Development of Simredity: An Interactive Strategic Intervention Material in Teaching Non-Mendelian Genetics to Grade 9 Learners

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ABSTRACT

Genetics, particularly Non-Mendelian Patterns of Inheritance, remains one of the most difficult topics for secondary learners due to its abstract nature and the higher-order reasoning it requires. This challenge is more evident in rural Philippine schools where access to interactive learning resources is limited. This study developed and evaluated SIMredity, an Interactive Strategic Intervention Material designed to enhance Grade 9 learners' conceptual understanding of non-Mendelian inheritance through print-based, visually enriched, and story-integrated activities. Guided by the 4D Model (Define, Design, Develop, Disseminate) and grounded in Constructivist Theory, Cognitive Load Theory, and Self-Directed Learning Theory, the study employed a mixed-methods design incorporating needs assessment, expert evaluation, quantitative testing, and qualitative feedback. Results from the needs assessment with six Science 9 teachers identified persistent learning difficulties in incomplete dominance, codominance, multiple alleles, and sex-linked traits, along with a lack of engaging instructional materials. SIMredity was subjected to expert evaluation using the Department of Education's LRMDS evaluation tool for print resources and received a Very Satisfactory rating across all components, with a 72.2% percentage agreement among evaluators, confirming its quality, clarity, and content accuracy. Implementation with 35 Grade 9 learners further demonstrated its effectiveness, as shown by a significant increase in mean scores from 9 in the pre-test to 21 in the post-test ($t = -22.21$, $p < 0.001$). Learners described the material as colorful, interactive, easy to follow, and helpful in supporting independent and self-paced learning. Overall, the findings indicate that SIMredity is a valid, usable, and effective instructional tool for improving learners' comprehension of non-Mendelian genetics, especially in resource-constrained educational settings.

Keywords: Strategic Intervention Material, Science Education, Non-Mendelian Inheritance, Interactive

INTRODUCTION

Genetics is a foundational branch of biology that enables learners to understand the mechanisms of heredity and variation among organisms. Despite its importance, it remains one of the most conceptually challenging areas for students due to its abstract and complex nature. Studies by Balan (2018), Knippels (2002), and Mussard and Reiss (2022) highlight those concepts such as gene expression, dominance, and chromosomal inheritance are particularly difficult to teach and learn. Among these, non-Mendelian patterns of inheritance pose persistent

challenges as they require higher-order reasoning, abstraction, and visualization skills. In the Philippine context, research by Santos et al. (2021) and Eviota and Boyles (2022) revealed that Grade 9 learners exhibit low mastery of non-Mendelian inheritance, a concern further compounded by limited instructional time and the lack of suitable learning materials. These challenges are even more pronounced in rural schools, where inadequate internet access, limited educational resources, and minimal exposure to interactive instruction hinder effective genetics learning (Santos et al., 2021; Pacala & Cabrales, 2023).

Strategic Intervention Materials (SIMs) have been recognized as effective tools for addressing these learning gaps by simplifying abstract concepts such as heredity and inheritance through visual, contextualized, and interactive components that bridge theory and practice. To mitigate persistent difficulties, the Department of Education (DepEd Memorandum No. 117, s. 2005) introduced SIMs as specialized remedial materials designed to enhance mastery of least-learned competencies through engaging, learner-centered approaches. Considering the limited access to digital resources in rural settings, the development of a print-based yet interactive SIM offers a promising means to promote inclusivity, engagement, and equitable science education. In this regard, the present study aimed to:

1. Identify the needs of teachers regarding the use of Strategic Intervention Materials in teaching heredity to science 9;

2. Develop an interactive intervention material to address the least mastered competencies in heredity; and

3. Evaluate the developed interactive SIM, entitled “SIMredity,” in terms of content quality, format, presentation, and technical accuracy;

4. Determine the significant difference between the conceptual understanding of learner respondents on Non-Mendelian Genetics before and after the utilization of “SIMredity";

5. Determine the perceptions of the learner respondents regarding the use of “SIMredity".

METHODOLOGY

Research Design

This study employed a mixed-methods approach, utilizing a one-group pretest–posttest design complemented by qualitative data. The learner respondents were exposed to the developed SIMredity, which served as the intervention material. For the qualitative component, feedback, comments, and suggestions from the key informants were collected during the needs assessment, alongside the learner respondents’ perceptions gathered through open ended questions. The one-group pretest–posttest design was deemed appropriate for determining significant differences in learners’ conceptual understanding, as the selected participants demonstrated low mastery levels and performance scores in Non-Mendelian Genetics.

