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# Bridging the Gap: Interactive Video Interventions in High School Biology Education for Misconception Rectification in Bhutan

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## Abstract

Persistent misconceptions pose significant challenges in science education, particularly in biology, hindering students' acquisition of accurate knowledge and scientific literacy. This study investigated the efficacy of interactive educational videos in addressing misconceptions among high school biology students in Bhutan. Using a quasi-experimental design, the study involved 228 students who participated in pre-tests, interventions, post-tests, and post-retention tests. Prevalent misconceptions highlighted the need for effective instructional interventions. Statistical analyses revealed substantial improvement in post-test scores within the experiment group compared to pre-tests and the control group. Moreover, the sustained effectiveness of the intervention was evident, as shown by the minimal discrepancies in scores between post-tests and post-retention tests in the Experiment group. This suggests that the interactive educational video lessons have enduring efficacy in addressing misconceptions and consolidating comprehension over an extended period. The findings of this study underscore the importance of evidence-based instructional strategies in fostering accurate understanding and dispelling misconceptions in biology education. The implications of the study extend to curriculum development, teacher training, and educational policy, with the aim of enhancing the quality of biology education and informing effective pedagogical approaches in science education.

**Keywords:** Misconceptions, interactive videos, biology education, photosynthesis, genes, chromosomes, retention, intervention

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## Introduction

In the domain of science education, misconceptions, also known as preconceptions or alternative conceptions, always represent erroneous ideas that students unintentionally introduce into their learning process. These misconceptions constitute significant hindrances to students' acquisition of a profound understanding of scientific knowledge and principles (Marisda & Handayani, 2020). In the context of biology education, these misconceptions frequently originate from preconceived notions, incorrect analogies, oversimplified ideas from prior learning experiences, or outdated information found in textbooks and media (Wahyono & Susetyarini, 2021). Yuliasari et al. (2023) highlighted a noteworthy misperception: the misconception that dark reactions invariably occur during the night. This arises from the biological terminology, where "light reactions" and "dark reactions" signify distinct phases of photosynthesis rather than specific times of day. This confusion compounds another misconception: the notion that photosynthesis exclusively occurs during daylight hours. The persistence of these misconceptions among students not only hampers the development and comprehension of accurate scientific concepts, but also presents a considerable challenge to educators, who may be unaware of their existence or origins. Similarly, Ibourk et al. (2018) revealed that secondary students commonly confuse genes with chromosomes, treating them as interchangeable terms and failing to recognise their distinct roles. Furthermore, though no empirical evidence is available, the existence of the aforementioned misconceptions has also been observed and ascertained from our engagement in biology education.

Therefore, recognising and addressing these misconceptions is imperative in the formulation of effective pedagogical strategies to rectify students' comprehension difficulties and ensure a comprehensive and precise biology education. Failing to address these misconceptions in biology education could lead to generations of students graduating with flawed knowledge of biology, potentially affecting their academic pursuits and professional careers in the field. Consequently, it is essential to confront these misconceptions among students to attain a genuine understanding of biological principles, thus making the identification and resolution of these misconceptions critical for the accurate comprehension of biological concepts and their practical applications.

## Research Aims and Objectives

This study aimed to identify the prevalence of misconceptions among high school students using a 3-tier diagnostic test and to address the misconceptions through interactive video lessons.
Given this context, the specific objectives include:

i. To identify the prevalence of misconceptions about biological concepts, especially regarding photosynthesis and genes/chromosomes, among high school students;
ii. To assess the effectiveness of interactive videos in correcting students' misconceptions about photosynthesis and genes/chromosomes;
iii. To assess the long-term retention of corrected knowledge on photosynthesis and genes/chromosomes in students after they have been exposed to instructional interactive videos;
iv. To compare the knowledge retention rates between the Experiment and Control groups using a post-retention test administered two months after the intervention.

**Research Questions**

The primary question is What is the impact of instructional interactive video on high school students' long-term retention and correction of misconceptions related to photosynthesis, gene and chromosome, compared to students who did not receive the intervention?

To address the primary question, the following sub-questions were posed:

1. What are the prevailing misconceptions among high school students concerning photosynthesis, genes, and chromosomes?
2. Does a significant disparity exist in students' achievement in biology between the Experiment group (exposed to instructional interactive videos) and the Control group (not exposed to the intervention)?
3. How proficiently do students retain corrected knowledge about photosynthesis, genes/chromosomes over extended periods following the intervention?
4. Is there a notable contrast in knowledge retention rates between students who underwent instructional interactive videos (Experiment group) and those who did not (Control group) when assessed two months post-intervention?

