



Level of Conceptual Understanding and Genetic Misconceptions of Grade 12 STEM Students: A Basis for a Proposed Genetics Misconception Remediation Worksheet (GMRW)

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ABSTRACT

This study determined the level of conceptual understanding and genetic misconceptions among Grade 12 STEM students and served as the basis for a proposed Genetics Misconception Remediation Worksheet (GMRW). The study employed a quantitative descriptive-comparative research design involving Grade 12 STEM students selected through simple random sampling. Data were gathered using a researcher-made Genetics Conceptual Understanding and Misconception Test (GCUMT) with a Certainty of Response Index (CRI). Findings revealed that students generally understood genetics concepts but demonstrated misconceptions in molecular genetics, DNA replication, protein synthesis, and genetic engineering. Based on the findings, a remediation worksheet was proposed to address identified misconceptions and improve conceptual understanding in genetics

INTRODUCTION

Genetics is an essential field of biology that explains how traits are inherited and expressed in living organisms. It plays a critical role in understanding heredity, evolution, and modern applications such as genetic engineering and personalized medicine. Since the foundational work of Gregor Mendel, genetics has become a core component of science education. In the Philippine K-12 curriculum, genetics is taught in Senior High School biology subjects to develop students' understanding of heredity and genetic variation. Scientific literacy, which includes genetics literacy, is necessary for students to make informed decisions about health and biotechnology (Organisation for Economic Co-operation and Development [OECD], 2023). According to Dougherty et al. (2021), genetics literacy enables individuals to understand genetic information and apply it in real-world contexts.

Understanding genetics is fundamental to the study of biology because it explains how traits are inherited and expressed in living organisms. Consequently, developing a strong understanding of genetic concepts is considered an important component of scientific literacy (Cary & Branchaw, 2017, as cited in Rusmana et al., 2021). Despite its importance, genetics remains one of the most difficult biology topics for students to master. The subject involves abstract and microscopic processes that cannot be directly observed, which increases cognitive demands on learners. Studies show that students develop misconceptions about genes, chromosomes, DNA, and inheritance (Walter et al., 2021). Misconceptions are persistent incorrect beliefs that differ from scientifically accepted explanations and may interfere with meaningful learning (Todd & Romine, 2022). Additionally, enhancing students' understanding of genetics requires greater attention within the educational system because the concepts involved are complex and often difficult for learners to grasp (Duncan & Reiser, 2007, as cited in Rusmana et al., 2021).

Recent research has shown that students commonly believe that dominant traits are stronger than recessive traits, that genes alone determine traits without environmental influence, and that acquired characteristics can be inherited (Opfer et al., 2022). These misconceptions may result from abstract concepts, ineffective teaching strategies, and prior knowledge (Tibell & Rundgren, 2020). If misconceptions are not corrected, they may persist and affect future learning (Dougherty et al., 2021). Therefore, it is important to identify genetic misconceptions among senior high school students.

Although previous studies have identified the students' misconceptions in genetics and related biological concepts, research continues to affirm the fact that misconceptions concerning genetics are common among secondary school students. For instance, studies conducted on the conceptual understanding of genetics concepts by students revealed that the majority of the students only have fragmented knowledge of genetics information, which makes them lack the ability to integrate the concepts of genes, DNA, and inheritance into a scientific explanation. The fragmented knowledge, therefore, contributes to the formation of misconceptions that are common among students (Machová et al., 2023). In addition, research studies have shown that a majority of secondary school

students lack a conceptual understanding of genetics, with the majority of the students being characterized by misconceptions, even after the topic is taught (Ojo, 2024).

Recent literature has also highlighted that genetics is a subject that is most prone to misconceptions due to the abstract ideas, complex scientific terminology, and processes that occur at microscopic levels that cannot be directly observed. These characteristics make genetics difficult for learners to conceptualize and often lead to incorrect interpretations of genetic phenomena (Maysyaroh et al., 2025). Moreover, misconceptions in biology education have been identified as major barriers to students' ability to apply scientific knowledge effectively, thereby hindering meaningful learning and scientific literacy development (Guerra-Reyes, 2024).