Purposive sampling was used to select the respondents, ensuring that participants were chosen based on specific characteristics relevant to the study. This non-random sampling technique allowed the researcher to focus on individuals who were most representative of the target population and who could provide meaningful insights into the effectiveness of SIMredity.

Research Participants

The needs assessment involved six in-service Science 9 teachers, collectively referred to as the Key Informants, who were surveyed to determine their instructional needs in teaching Non-Mendelian Genetics. The Key Informants were selected based on their current employment as Grade 9 Science teachers and a minimum of three years of teaching experience.

In the development and evaluation of SIMredity, six in-service Science teachers, referred to as the panel of evaluators, assessed the learning material in terms of content, format, presentation and organization, and the

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accuracy and currency of information. Evaluators were selected based on their role as current Science 9 teachers with at least five years of teaching experience.

The learner respondents consisted of thirty-five Grade 9 learners from three sections of Cabalantian National High School. These learners were purposively selected based documented low performance in Non-Mendelian Genetics.

Data Gathering Procedure

The development of the SIMredity on Non-Mendelian Inheritance followed the 4D Model by Thiagarajan, Semmel, and Semmel (1974), which includes the phases Define, Design, Develop, and Disseminate.

Figure 1 4D Model developed by S. Thiagarajan, Semmel, and Semmel (1974)

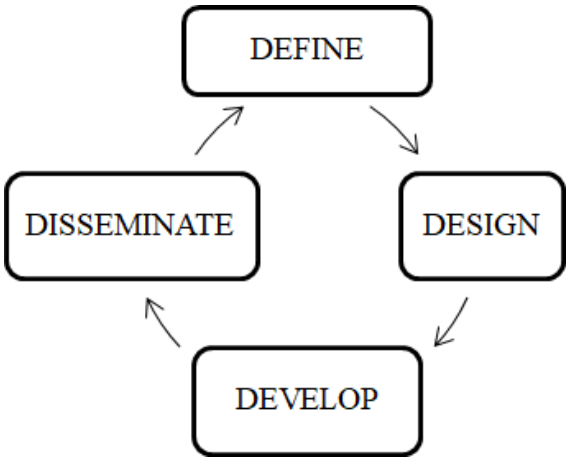

Figure 1 shows the 4D model used in this study. The Define phase involved document analysis and identifying instructional challenges in teaching heredity through a needs assessment, which revealed that the competency "Explain the patterns of Non-Mendelian Inheritance" (S9LT-Id-29) was among the least mastered. The Design phase focused on planning the structure, layout, and content flow of the SIM—later named SIMredity—using the CANVA platform. It featured motivation, story guided activities, exploration, and self-assessment tasks, complemented by visuals and interactive elements to accommodate diverse learners. During the Develop phase, the first version (Draft I) was subjected to face validation by the adviser and panel members. Revision was made based on the comments and suggestions of the adviser and panel members. The revised version (Draft 2) was evaluated by expert science teachers in terms of content quality, format, presentation, and technical accuracy using the Department of Education's Learning Resource Management and Development System (LRMDS) evaluation tool. From the comments and suggestions of the teacher evaluators, the material had undergone final revision. Inter-rater reliability through percentage agreement was done to see how consistent the evaluators' judgments are. Finally, the Disseminate phase involved the implementation of SIMredity with the selected learner respondents. A 30-item pretest was first administered to assess their baseline conceptual understanding. The learners then used SIMredity during 45-minute remedial sessions over a two-week period, and also at home to reinforce learning. Following the intervention, a posttest containing the same questions—rearranged in a different order—was administered to measure changes in understanding. This phase also included the collection of perceptions and feedback from learners who has high scores and low scores in the activities of SIMredity to evaluate its effectiveness.