## Literature Review

Plant photosynthesis and genetics are fundamental topics in biology education, yet students often harbour misconceptions that hinder their understanding of these complex processes.

Misconceptions correspond to concepts that have peculiar interpretations and meanings in students' articulations, which are not scientifically accurate (Bahar, 2003). Furthermore, Kumandas (2015) defines misconceptions as incorrect ideas that are distant from the actual scientific phenomena. Butler et al. (2015) revealed the presence of an unacceptably high level of misconceptions and uncovered flaws in both students' and teachers' understanding of ecological concepts through diagnostic tests conducted with biology students and pre-service teachers in Ireland. According to Chophel (2022), most of the misconceptions that students possess are rooted in their inability to understand chemical concepts from macroscopic, submicroscopic, and symbolic perspectives in chemistry. He claimed that teaching chemistry with video animations helps students develop canonical scientific knowledge. Likewise, Marisda and Hangayani (2020) conclude that providing Macromedia Flash learning media simulations can minimise misconceptions in science. In physics, the misconception regarding the concept of free-fall motion was reduced by using narrative feedback and realistic video (Halim et al., 2021).

**Misconceptions in Plant Photosynthesis -** he differentiation between light and dark reactions in photosynthesis poses a common hurdle for students, leading to prevalent misconceptions. One widespread misunderstanding is the belief that the entire photosynthesis process unfolds exclusively in the presence of light, neglecting the essential distinction between light and dark reactions as two distinct phases. Yuliasari et al. (2023) highlighted a noteworthy misperception: the misconception that dark reactions invariably occur during the night. This arises from the biological terminology, where "light reactions" and "dark reactions" signify distinct phases of photosynthesis rather than specific times of day. This confusion compounds another misconception: the notion that photosynthesis exclusively occurs during daylight hours. Overlooking the flexibility of photosynthesis, students may erroneously assume that sunlight is the sole prerequisite. Darko et al. (2014) emphasise that this misconception obstructs a comprehensive understanding, as students fail to recognise that plants can undergo photosynthesis under artificial light sources. This lack of comprehension underscores the necessity for a broader understanding of the factors influencing photosynthesis beyond natural sunlight.

**Genes/Chromosome Misconceptions -**In the realm of genetics, students frequently struggle with misconceptions related to genes/chromosomes. Ibourk et al. (2018) revealed that students commonly confuse genes with chromosomes, treating them as interchangeable terms and failing to recognise their distinct roles. For instance, students may inaccurately perceive genes as discrete entities within chromosomes without understanding the dynamic interplay between genes and their locations on chromosomes. Building on this, Gusmalini and Wulandari (2020) reported that 42.1% of high school students experienced misconceptions in genes/chromosomes, with the primary cause rooted in the complexity of genetic concepts. Misconceptions in biology education present a significant challenge, hindering students' grasp of fundamental concepts in various areas, including photosynthesis and genetics.

Misconceptions in biology education represent a critical challenge hindering students' mastery of fundamental concepts. Recognising the prevalence of these misconceptions is essential for educators and curriculum developers to design effective instructional strategies and timely interventions that foster a more accurate and comprehensive understanding of biological concepts among students. This review underscores the necessity for customised instructional approaches in plant photosynthesis and genetics, particularly within the Bhutanese educational context.

## Methodology

### Research Design

This study employed purely a quantitative approach, allowing for statistical analysis that could reveal patterns, associations, or trends within a large sample. A quasi-experimental design (Experiment and Control groups) was employed, comprising a pre-test, intervention, post-test, and post-retention test to understand the effectiveness of the intervention in addressing misconceptions identified through the 3-tier diagnostic test. Since the study was targeted at addressing student misconceptions, eventually enhancing their cognitive development, constructivism served as the guiding paradigm for this study.