Despite the growing body of literature on genetics misconceptions, most existing studies have focused on identifying misconceptions among general secondary students or university learners in different educational contexts. There remains limited research that quantitatively examines the prevalence and nature of genetic misconceptions among Senior High School students within specific curriculum frameworks. Therefore, further investigation is necessary to identify the common genetic misconceptions held by Senior High School STEM students. Consequently, this study aims to determine the genetic misconceptions and level of conceptual understanding among STEM students. The findings of this study will serve as a basis for proposing a Genetics Misconception Remediation Worksheet (GMRW) that may help address the identified learning gaps and improve students' conceptual understanding. Specifically, this study sought to determine the students' level of conceptual understanding in genetics, identify common misconceptions, and propose a Genetics Misconception Remediation Worksheet (GMRW) based on the findings.

THEORETICAL REVIEW

Constructivist Learning Theory

Constructivist Learning Theory explains that learners actively construct knowledge based on prior experiences and existing ideas. According to constructivist perspectives, misconceptions arise when learners interpret new information using incomplete or incorrect prior knowledge. Recent studies in science education emphasize that learners develop scientific understanding through active engagement, reflection, and interaction with learning experiences rather than passive reception of information (Guerra-Reyes, 2024). In genetics education, students often develop misconceptions because genetics concepts involve abstract and microscopic processes that are difficult to visualize. Research further suggests that misconceptions persist when students are unable to connect new scientific explanations with their prior understanding (Machová & Ehler, 2023). The theory therefore supports the importance of identifying students' misconceptions and designing remediation activities that allow learners to reconstruct scientifically accurate understanding.

Conceptual Change Theory

Conceptual Change Theory explains how learners replace misconceptions with scientifically accepted concepts through guided instruction and reflective learning. The theory posits that conceptual change occurs when learners recognize inconsistencies between their existing misconceptions and scientifically accepted explanations. Contemporary studies in biology education emphasize that conceptual change strategies are effective in addressing persistent misconceptions in genetics and molecular biology (Todd & Romine, 2022). Similarly, Ojo (2024) reported that students' misconceptions in genetics may be reduced through instructional interventions that encourage conceptual clarification and reflective thinking. In the context of this study, the proposed Genetics Misconception Remediation Worksheet (GMRW) aims to promote conceptual change through clarification activities, guided exercises, visual representations, and reflective learning tasks that encourage students to re-evaluate their existing understanding of genetics concepts.

Genetics Literacy

Genetics literacy refers to the ability to understand and apply genetics concepts in real-world situations. Genetics literacy is considered an important component of scientific literacy because genetics concepts influence decision-making related to health, heredity, and biotechnology. According to the Organisation for Economic Co-operation and Development (OECD, 2023), scientific literacy enables individuals to engage critically with scientific issues and make evidence-based decisions. Dougherty et al. (2021) further emphasized that genetics literacy allows individuals to understand genetic information and apply genetics-related knowledge in practical contexts. However, misconceptions in genetics may negatively affect students' scientific reasoning and conceptual understanding. The present study is therefore anchored on the idea that conceptual understanding and misconceptions significantly influence students' genetics literacy and their ability to understand genetics-related phenomena scientifically.

Conceptual Change Framework

The study is anchored in the Conceptual Change Framework, which explains how learners replace misconceptions with scientifically accepted concepts through reflective learning and instructional intervention. Conceptual change occurs when students recognize inconsistencies between their existing knowledge and scientific explanations, leading them to reconstruct their understanding of concepts. Recent studies in science education emphasize that misconceptions in biology and genetics persist because students often rely on fragmented prior knowledge and intuitive reasoning when interpreting abstract scientific concepts (Machová & Ehler, 2023). Genetics concepts are particularly prone to misconceptions due to their abstract nature, complex terminology, and microscopic processes that cannot be directly observed (Maysyaroh et al., 2025). Moreover, research has shown that identifying misconceptions is essential in designing targeted remediation strategies that promote meaningful learning and improve conceptual understanding among students (Guerra-Reyes, 2024). Therefore, the present study utilized the Conceptual Change Framework to explain how the identification of students' misconceptions through the Genetics

Conceptual Understanding and Misconception Test (GCUMT) and Certainty of Response Index (CRI) served as the basis for developing the proposed Genetics Misconception Remediation Worksheet (GMRW).