RESULTS AND DISCUSSIONS

Summary of the Results of the Needs Assessment Interview of the Key Informants

The six (6) in-service grade 9 science teachers were among the respondents in the needs assessment interview. To ensure respondent privacy, the study employed data coding, where ST01, ST02, ST03, ST04, ST05 and

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ST065 referred to the School Science Coordinators Needs Assessment, and ST1, ST2, ST3, ST4, and ST5 stood for the Science Teachers.

From the results of the needs assessment, all teacher respondents (100%) indicated that learners experience difficulty in understanding the different patterns of inheritance of non-Mendelian Genetics, indicating a consistent challenge across classes. The table 4.1.1 below shows the summary of responses of science teachers on their problems encountered in teaching heredity.

Table 1 Summary of responses of the Science Teachers on Problems Encountered in Teaching Heredity

Themes	Codes	Utterances
Problems encountered in teaching Heredity	Difficulty understanding complex heredity concepts	**ST01**: "Some students have difficulty understanding the concepts and patterns of non-mendelian inheritance." **ST02:** "Students struggle with identifying the specific inheritance pattern…...they find it very difficult but willing to learn more… Punnett squares overwhelm them." **ST03:** "One of it was, students struggle in the complexity of the concepts." **ST05:** "They have difficulty in the heredity topic because they lack some science literacy skills." **ST06: "**My students find it difficult to understand heredity because its complex."
	Lack of materials/resources	**ST02:** "Textbooks provide too few examples." **ST03:** "One of it was, students struggle in ……also the inadequate learning resources in our school." **ST04: "**Unavailability of learning materials that are interactive." **ST06: "**Lack of proper learning materials Books are not colored and engaging."
	Limited Time	**ST02:** "Students need more time to understand and solve non-mendelian problems compared to mendelian ones." **ST05:** Limited time also is the problem."

The data from Table 1 show that teachers identified students' difficulty in understanding complex genetic concepts—especially non-Mendelian inheritance—as the main challenge in teaching heredity. This finding aligns with previous studies (Balan, 2018; Mussard & Reiss, 2022) that described genetics as an abstract and conceptually demanding topic. Teachers also pointed to the lack of instructional materials, consistent with Fasasi and Oladejo (2022), who emphasized the importance of visual and hands-on resources for linking theory to real examples. Similarly, Kılıç Mocan (2021) highlighted the value of visual and interactive tools in clarifying abstract genetic ideas, an insight applied in the design of SIMredity. Limited instructional time and resource constraints, particularly in rural schools, were also noted as significant barriers, echoing the observations of Kumar et al. (2020) and Pacala and Cabrales (2023).

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Table 2 Summary of responses of the Science Teachers on Interventions Done to Address the Problems encountered in teaching Non-Mendelian Pattern of Inheritance

Themes	Codes	Utterances
Interventions to Address the Problems	Use of Visual and Interactive Tools	**ST01:** "To aid, I used video lessons and different learning materials." **ST02:** "I use videos or animations to visualize how traits are inherited." **ST03:** "I make sure of utilizing activities and engaging example to foster deeper understanding" **ST04:** "I incorporate interactive activities and videos." **ST05:** "I incorporate….videos and interactive activities." **ST06:** "I used colored learning materials and I used video lessons when discussing."
	General to specific Approach	**ST02:** "begin with simple non-mendelian patterns before moving to complex ones." **ST05:** "I incorporate simple examples, videos and interactive activities."
	Student Centered Approach	**ST02:** "I let the students collaborate on solving genetic problems."