### Population and Sample

The target population for this study comprised secondary school students studying biology. Sample participants were high school biology students from all five secondary schools in the Samtse district. A purposive sampling method was used to intentionally select these schools based on criteria such as accessibility, socio-economic diversity, and commitment to biology education. This approach ensured a comprehensive and representative sample of biology students, capturing a broad spectrum of experiences and perspectives. Additionally, this broadened the scope of the research and increased the validity of the findings, as they were based on a wider cross-section of students in Samtse district. A total sample size of 228 students from grades IX to XI was selected as participants for this research. This age group was deemed crucial as their understanding of intricate biological concepts, such as photosynthesis and chromosomes, intensified during this stage. Their misconceptions at this juncture could significantly impact their understanding of related future concepts.

### Data Collection Procedures

The data collection procedures involved the following exercises:

**Research Instruments (Three-tier Diagnostic Test):**

The Three-tier Diagnostic Test is a globally used tool to identify the prevalence of misconceptions in educational settings. This instrument encompasses:

- **Tier One:** The initial tier functions to evaluate content knowledge through the presentation of multiple-choice questions pertaining to various biology topics.
- **Tier Two:** Subsequently, the second tier offers an opportunity for respondents to elucidate the reasoning behind their chosen answers from Tier One.
- **Tier Three:** Finally, the third-tier prompts students to indicate their confidence level concerning the accuracy of their responses.

### Designing the 3-Tier Diagnostic Test

A 3-tier diagnostic test was crafted by a team of biology educators. The design focused on common topics in the biology syllabus where misconceptions were frequently observed in most biological concepts (e.g., light and dark reactions in photosynthesis and chromosomes and genes being synonymous). Each question had three tiers: a multiple-choice question, a reasoning section, and a confidence level to collect deeper insights. The tiers were structured in a way that moved from identifying what the student thought, to why they thought that, and finally to analysing the degree of confidence in their answer. This systematic approach provided a more holistic understanding of the student's thought process, allowing researchers to effectively address and correct those misconceptions.

### Pre-test Event

Schools and biology teachers were contacted to collaborate in this research intervention. Before implementing the classroom intervention, researchers conducted a pre-test assessment of the participating students from four secondary schools to identify the prevalent misconceptions in photosynthesis, genes, and cell chromosomes. This initial data served as a benchmark to measure the effectiveness of the interactive video interventions.

### Instructional Materials Design and Development

Instructional materials (interactive video lessons) were designed and developed based on the students' misconceptions identified during the pre-test event through the 3-tier diagnostic test. Pre-test results served as a foundational basis for our interactive video content. To ensure the interactivity of the instructional materials, researchers incorporated quizzes, drag-and-drop activities, graphical animation, and clickable segments into the videos. Throughout the videos, students were prompted at various points to answer questions related to the content just covered. This approach facilitated real-time measurement by researchers to determine the effectiveness of addressing and rectifying misconceptions.

### Classroom Intervention

Researchers coordinated with the school authority and biology teachers to schedule the interactive video lesson sessions, ensuring minimal disruption to regular classes. The interactive video lessons, designed specifically to address common misconceptions were introduced to the students. It was ensured that each student interacted with the video content individually, enabling them to progress at their own pace and engage with interactive elements without peer pressure. After each video session, facilitated group discussions were held. Students discussed their learnings, clarified doubts, and reflected on their previous misconceptions. This collaborative learning environment further reinforced correct concepts.

### Post-test Event

A post-test assessment was conducted using the same 3-tier diagnostic test survey questionnaires used during the pre-test event.

### Post-Retention Test

A post-retention test was administered after an extended period of two months to measure the long-term impact of the interactive video interventions on the knowledge retention ability of the students in the experiment group. The same survey questionnaires used during the pre-test and post-test events were employed for this purpose.

### Data Analysis

The data underwent a systematic analysis comprising several stages. These encompassed an initial pre-test analysis aimed at identifying prevalent misconceptions, followed by a comparison of pre-intervention scores between the experiment and control groups employing descriptive statistics and independent sample t-tests. Subsequently, post-intervention scores were examined to gauge improvements, with a subsequent comparison conducted between experiment and control groups post-intervention utilising independent sample t-tests. Within the Experiment group, paired-sample t-tests were employed to evaluate changes from pre-test to post-test. Finally, the assessment of long-term retention involved comparing post-test and post-retention test scores using paired samples tests.

