2022) wherein the experimental group exposed to their simulation activity performed better in the three major concepts of the central dogma of molecular biology. This shows how well the kit works to improve students' comprehension and retention of the concept, particularly in DNA Replication and Transcription. However, given that performance in the area of translation was deemed to be below average, some students may benefit from additional assistance or reinforcement.

Table 5 on the next page presents the control group of learners' mastery level after exposure to traditional method of teaching in the central dogma of molecular biology as part of Microbial Genetics.

Table 6. T-Test of the two groups of learners' mean mastery level scores

Concepts	Experimental	Control	Mean difference
	Mean ± SD	Mean ± SD	
A. DNA Replication	6.80 ± 0.41	6.50 ± 0.69	0.30
B. Transcription	6.30 ± 0.80	5.95 ± 0.89	0.35
C. Translation	5.05 ± 0.88	3.95 ± 1.54	1.10*
Over-all	18.15 ± 1.46	16.40 ± 1.43	1.75*

Note. *Significant at .05 level of significance

The table shows that the control group of BSFT learners exposed to traditional method of teaching exhibits a very superior performance in DNA replication, low average performance in transcription and failed performance in translation with the means of 6.50, 5.95 and 3.95 respectively with standard deviation of 0.69, 0.89 and -1.54.

The average score of 16.40 out of 20 indicates adequate mastery. This implies that; while traditional teaching approaches are good in some areas, they may need to be improved further to provide a consistently high level of learning across all biological concepts. This connotes the findings of Mushimiyimana (2022) and Esezi *et al.* (2019) which emphasize the use of the improvisation of instructional materials in chemistry and social sciences to make learning more engaging, inclusive and participative among learners.

Accordingly, students who learned about DNA replication through conventional teaching methods had an exceptionally high level of competence (Branton, 2012). Although students were able to grasp an adequate amount of concept when it came to Transcription as well, many struggled with Translation. While the overall level of competence is adequate, it suggests that more work needs to be done to guarantee that all biological concepts are consistently and fluently mastered. Because of this, it's clear that students might benefit from using the RNA-DNA Kit and other non-traditional teaching tools to better grasp complex topics like Translation.

Table 6 presents both the control and experimental group of learners' mastery level after exposure to traditional method of teaching in the central dogma of molecular biology as part of Microbial Genetics.

The table depicts that there is a significant difference in the overall mastery level scores for all concepts between the two groups. The experimental group obtained a higher mean score of 18.15 compared to the control group's mean score of 16.40. This study demonstrates the high efficacy of the RNA-DNA Kit as an instructional tool, leading to a substantial improvement in overall mastery.

Conclusion

In conclusion, the t-test results indicate that the experimental group, which was exposed to the RNA-DNA Kit, demonstrated significantly higher performance compared to the control group that received traditional teaching methods. This superiority was observed most especially in DNA replication, and partly in Transcription, there should be more reinforcement and improvement on Translation to further enhance its overall mastery. This is parallel on a few researchers on the use of instructional materials in elevating student's academic achievement and performance. The RNA-DNA Kit demonstrated significant efficacy in improving students' comprehension of intricate biological concepts, highlighting its potential as a valuable instructional resource in biology education.

Recommendations

Based on the findings, the researchers recommended the following:

1. Use the RNA-DNA kit as instructional material in teaching Biology (genetics).
2. Conduct follow-up studies considering the feature of the output.
3. Development of lockable RNA-DNA puzzles pieces.
4. Enhance the activities about the concept of translation in the RNA-DNA kit manual.

5. Conduct improvisation studies on the effectiveness of the RNA-DNA kit through a project -based method of teaching.

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