Table 2 reveals that teachers address learning challenges in heredity by using visual and interactive tools such as videos, animations, and activity-based exercises, along with a general-to-specific teaching approach and student-centered learning activities. These strategies are supported by Anwar et al. (2022) and Liu and Lee (2018), who found that interactive and visual materials enhance engagement and understanding of abstract concepts. The use of the general-to-specific method aligns with the constructivist framework (Upu & Bustang, 2016), which emphasizes learning through guided exploration and building on prior knowledge. Collaborative learning strategies reflect Vygotsky's Social Development Theory and are supported by studies (Cordova et al., 2019; Cabildo, 2024) showing that constructivist-based SIMs improve comprehension and retention.

Table 3. Summary of responses of the Science Teachers on Strategic Intervention Material (SIM)

Themes	Codes	Utterances
Familiarity with Strategic Intervention Material (SIM)	Designed Educational Material/Tool	**ST01:** "SIM is a teaching tool design to help learners understand difficult concepts and overcome learning gaps." **ST03:** "SIM is especially designed to help students master concepts and skills they don't usually learn that easy during regular classroom instructions." **ST04:** "SIM are designed to address specific learning gaps and I've found the useful for differentiating instruction and providing support to students who are struggling with certain topic."
	Remedial Material	**ST02:** "I think SIM is a remedial material prepared by teachers to help students with difficulty in understanding the topic."

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		ST05: "It is material used for remediation of learners with least mastered skills."
	Used for reteaching	**ST06**: "SIM is used to reteach difficult or least mastered topics."
Training on SIM	Attended seminars/webinars	**ST01**: "Yes, I learned that SIM can make lessons more engaging and easier to understand when used properly." **ST03**: "yes, I am one of the teacher-participant in the Division level, my insights were SIM purely foster independent learning, provided activities (hands-on) to reinforce and improve academic achievement." **ST04**: "Yes, SIM can help improve the understanding of the students." **ST05**: "yes, it can help in the understanding and engagement of students in learning science."
Benefits of Interactive Strategic Intervention Material	Increased engagement and motivation	**ST02:** "Yes, it is very useful. I think interactive strategic intervention simplifies complex lesson and it helps increases engagement and motivation." **ST05:** "Yes we all know heredity is a complication topic and SIM could make topic engaging ang easy to understand by learners."
	Simplified the lessons	**ST01:** "SIM can simplify the lessons, give visual examples and encourage active learning." **ST02:** "I think interactive strategic intervention simplifies complex lesson and it helps increases engagement and motivation."
	Targeted Learning difficulties	**ST03:** "It is very much useful, much more in this topic (Heredity) because students got to be helped in overcoming specific learning difficulties of heredity topic." **ST06:** "Yes it could really help learner understand better the difficult topics."

The data in Table 3 indicate that teachers are highly familiar with Strategic Intervention Materials (SIMs), viewing them as valuable tools for remediation, reteaching, and simplifying complex lessons to address individual learning needs. This aligns with DepEd Memorandum No. 117 s. 2005 and studies by De Jesus (2019) and Samosa (2021), which highlight SIMs as instruments for bridging learning gaps and supporting differentiated instruction. Teachers' experiences also echoed the findings of Villonez (2018) and Limbago-Bastida and Bastida (2020), who reported significant learning gains from SIM-based instruction. Most teachers had attended SIM-related training, consistent with Herrera and Soriano (2016), emphasizing how such exposure enhances teachers' capacity to create learner-centered materials. They also noted that interactive SIMs increase student motivation and engagement (Pasion, 2019; Acedillo et al., 2022) and support understanding through visual design and simplified structure, in line with Cognitive Load Theory (Sweller, 1988).

Development of Interactive Strategic Intervention Material (SIMredity)

Following the 4D model: Define, Design, Develop, and Disseminate, the SIMredity was carefully designed to include interactive features such as visual simulations, interactive elements and story guided activities that make abstract genetic principles more concrete and meaningful.