## Results

#### *Participants' demography*

The study involved 228 secondary school students, divided into a experiment group (n=115) and a control group (n=113). Table 1 below illustrates the demographic breakdown of research participants by gender in both the experiment and control groups. These demographic statistics indicate a balanced representation of gender within the study groups, thereby establishing a baseline for investigating the impact of the instructional intervention on misconceptions pertaining to photosynthesis, genes, and cell chromosomes among secondary school students.

**Table 1**

*Demographic Information of the Participants*

| Gender | Experiment | Control |
|---|---|---|
| Male | 62 | 58 |
| Female | 63 | 55 |
| Total participants | 115 | 113 |

## Misconceptions Prevalence among High School Students

The initial data obtained from the three-tier diagnostic survey in the Experiment group were segregated into three categories. Each concept is assessed through a series of statements, with responses categorised as either "Yes" (indicating a correct answer) or "No" (indicating an incorrect answer). Furthermore, this comprehensive analysis incorporates students' reasoning behind their responses, along with self-rated confidence levels. These analyses offer insights into students' understanding and areas of misconception, guiding targeted educational interventions.

Table 2a provides an overview of the frequency and percentage of correct (Yes) and incorrect (No) responses to each survey statement, alongside the frequency and percentage of students' reasoning and confidence levels during the pre-test phase.

### *Misconceptions in Photosynthesis:*

In examining students' understanding of plant photosynthesis, several prevalent misconceptions emerged. Firstly, a significant proportion of students (59.1%) inaccurately identified true statements about photosynthesis. This suggests a fundamental misunderstanding of the key principles of the process. Additionally, over half of the students (53.9%) demonstrated a misconception regarding the dark reactions (Calvin cycle) of photosynthesis, indicating confusion about this crucial aspect of the process. Furthermore, a notable percentage (35.7%) inaccurately described the dark reaction in photosynthesis, revealing a lack of comprehension about its mechanisms (Table 2a). Another area of misconception relates to the plant parts involved in photosynthesis. A substantial portion of students (21.7%) incorrectly identified these parts, reflecting confusion about the anatomical components crucial for photosynthetic processes. Moreover, an overwhelming majority (67.8%) failed to accurately identify the pigments involved in photosynthesis, indicating a widespread misunderstanding of the molecules responsible for light absorption.

Students also exhibited confusion regarding the relationship between light and dark reactions in photosynthesis. Nearly a third of the participants (27.8%) misunderstood this relationship, highlighting a gap in understanding the coordinated processes that drive photosynthetic activity. Additionally, over half of the students (52.2%) incorrectly identified the energy source for plant growth and activities, indicating a misconception about the fundamental fuel for photosynthesis.

Furthermore, a considerable proportion of students (39.1%) inaccurately identified the primary purpose of photosynthesis, suggesting a lack of clarity about its role in sustaining life processes. These misconceptions collectively underscore the need for effective educational strategies to enhance students' understanding of photosynthesis and address common points of confusion (Table 2a).

***Misconceptions in Genes/Chromosomes*:**

In exploring students' understanding of genes/chromosomes, several notable misconceptions surface. Firstly, a majority of students (62.6%) incorrectly associated skin cell division with chromosomes, indicating confusion about the role of chromosomes in cellular processes. Additionally, a significant proportion (73.9%) misunderstood genetic information during human development, suggesting a misunderstanding of the transmission and expression of genetic material.

Moreover, a substantial percentage of students (67.8%) demonstrated a misconception regarding genetic similarity in Paramecium reproduction, highlighting a lack of comprehension about genetic inheritance in single-celled organisms. Interestingly, all students (100%) misunderstood the genetic composition in different cell types, indicating a pervasive misunderstanding of cellular genetics. Furthermore, a notable proportion of students (19.1%) misunderstood the genetic makeup of twins, suggesting misconceptions about the hereditary basis of twinning. Additionally, nearly half of the participants (47.8%) incorrectly identified structures in a diagrammatic representation, indicating difficulties in interpreting visual representations of genetic concepts (Table 2a).

Finally, a small percentage of students (10.4%) misunderstood the number of kidneys in offspring, revealing misconceptions about genetic inheritance patterns. These findings highlight the prevalence of misconceptions among students regarding genes/chromosomes, emphasising the importance of effective educational interventions to improve understanding in these areas (Table 2a).