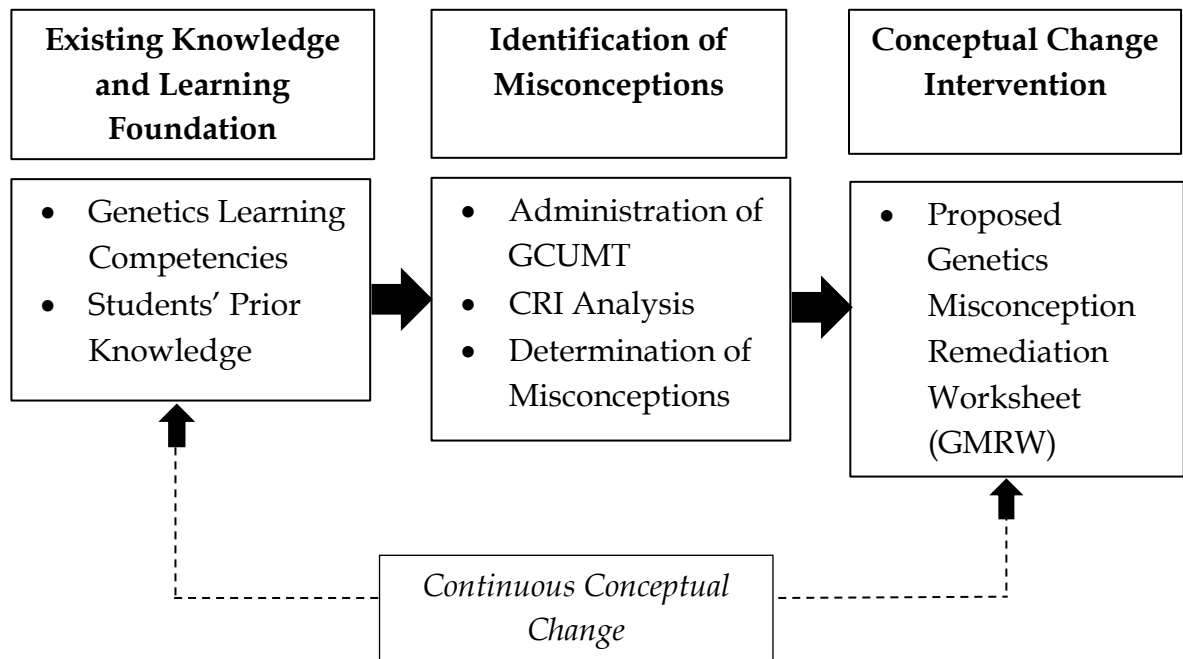


Figure 1. Conceptual Change Framework of the Study

METHODOLOGY

This study employed a quantitative descriptive research design to determine the level of conceptual understanding and common misconceptions in genetics among Grade 12 STEM students. Quantitative methods allow the systematic collection and analysis of numerical data, making them appropriate for assessing students' conceptual understanding and identifying misconceptions (Creswell & Creswell, 2023). The descriptive approach was utilized to describe the students' level of conceptual understanding and determine the misconceptions commonly held in genetics. Descriptive research is appropriate when the purpose of the study is to identify and describe characteristics, trends, and conditions within a population (McCombes, 2023).