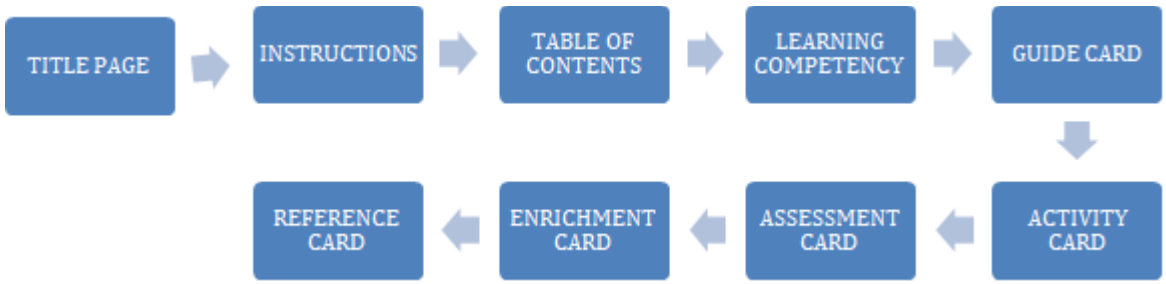

Figure 2. Elements in designing the Interactive Strategic Intervention Material (SIMredity)

Figure 2 presents the elements involved in designing the Interactive Strategic Intervention Material (SIMredity) based on the DepEd (2009) framework for developing instructional materials. This sequential structure ensures that the material follows the prescribed pedagogical flow — from orientation to application — designed to facilitate both independent and guided learning. Each component of the SIM performs a specific instructional function that supports the learner's gradual mastery of the targeted competency on the Non-Mendelian Patterns of Inheritance.

Figure 3 Sample of Initial Design of SIMredity (Draft I)

Figure 3. shows the initial design of the developed Interactive Strategic Intervention Materials (CSIM) on Heredity – Different Pattern of Non-Mendelian Inheritance. The content of the interactive SIM follows the elements in designing the SIM from DepEd (2009). It integrates storytelling missions, and guided problem-solving activities to foster learner engagement and conceptual understanding.