**Table 2a**

*Frequency and Percentage of Responses to Pre-test Diagnostic Test Statements*

| Statements | Yes (n=115) | No (n=115) | Yes (%) | No (%) |
|---|---|---|---|---|
| 1. a) The correct sequence of parts in living systems from largest to smallest | 7 | 108 | 6.1 | 93.9 |
| 1. b) Reason for the answer | 80 | 35 | 69.6 | 30.4 |
| 1. c) Confidence levels | 26 | 89 | 22.6 | 77.4 |
| 2. a) Skin cells division and chromosomes | 43 | 72 | 37.4 | 62.6 |
| 2. b) Reason for the answer | 62 | 53 | 53.9 | 46.1 |
| 2. c) Confidence levels | 68 | 47 | 59.1 | 40.9 |
| 3. a) Genetic information during human development | 30 | 85 | 26.1 | 73.9 |
| 3. b) Reason for the answer | 104 | 11 | 90.4 | 9.6 |
| 3. c) Confidence levels | 52 | 63 | 45.2 | 54.8 |
| 4. a) Genetic similarity in Paramecium reproduction | 37 | 78 | 32.2 | 67.8 |
| 4. b) Reason for the answer | 54 | 61 | 47 | 53 |
| 4. c) Confidence levels | 64 | 51 | 55.7 | 44.3 |
| 5. a) Genetic composition in different cell types | 0 | 115 | 0 | 100 |
| 5. b) Reason for the answer | 14 | 101 | 12.2 | 87.8 |
| 5. c) Confidence levels | 75 | 40 | 65.2 | 34.8 |
| 6. a) Genetic makeup of twins | 93 | 22 | 80.9 | 19.1 |
| 6. b) Reason for the answer | 0 | 115 | 0 | 100 |
| 6. c) Confidence levels | 36 | 79 | 31.3 | 68.7 |
| 7. a) Structures circled in diagram representation | 60 | 55 | 52.2 | 47.8 |
| 7. b) Reason for the answer | 78 | 37 | 67.8 | 32.2 |

| Statements | Yes (n=115) | No (n=115) | Yes (%) | No (%) |
|---|---|---|---|---|
| 7. c) Confidence levels | 54 | 61 | 47 | 53 |
| 8. a) Number of kidneys in offspring | 103 | 12 | 89.6 | 10.4 |
| 8. b) Reason for the answer | 75 | 40 | 65.2 | 34.8 |
| 8. c) Confidence levels | 48 | 67 | 41.7 | 58.3 |
| 9. a) True statements about photosynthesis | 47 | 68 | 40.9 | 59.1 |
| 9. b) Reason for the answer | 40 | 75 | 34.8 | 65.2 |
| 9. c) Confidence levels | 39 | 76 | 33.9 | 66.1 |
| 10. a) Dark reactions (Calvin cycle) of photosynthesis | 53 | 62 | 46.1 | 53.9 |
| 10. b) Reason for the answer | 13 | 102 | 11.3 | 88.7 |
| 10. c) Confidence levels | 36 | 79 | 31.3 | 68.7 |
| 11. a) Description of dark reaction in photosynthesis | 74 | 41 | 64.3 | 35.7 |
| 11. b) Reason for the answer | 62 | 53 | 53.9 | 46.1 |
| 11. c) Confidence levels | 44 | 71 | 38.3 | 61.7 |
| 12. a) Plant parts involved in photosynthesis | 90 | 25 | 78.3 | 21.7 |
| 12. b) Reason for the answer | 87 | 28 | 75.7 | 24.3 |
| 12. c) Confidence levels | 32 | 83 | 27.8 | 72.2 |
| 13. a) Pigments involved in photosynthesis | 37 | 78 | 32.2 | 67.8 |
| 13. b) Reason for the answer | 50 | 65 | 43.5 | 56.5 |
| 13. c) Confidence levels | 37 | 78 | 32.2 | 67.8 |
| 14. a) Relationship between light and dark reactions | 83 | 32 | 72.2 | 27.8 |
| 14. b) Reason for the answer | 93 | 22 | 80.9 | 19.1 |
| 14. c) Confidence levels | 32 | 83 | 27.8 | 72.2 |
| 15. a) Energy source for plant growth and activities | 55 | 60 | 47.8 | 52.2 |
| 15. b) Reason for the answer | 74 | 41 | 64.3 | 35.7 |
| 15. c) Confidence levels | 32 | 83 | 27.8 | 72.2 |
| 16. a) Primary purpose of photosynthesis | 70 | 45 | 60.9 | 39.1 |
| 16. b) Reason for the answer | 53 | 62 | 46.1 | 53.9 |
| 16. c) Confidence levels | 43 | 72 | 37.4 | 62.6 |