The respondents of the study consisted of Grade 12 Senior High School students enrolled in the STEM strand. Grade 12 STEM students were selected because they had already completed Biology 1 and were currently taking Biology 2, where genetics concepts are introduced and reinforced. Their prior and ongoing exposure to biology content made them appropriate participants for assessing conceptual understanding and misconceptions in genetics. The total population of the study consisted of 332 Grade 12 STEM students. To determine the appropriate sample size, the researcher utilized the Raosoft Sample Size Calculator (Raosoft Inc., 2004) using a 95% confidence level, 5% margin of error, and 50% response distribution. The use of appropriate sample size estimation procedures is supported in methodological literature to ensure the reliability and

generalizability of findings (Memon et al., 2020). Based on these parameters, the computed sample size was 152 respondents. Simple random sampling was employed to ensure that each member of the population had an equal chance of being selected, thereby minimizing bias and improving the representativeness of the sample (Creswell & Creswell, 2023).

The study utilized a researcher-made Genetics Conceptual Understanding and Misconception Test (GCUMT) designed to assess students’ conceptual understanding and identify possible misconceptions in genetics. The development of the instrument was guided by the learning competencies in the Senior High School General Biology 2 curriculum, particularly topics on patterns of inheritance, central dogma and DNA, and genetic engineering (Department of Education, 2020). The instrument was also informed by studies identifying common misconceptions in genetics, including misunderstandings related to gene–DNA–chromosome relationships and inheritance patterns (Machová & Ehler, 2023; Ojo, 2024). The GCUMT consisted of 30 multiple-choice items with four options and one correct answer. The instrument was complemented by the Certainty of Response Index (CRI) adopted from Hasan et al. (1999), as cited in Duda et al. (2021) and Ojo (2024), which measured students’ confidence levels in answering each item. The identification of students’ misconceptions was based on the Certainty of Response Index (CRI), which determines the respondents’ level of confidence in answering each test item, as shown in Table 1. The classification of students as having conceptual understanding, misconceptions, or a lack of understanding was based on the CRI interpretation criteria shown in Table 2.

Table 1. CRI Scores (Certainty of Response Index) and the Criteria

<i>CRI</i>	<i>CRITERIA</i>
0	totally guessed
1	almost guessed
2	not sure
3	sure
4	almost certain/ almost confident
5	certain/confident

Table 2. The Criteria of CRI Conditions for Students' Answers

Answer criteria	Low CRI (CRI < 2.5)	High CRI (CRI > 2.5)
Correct Answer	Correct answer, but CRI is low means do not know understand concepts	Correct answer and CRI high, means understand concepts
Wrong Answer	Wrong answer but CRI is low means do not understand concepts	Wrong answer & high CRI means a misconception

Incorrect answers with high confidence were interpreted as misconceptions, while correct answers with high confidence indicated conceptual understanding. Recent studies support the use of CRI in distinguishing misconceptions from lack of knowledge (Maysyaroh et al., 2025; Duran, 2024).

To establish validity, the instrument underwent content and face validation by biology educators, science teachers, and research specialists. A Table of Specifications (TOS) was also prepared to ensure alignment between the test items and the learning competencies in the curriculum. After validation, the instrument was pilot-tested among Grade 12 STEM students who were not included in the actual study. Reliability testing using Cronbach's alpha yielded a coefficient of 0.93, indicating excellent internal consistency and reliability of the instrument. Recent studies emphasize that validity and reliability testing are essential in establishing the psychometric quality of educational research instruments (Ramírez-Montoya et al., 2024).

Prior to data gathering, the researcher secured the necessary permissions from the school administration and informed the respondents about the purpose of the study. Participation was voluntary, and informed consent was obtained from the respondents. Confidentiality, anonymity, and proper handling of the gathered data were strictly observed throughout the conduct of the study. The collected data were analyzed using frequency counts, percentages, mean percentage scores, and the Certainty of Response Index (CRI) to determine students' conceptual understanding and identify misconceptions in genetics.

RESULTS

This section presents the findings of the study regarding the level of conceptual understanding and genetic misconceptions among Grade 12 STEM students. The results were organized according to the objectives of the study, specifically the students' level of conceptual understanding in genetics, the identification of misconceptions using the Certainty of Response Index (CRI), and the proposed Genetics Misconception Remediation Worksheet (GMRW).