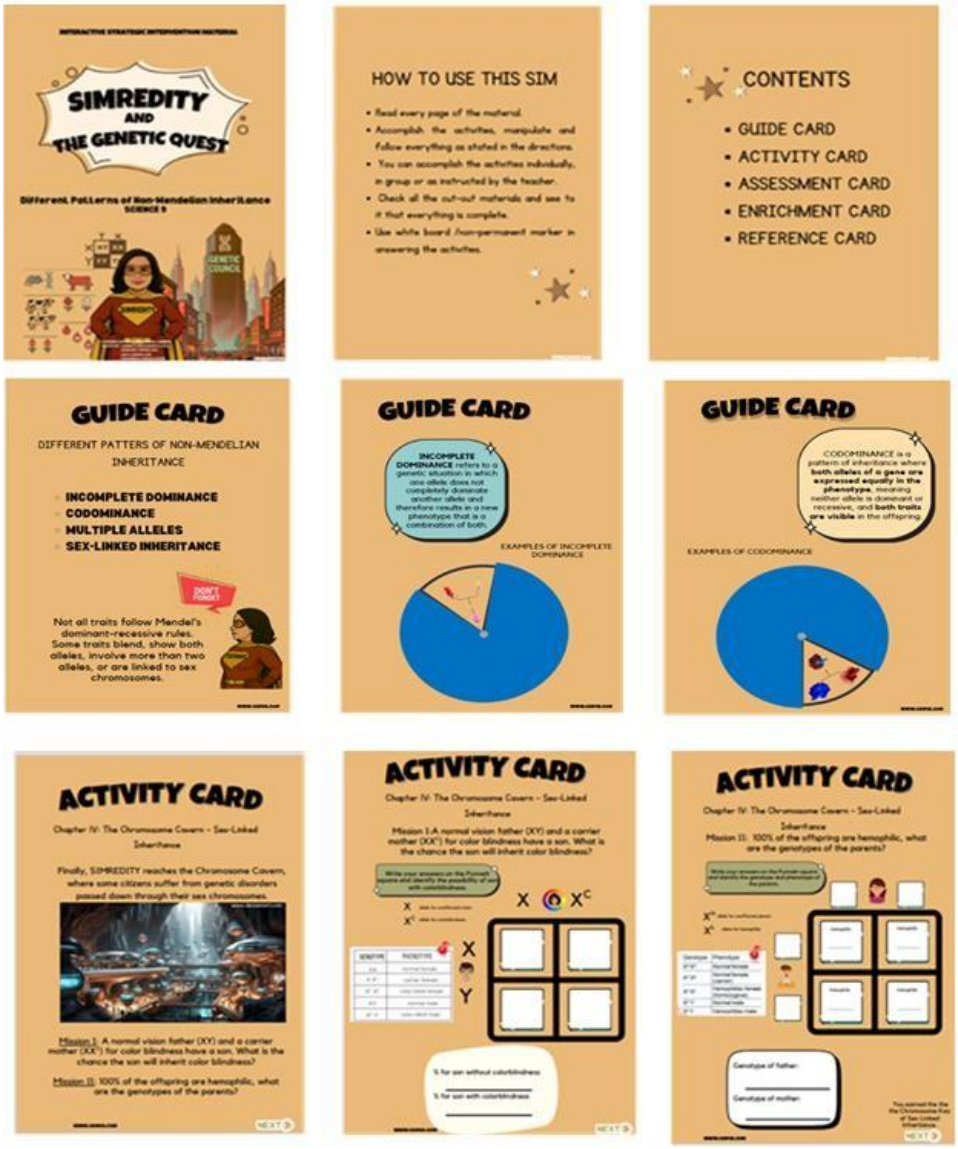

Figure 4. Sample of SIMredity (Final Version)

Figure 4 shows the final material of the Developed Interactive Strategic Intervention Materials (SIMredity) on Different Patterns of Non-Mendelian Inheritance. All the comments and suggestions coming from the Thesis adviser, Panel members and evaluators were incorporated.

Evaluation of the SIMredity

Table 4 Evaluator's Rating of the SIMredity based on DepEd-LRDMS Evaluation Tool

Components	Mean	Description
Factor 1: Content	3.84	Very satisfactory
Factor 2: Format	3.92	Very satisfactory
Factor 3. Presentation and Organization	3.97	Very satisfactory
Factor 4. Accuracy and Up-to-datedness of Information	3.94	Very satisfactory

Legend (factors 1-3): 1.00-1.74 (not satisfactory); 1.75-2.49 (poor); 2.50-3.24 (satisfactory); 3.25-4.00 (very satisfactory)

Table 4 presents the ratings of the evaluators on the developed SIMredity. The content quality received a mean rating of 3.84 indicating that the content of the game is consistent with the topics found in the learning competencies of the Department of Education. The content is also found to be relevant, promotes critical thinking, and helps in the mastery of learning objectives. The Format category received high ratings with 3.92, reflecting the clarity, consistency, and aesthetic quality of the material. Evaluators commended the interactive design, use of visual aids, and color-coded sections that facilitated easy navigation. The Presentation and Organization component also garnered "Very Satisfactory" ratings with a mean of 3,97. Evaluators observed that lessons were logically sequenced, progressing from simple to complex concepts. Accuracy and up-to-datedness scored 3.83, with no significant conceptual, factual, grammatical, or computational errors, confirming the quality and effectiveness of the materials. The four components in the DepED-LRDMS evaluation tool were itemize into thirty-six subcomponents which was used in computing the percentage agreement among the evaluators.

Table 5. Percentage Agreement of Evaluators on the Developed SIMredity

Category	Number of components with Full Agreement	Total Number of Components	Percentage Agreement (%)
4 (Very Satisfactory, VS)	26	36	72.2
3 (Satisfactory, S)	1	36	2.8
2 (Poor)	0	36	0
1 (Not Satisfactory, NS)	0	36	0

The percentage agreement among the six evaluators indicates that 72.2% of the components in the evaluation tool were unanimously rated as Very Satisfactory (VS), showing strong consistency in recognizing high-quality responses. Only 2.8% of the components were fully agreed upon as Satisfactory (S), and no items were fully agreed upon as Poor or Not Satisfactory. This demonstrates that most components in the evaluation tool were clearly understood and consistently scored, although some variability existed for lower-rated responses.