Following the intervention, there was a notable improvement in students' understanding, as evidenced by a significant increase in the percentage of correct responses across most statements. For example, in statement 1a, the percentage of correct responses increased from 6.1% in the pre-test to 85.2% in the post-test, indicating a substantial reduction in misconceptions regarding the correct sequence of parts in living systems. Similarly, statement 10a showed a significant improvement, with 90.4% of students providing the correct response regarding the dark reactions (Calvin cycle) of photosynthesis (Table 2b).

**Table 2b**

*Frequency and Percentage of Responses to Pre-test Diagnostic Test Statements*

| Statements | Yes (n=115) | No (n=115) | Yes (%) | No (%) |
|---|---|---|---|---|
| 1. a) The correct sequence of parts in living systems from largest to smallest | 98 | 17 | 85.2 | 14.8 |

| Statements | Yes (n=115) | No (n=115) | Yes (%) | No (%) |
|---|---|---|---|---|
| 1. b) Reason for the answer | 91 | 24 | 79.1 | 20.9 |
| 1. c) Confidence levels | 58 | 57 | 50.4 | 49.6 |
| 2. a) Skin cells division and chromosomes | 89 | 26 | 77.4 | 22.6 |
| 2. b) Reason for the answer | 82 | 33 | 71.3 | 28.7 |
| 2. c) Confidence levels | 60 | 55 | 52.2 | 47.8 |
| 3. a) Genetic information during human development | 50 | 65 | 43.5 | 56.5 |
| 3. b) Reason for the answer | 87 | 28 | 75.7 | 24.3 |
| 3. c) Confidence levels | 52 | 63 | 45.2 | 54.8 |
| 4. a) Genetic similarity in Paramecium reproduction | 65 | 50 | 56.5 | 43.5 |
| 4. b) Reason for the answer | 74 | 41 | 64.3 | 35.7 |
| 4. c) Confidence levels | 56 | 59 | 48.7 | 51.3 |
| 5. a) Genetic composition in different cell types | 54 | 61 | 47 | 53 |
| 5. b) Reason for the answer | 49 | 66 | 42.6 | 57.4 |
| 5. c) Confidence levels | 41 | 74 | 35.7 | 64.3 |
| 6. a) Genetic makeup of twins | 98 | 17 | 85.2 | 14.8 |
| 6. b) Reason for the answer | 104 | 11 | 90.4 | 9.6 |
| 6. c) Confidence levels | 53 | 62 | 46.1 | 53.9 |
| 7. a) Structures circled in diagram representation | 85 | 30 | 73.9 | 26.1 |
| 7. b) Reason for the answer | 104 | 11 | 90.4 | 9.6 |
| 7. c) Confidence levels | 51 | 64 | 44.3 | 55.7 |
| 8. a) Number of kidneys in offspring | 104 | 11 | 90.4 | 9.6 |
| 8. b) Reason for the answer | 87 | 28 | 75.7 | 24.3 |
| 8. c) Confidence levels | 55 | 60 | 47.8 | 52.2 |
| 9. a) True statements about photosynthesis | 91 | 24 | 79.1 | 20.9 |
| 9. b) Reason for the answer | 65 | 50 | 56.5 | 43.5 |
| 9. c) Confidence levels | 59 | 56 | 51.3 | 48.7 |
| 10. a) Dark reactions (Calvin cycle) of photosynthesis | 104 | 11 | 90.4 | 9.6 |
| 10. b) Reason for the answer | 43 | 72 | 37.4 | 62.6 |
| 10. c) Confidence levels | 57 | 58 | 49.6 | 50.4 |
| 11. a) Description of dark reaction in photosynthesis | 93 | 22 | 80.9 | 19.1 |
| 11. b) Reason for the answer | 99 | 16 | 86.1 | 13.9 |
| 11. c) Confidence levels | 60 | 55 | 52.2 | 47.8 |
| 12. a) Plant parts involved in photosynthesis | 109 | 6 | 94.8 | 5.2 |
| 12. b) Reason for the answer | 95 | 20 | 82.6 | 17.4 |
| 12. c) Confidence levels | 62 | 53 | 53.9 | 46.1 |
| 13. a) Pigments involved in photosynthesis | 97 | 18 | 84.3 | 15.7 |
| 13. b) Reason for the answer | 81 | 34 | 70.4 | 29.6 |
| 13. c) Confidence levels | 62 | 53 | 53.9 | 46.1 |
| 14. a) Relationship between light and dark reactions | 93 | 22 | 80.9 | 19.1 |
| 14. b) Reason for the answer | 95 | 20 | 82.6 | 17.4 |
| 14. c) Confidence levels | 56 | 59 | 48.7 | 51.3 |
| 15. a) Energy source for plant growth and activities | 79 | 36 | 68.7 | 31.3 |
| 15. b) Reason for the answer | 88 | 27 | 76.5 | 23.5 |
| 15. c) Confidence levels | 56 | 59 | 48.7 | 51.3 |
| 16. a) Primary purpose of photosynthesis | 64 | 51 | 55.7 | 44.3 |
| 16. b) Reason for the answer | 61 | 54 | 53 | 47 |
| 16. c) Confidence levels | 46 | 69 | 40 | 60 |