Table 3. Distribution of Questions According to Topics and Learning Competencies

Topics	Learning Competencies	Question Number
Patterns of Inheritance	Predict genotypes and phenotypes of parents and offspring using the laws of inheritance;	Nos. 1, 2, 3, 4, 5, 6, 7, 8
	Describe modifications to Mendel's classic ratios (gene interaction)	Nos. 9, 10, 11, 12, 13
Central Dogma and DNA	Illustrate the molecular structure of DNA, RNA, and proteins	Nos. 14, 15, 16, 17, 18
	Diagram the steps in DNA replication and protein synthesis	Nos. 19, 20, 21, 22, 23
Genetic Engineering	Outline the processes involved in genetic engineering	Nos. 24, 25, 26, 27, 28, 29, 30

Table 3 presents the distribution of the test questions according to the identified genetics topics and learning competencies included in the Senior High School General Biology 2 curriculum. The organization of the test items ensured alignment between the assessment instrument and the intended curriculum competencies. The table further shows that the instrument covered major genetics topics, including inheritance, molecular genetics, and genetic engineering, which allowed the researcher to identify areas where students demonstrated conceptual understanding and misconceptions.

Table 4. Data of the Percentage on the Level of Conceptual Understanding in Genetics of Grade 12 STEM Students

Topics	Learning Competencies	Question Number	Average Percentage of Correct Responses	Interpretation
Patterns of Inheritance	Predict genotypes and phenotypes of parents and offspring using the laws of inheritance;	Nos. 1, 2, 3, 4, 5, 6, 7, 8	88.17%	Understands Concepts
	Describe modifications to Mendel's classic ratios (gene interaction)	Nos. 9, 10, 11, 12, 13	78.92%	Understands Concepts
Central Dogma and DNA	Illustrate the molecular structure of DNA, RNA, and proteins	Nos. 14, 15, 16, 17, 18	89.03%	Understands Concepts
	Diagram the steps in DNA replication and protein synthesis	Nos. 19, 20, 21, 22, 23	64.52%	Moderately Understands Concepts
Genetic Engineering	Outline the processes involved in genetic engineering	Nos. 24, 25, 26, 27, 28, 29, 30	82.95%	Understands Concepts

Overall	80.72%	Understands Concepts
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Legend for Interpretation	
Percentage Range	Interpretation
90–100%	Highly Understands Concepts
75–89%	Understands Concepts
50–74%	Moderately Understands Concepts
Below 50%	Poor Understanding of Concepts

Adapted from from Ojo (2024) and the researcher's interpretation scale.

Table 4 presents the percentage on the level of conceptual understanding in genetics among Grade 12 STEM students. The findings revealed that the respondents generally demonstrated conceptual understanding in genetics, with an overall average percentage of 80.72%, interpreted as “Understands Concepts.” Among the identified topics, the highest conceptual understanding was observed in DNA Structure and Proteins with 89.03%, followed by Patterns of Inheritance with 88.17%. Meanwhile, the lowest level of conceptual understanding was observed in DNA Replication and Protein Synthesis with 64.52%, interpreted as “Moderately Understands Concepts.” The findings suggest that students experienced greater difficulty in understanding abstract molecular genetics processes compared to observable inheritance patterns.

Table 5. Genetic Misconceptions of Grade 12 STEM Students Based on CRI Analysis

Question Number	Correct Responses	Correct Response CRI	Incorrect Responses	Incorrect Response CRI	Interpretation
1	83	4.27	10	2.90	Misconception Present
2	79	3.92	14	2.79	Misconception Present
3	89	3.63	4	2.00	Understands Concepts
4	77	3.90	16	2.44	Lack of Understanding
5	72	3.72	21	2.76	Misconception Present
6	86	4.10	7	3.00	Misconception Present
7	86	3.76	7	—	Understands Concepts
8	86	3.45	7	2.14	Lack of Understanding