Table 6 Summary of evaluators' suggestion for improvement

Aspect	Suggestions
Content	ST01: "Make a guide for genotype and phenotype for activity in Chapter IV."
Format	ST01: "Make the wheel of examples and images big enough to be clearly seen."
Presentation	ST03: "Change the background image of the cover page where it can indicate the topic or lesson even without looking at the title of the SIM."

Table 6 presents the evaluators' suggestions for improving SIMredity across content, format, and presentation aspects. These suggestions were considered valuable inputs for refining the overall quality and usability of the material.

Conceptual Understanding of Learners in non-Mendelian Genetics

Table 7 Pretest and Post test scores of the Leaner Respondents

		PRE- TEST		POST TEST		DESCRIPTION
SCORE RANGE	EQUIVALENT PERCENTAGE SCORE	FREQUENCY	%	FREQUENCY	%	

28-30	90-100	0	0	0	0	Outstanding
26-27	85-89	0	0	2	6	Very Satisfactory
24-25	80-84	0	0	3	9	Satisfactory
22-23	75-79	0	0	13	37	Fairly Satisfactory
Below 21	Below 75	35	100	17	48	Did not meet the Expectations

Legend: Outstanding = 90-100, Very Satisfactory= 85-89, Satisfactory= 80-84, Fairly Satisfactory=75-79, Did meet the Expectations = Below 75

Table 7 presents a comparison of learner performance before (pre-test) and after (post-test) the implementation of the SIMredity, categorized by score ranges, frequency percentage and descriptors. Before the use of SIMredity, all 35 learners (100%) scored below 75%, indicating that none met the expected level of mastery. After the intervention, learner performance improved notably—48% still scored below 75%, but 37% reached the Fairly Satisfactory level, 9% achieved Satisfactory scores, and 6% attained Very Satisfactory performance. Although no learner reached the Outstanding range, the overall results reflect a marked improvement in understanding and mastery.

While nearly half of the learners continued to struggle, 52% demonstrated progress by moving to higher performance categories. This indicates that SIMredity effectively enhanced learners' comprehension of the topic, resulting in improved achievement, though additional reinforcement is still needed to help all learners attain mastery.

Table 8 Paired Sample Test of Pretest and Post test

Group	Mean	t-statistics	P value	Remark
Pre- test	9	-22.21	<0.001	Significant
Post- test	21			

Table 8 shows paired t-test results indicate a significant improvement in learners' performance, with the mean score rising from 9 in the pre-test to 21 in the post-test. The t-statistic of -22.21 and a p-value of less than 0.001 confirm that this difference is statistically significant, demonstrating that the increase in scores after using SIMredity was not due to chance and that the intervention had a meaningful positive effect on learner achievement.

Table 9. Qualitative Feedback from Learners with High Scores on the Developed SIMredity

Theme	Codes	Utterances
1. Ease of Learning and Understanding	The SIM helped simplify complex heredity concepts	- "They helped me understand the topic because it is easy." (TS02, TS03, TS04) - "The SIM is colorful. I can manipulate the activities." (TS01)
2. Interactivity and Manipulative Learning	Hands-on and participatory activities promoted understanding	- "The most engaging aspect is the activities that I can hold." (TS01) - "It has interactive activity that I can hold." (TS03) - "I can manipulate my answers." (TS05)
3. Engaging and Enjoyable Features	Colorful visuals, stories, and games increased interest	- "The SIM is colorful." (TS01) - "I like the story and activities." (TS05) - "I like the superhero story." (TS03, TS04)