***Comparison of pre-test scores between Experiment and Control groups***

The descriptive statistics provided an initial exploration into the central tendency and variability of scores within each group, laying the foundation for subsequent inferential analyses aimed at assessing the statistical significance of differences between the experiment and control groups. Data suggest that there was no significant difference in pre-test scores between the experiment and control groups. Both groups exhibited similar mean pre-test scores, with the experiment group scoring slightly lower *(M=16.43, SD=4.661)* compared to the control group *(M=16.65, SD = 4.836)* with no evidence of a statistically significant difference $t(226) = -0.357$, $p > .05$ as shown in Table 3a and 3b. Furthermore, the standard errors of the means (SE) were also comparable between the two groups, implying that participants in both groups had similar baseline performance levels prior to any instructional intervention or experiment. Additionally, a Levene's test was conducted to evaluate the equality of variances between the experiment and control groups based on pre-test scores. The assumption of equal variances was met, as evidenced by a non-significant result, $F(1, 226) = 0.086$, $p > .05$ (see Table 3b), satisfying the assumption requirements of the independent samples t-test. Consequently, any discrepancies observed in subsequent analyses or outcomes can be more confidently attributed to the instructional intervention itself rather than initial differences in baseline scores.

**Table 3a**

*Descriptive Statistics of Pre-test scores between Experiment and Control Groups prior to the Intervention*

| | **Groups** | **N** | **Mean** | **SD** | **Std. Error Mean** |
|---|---|---|---|---|---|
| Pre-test scores | Experiment | 115 | 16.43 | 4.661 | .435 |
| | Control | 113 | 16.65 | 4.836 | .455 |

**Table 3b**

*Inferential Statistics of Pre-test scores of Experiment and Control prior to the Intervention*

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | |
|---|---|---|---|---|---|---|---|
| | | F | Sig. | *t* | *df* | *Sig.(2-tailed)* | Mean difference |
| Pre-test scores Experiment vs Control | Equal variances assumed | .086 | .769 | -.357 | 226 | .722 | .629 |
| | Equal variances not assumed | | | -.357 | 225.329 | .722 | .629 |

The above sequence of analyses provides a comprehensive overview of the pre-intervention scores between the experiment and control groups, establishing a robust foundation for further investigation into the effectiveness of the intervention.

**A Comparative Analysis of Pre-test and Post-test Scores in the Experiment Group**

A paired-sample t-test was performed to evaluate the mean discrepancy between the pre-test *(M = 51.34, SD = 14.56)* and post-test *(M = 71.37, SD = 22.19)* scores within the experiment group. The results revealed a statistically significant disparity, $t(114) = -8.451$, $p < .001$ (see Table 4), indicating that the intervention, which involved interactive video lessons, successfully addressed existing misconceptions among high school students, particularly in the areas of photosynthesis, genes, and chromosomes.