9	67	3.30	26	2.38	Lack of Understanding
10	82	3.72	11	2.18	Lack of Understanding
11	71	3.94	22	2.45	Lack of Understanding
12	60	3.73	33	3.85	Misconception Present
13	84	3.01	9	1.67	Understands Concepts
14	85	3.96	8	2.63	Misconception Present
15	89	4.42	4	3.00	Misconception Present
16	89	3.83	4	3.00	Misconception Present
17	62	3.44	31	3.00	Misconception Present
18	93	3.70	0	—	Understands Concepts
19	48	3.27	45	1.87	Lack of Understanding
20	70	3.29	23	1.30	Lack of Understanding
21	56	2.93	37	1.78	Lack of Understanding
22	61	3.10	32	2.19	Lack of Understanding
23	65	3.34	28	2.75	Misconception Present
24	91	3.96	2	1.50	Understands Concepts
25	66	3.58	27	3.11	Misconception Present
26	76	3.67	17	2.53	Misconception Present
27	71	2.94	22	1.41	Lack of Understanding
28	84	3.56	9	2.44	Lack of Understanding
29	75	3.55	18	2.67	Misconception Present
30	73	3.89	20	2.35	Lack of Understanding

Table 5 presents the identified misconceptions of Grade 12 STEM students based on the Certainty of Response Index (CRI) analysis. The findings revealed that several misconceptions were evident among the respondents, particularly in topics related to modified Mendelian inheritance, DNA structure, protein synthesis, and genetic engineering. The presence of incorrect answers with high confidence levels indicated that students possessed firmly held misconceptions rather than mere lack of knowledge. The results further suggest that students may struggle in connecting abstract molecular genetics concepts with scientific explanations, leading to scientifically inaccurate interpretations.

Table 6. Proposed Genetics Misconception Remediation Worksheet

Proposed Genetics Misconception Remediation Worksheet (GMRW)	
Target Learners	Grade 12 STEM Students
Basis of the Proposed Worksheet	Findings of the study on the level of conceptual understanding and genetic misconceptions of Grade 12 STEM students
General Objective	To provide remediation activities that may help address the identified misconceptions and learning difficulties in genetics
Topic 1	Patterns of Inheritance and Gene Interaction
Identified Misconceptions	Misconceptions on dominant and recessive traits, genotype and phenotype prediction, and modified Mendelian inheritance
Proposed Remediation Activities	Guided Punnett square exercises, illustration analysis, concept mapping, and misconception correction activities
Learning Materials	Punnett square charts, inheritance diagrams, guided worksheets
Expected Output	Improved understanding of inheritance patterns and gene interaction
Topic	DNA Structure and Molecular Genetics
Identified Misconceptions	Confusion among DNA, genes, chromosomes, and proteins
Proposed Remediation Activities	Labeling activities, molecular structure diagrams, matching exercises, and concept clarification tasks
Learning Materials	DNA models, labeled diagrams, visual organizers
Expected Output	Better understanding of the relationship among DNA, genes, chromosomes, and proteins
Topic	DNA Replication and Protein Synthesis
Identified Misconceptions	Difficulty understanding replication, transcription, and translation processes
Proposed Remediation Activities	Sequencing activities, flowchart completion, codon translation exercises, and guided discussions
Learning Materials	Flowcharts, process diagrams, codon charts

Expected Output	Improved conceptual understanding of DNA replication and protein synthesis
Topic	Genetic Engineering
Identified Misconceptions	Misunderstanding of genetic engineering processes and biotechnology applications
Proposed Remediation Activities	Case analysis, biotechnology application activities, diagram interpretation, and concept mapping
Learning Materials	Biotechnology illustrations, process flowcharts, activity sheets
Expected Output	Enhanced understanding of genetic engineering concepts and applications

Table 6 presents the proposed Genetics Misconception Remediation Worksheet (GMRW) developed based on the findings of the study regarding the conceptual understanding and genetic misconceptions of Grade 12 STEM students. The proposed worksheet is intended to serve as a supplementary remediation material that may help address the identified misconceptions and learning difficulties in genetics. The development of remediation activities was anchored on the identified misconceptions revealed through the Certainty of Response Index (CRI) analysis and the students' level of conceptual understanding. The proposed Genetics Misconception Remediation Worksheet (GMRW) aims to help reduce students' misconceptions and strengthen their conceptual understanding in genetics through targeted remediation activities aligned with the identified learning gaps in the study.