4. Identified Challenges and Difficult Sections	Some topics and activities were difficult to grasp	- "The challenging part is the puzzle part." (TS01, TS05) - "Chapter III – The Blood Labyrinth: Multiple Alleles." (TS04) - "Chapter IV part about the sex-linked inheritance." (TS03)
5. Independent and Self-Paced Learning	Students valued being able to use the SIM at home	- "I can bring it at home. I also enjoy the story and answering at home." (TS03, TS04)

The analysis on the table 9 reveals that students with high scores perceived the developed SIMredity as easy to understand, interactive, and enjoyable, highlighting its potential to enhance learning in heredity. However, some challenging parts (e.g., puzzles and chapters on Multiple Alleles and Sex-linked Inheritance) suggest a need for further simplification. Students also appreciated that the SIMredity encouraged independent learning, allowing them to study at their own pace outside the classroom.

Table 10. Qualitative Feedback from Learners with Low Scores on the Developed SIMredity

Theme	Codes	Utterances
1. Ease of Learning and Understanding	The SIM helped make complex genetic concepts easier to understand through simple, engaging content.	- "The SIM is colorful. The activities are simple." (BS01) - "I enjoy answering the activities. I like the superhero story." (BS02) - "The activities are interactive and I enjoyed it." (BS03)
2. Interactivity and Manipulative Learning	Hands-on and manipulative parts such as the Punnett square and wheel of example promoted active participation.	- "I like the Punnett square part where I can hold the material." (BS01) - "I like the Punnett square where I can manipulate the answer." (BS02) - "The most engaging is the wheel of example and the Punnett square part." (BS03) - "The most engaging is the activities that I can hold." (BS05)
3. Visual and Story-Based Engagement	The use of visuals and superhero storytelling increased motivation and interest in the topic.	- "The SIM is colorful not like the books in the school." (BS05) - "The SIM is interactive and I enjoyed the story." (BS04) - "I like the superhero story." (BS02)
4. Learning Challenges in Specific Content	Learners found certain parts, especially Chapter 4, difficult to grasp.	- "The challenging part is Chapter 4." (BS01–BS05) - "The difficult part is Chapter 4 and puzzle." (BS02, BS03, BS05)
5. Difficulty with Puzzle and Enrichment Activities	Puzzle-based and enrichment activities were engaging but required clearer guidance.	- "The challenging part is puzzle and Chapter 4." (BS01, BS04) - "The puzzle or enrichment." (BS04)

Table 10 shows the analysis of learners' responses on SIMredity revealed that it effectively facilitated understanding of Non-Mendelian Patterns of Inheritance through its organized, colorful, and story-based design. Learners with low scores in SIMredity activities appreciated the hands-on and manipulative activities, such as the Punnett square and example wheels, which promoted active learning and retention of complex concepts. The superhero storyline and visual elements increased motivation and engagement, making the material more relatable and enjoyable. However, learners reported challenges with Chapter 4 content and certain puzzle and enrichment activities, indicating a need for clearer instructions and additional scaffolding.

CONCLUSION

The development and implementation of SIMredity successfully addressed the persistent learning difficulties of Grade 9 students in non-Mendelian genetics. Through the systematic application of the 4D model, the material

was carefully designed, refined, and validated to ensure pedagogical soundness, accuracy, and learner-centered features. Expert evaluation confirmed that SIMredity met the standards of quality instructional materials, receiving Very Satisfactory ratings across all DepEd LRMDS evaluation tool components and demonstrating consistency among evaluators. Findings from the one-group pretest–posttest design revealed a significant improvement in learners' conceptual understanding, validating the material's effectiveness as an instructional intervention. Learners reported that SIMredity's colorful visuals, interactive elements, and story-based activities made abstract genetic concepts more engaging and easier to understand, while also supporting independent and self-paced learning. Despite some challenges noted in complex sections such as the sex-linked traits and puzzle enrichment section, the overall positive impact indicates that SIMredity is an effective, validated and high-quality tool, especially in rural schools with limited digital resources. The study concludes that interactive, print-based Strategic Intervention Materials can meaningfully enhance students' mastery of difficult science concepts.

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