DISCUSSION

The findings revealed that Grade 12 STEM students generally demonstrated an acceptable level of conceptual understanding in genetics. Students showed strong understanding in topics related to Mendelian inheritance, DNA structure, and genetic engineering. However, students experienced greater difficulty in understanding DNA replication and protein synthesis. The lower conceptual understanding in these topics may be attributed to the abstract and microscopic nature of molecular genetics concepts. Tibell and Rundgren (2020) explained that molecular biology concepts are difficult for students to visualize because they occur at microscopic levels that cannot be directly observed.

The presence of misconceptions among students further supports previous studies indicating that genetics is one of the most misconception-prone areas in biology education. Misconceptions identified in the present study involved dominant and recessive traits, modified Mendelian inheritance, DNA structure, protein synthesis, and genetic engineering. Similar findings were reported by Ojo (2024), who found that secondary school students continued to demonstrate misconceptions in genetics even after instruction.

The misconceptions observed in DNA replication and protein synthesis may result from students' fragmented understanding of molecular processes.

According to Machová and Ehler (2023), students often fail to connect the relationships among DNA, genes, chromosomes, and proteins, leading to scientifically inaccurate interpretations.

The findings also support Constructivist Learning Theory, which explains that misconceptions develop from learners' prior knowledge and experiences. Students may construct incorrect explanations when abstract concepts are not effectively clarified through instruction. Likewise, Conceptual Change Theory emphasizes the importance of remediation activities in helping learners replace misconceptions with scientifically accepted concepts.

Based on the identified misconceptions, the proposed Genetics Misconception Remediation Worksheet (GMRW) was developed to strengthen students' conceptual understanding through guided activities, visual learning materials, concept clarification, and reflective learning tasks. Guerra-Reyes (2024) emphasized that targeted remediation strategies may help reduce misconceptions and improve meaningful learning in science education.

CONCLUSIONS AND RECOMMENDATIONS

The study determined the level of conceptual understanding and genetic misconceptions among Grade 12 STEM students. Findings revealed that students generally demonstrated an acceptable level of conceptual understanding in genetics. However, misconceptions remained evident in several complex and abstract areas of genetics, particularly DNA replication, protein synthesis, and molecular genetics.

The study further revealed that misconceptions persisted even among students who demonstrated confidence in their responses. These misconceptions may hinder meaningful learning and scientific literacy development if not properly addressed.

Based on the findings, the study proposed a Genetics Misconception Remediation Worksheet (GMRW) to help address misconceptions and improve conceptual understanding among students.

The following recommendations are proposed:

1. Science teachers may utilize remediation activities and visual learning strategies to address misconceptions in genetics.
2. Schools may consider using the proposed GMRW as supplementary instructional material.
3. Teachers may incorporate learner-centered strategies such as concept mapping, simulations, and guided discussions.
4. Future researchers may evaluate the effectiveness of the proposed GMRW through intervention studies.
5. Future studies may include larger samples and respondents from different educational settings.

FURTHER STUDY

This study focused only on Grade 12 STEM students and selected genetics topics included in the Senior High School General Biology 2 curriculum. The findings may therefore be more applicable to STEM learners and may not fully represent students from other strands or educational levels.

The study also relied on a researcher-made questionnaire and the Certainty of Response Index (CRI) to identify misconceptions. Although validity and reliability procedures were conducted, students' responses may still have been influenced by guessing, misunderstanding of test items, or test anxiety.

Future studies may further investigate other factors influencing misconceptions in genetics, such as teaching strategies, learning resources, prior knowledge, and students' attitudes toward science learning. Researchers may also evaluate the effectiveness of the proposed remediation worksheet in improving conceptual understanding.

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