**Table 4**

*Paired Samples t-test (pre-test score and post-test scores) of the Experiment Group*

| Paired Samples T-Test | | Mean | N | SD | *t* | *df* | *p-value* |
|---|---|---|---|---|---|---|---|
| Pair 1 | Pre-test for the Experiment | 51.34 | 115 | 14.560 | -8.451 | 114 | .000 |
| | Post-test for the Experiment | 71.3730 | 115 | 22.193 | | | |

***Comparison of Post-test scores between Experiment and Control Groups***

Additionally, an independent samples t-test was conducted to assess the statistical significance of the difference between the Experiment and Control groups. Levene's Test for Equality of Variances yielded a statistically significant result $F(1,226)=20.312$, $p<.001$, indicating unequal variances between the two groups. Therefore, both equal variances assumed and not assumed analyses were performed.

Under the assumption of equal variances, the independent samples t-test revealed a statistically significant difference between the Experiment and Control groups $t(226)=13.278$, $p<.001$. Similarly, under the assumption of unequal variances, the t-test still demonstrated a significant difference $t(196.84)=13.325$, $p<.001$, as presented in Table 5. These analyses indicate significant differences in both variances and means between the Experiment and Control groups, suggesting potential disparities in the effects of the instructional interventions administered.

**Table 5**

*Independent Samples t-test on Post-test scores between Experiment and Control after the Intervention*

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | |
|---|---|---|---|---|---|---|
| | | **F** | **Sig.** | ***t*** | ***df*** | ***Sig. (2-tailed)*** |
| Experiment Vs. Control | Equal variances assumed | 20.312 | .000 | 13.278 | 226 | .000 |
| | Equal variances not assumed | | | 13.325 | 196.84 | .000 |

***Long-Term Retention of Corrected Knowledge:***

In the comparison of post-test and post-retention test scores within the Experiment group, Table 6a presents relevant statistical data. The mean post-test score was M = 22.834 (SD = 7.10), while the mean post-retention test score was slightly lower at M = 22.713 (SD = 7.28).

Table 6b displays the outcomes of the paired samples test, examining the difference between post-test and post-retention test scores. The mean difference was minimal (M = .12174, SD = 9.384), and a two-tailed t-test revealed no statistically significant difference between post-test scores and post-retention test scores, $t(114) = .139$, $p>.05$, indicating the lasting of Experiment effects over time. This implies that there was no significant decline in the retention of corrected knowledge among students over an extended period following the intervention.

**Table 6a**

*Comparison of Post-test and Post-Retention Test Scores for Experiment Group*

| | **Experiment** | **N** | **M** | **SD** | **Std. Error Mean** |
|---|---|---|---|---|---|
| Post-test vs. Post-retention test | Post-test score | 115 | 22.834 | 7.100 | .66214 |
| | Post-retention test score | 115 | 22.713 | 7.281 | .67896 |

**Table 6b**

*Paired Samples Test Results Comparing Post-test Scores and Post-retention Test Scores*

| | | **Mean** | **SD** | ***t*** | ***df*** | ***Sig. (2-tailed)*** |
|---|---|---|---|---|---|---|
| Pair 1 | Post-test Scores - Post-retention Test Scores | .12174 | 9.384 | .139 | 114 | .890 |

## Discussion

### Misconceptions in Plant Photosynthesis and Genes/Chromosomes

In this study, we explored the prevalence of common misconceptions among high school students regarding two fundamental biological concepts: photosynthesis and genes/chromosomes. Photosynthesis, the vital process by which plants convert light energy into chemical energy, is a cornerstone of biology education. However, the present study reveals several prevalent misconceptions among high school students regarding this fundamental process. While some students demonstrated a sound understanding of certain key concepts in photosynthesis, genes, and cell chromosomes, many exhibited significant gaps in knowledge. The prevalence of misconceptions among students underscores the importance of effective interventions to improve biology education. Misconceptions can hinder students' ability to grasp fundamental concepts and may persist for a lifetime without proper educational interventions. Addressing these misconceptions through effective teaching strategies and interactive learning experiences is essential for promoting accurate understanding and conceptual clarity, thus fostering scientific literacy among students.

The prevalence of misconceptions in biology education, particularly regarding photosynthesis and genes/chromosomes, underscores the need for targeted or effective interventions. Bahar (2003) notes that misconceptions hinder conceptual understanding and impede students' grasp of scientific skills and principles. Our study identifies common misconceptions in photosynthesis, such as misunderstanding the dark reactions, consistent with previous research (Kumandaş, 2015).

Similarly, misconceptions about genes/chromosomes were prominent. For example, many students demonstrated confusion about genetic information transmission during human development and inaccurately associated skin cell division with chromosomes in this study. These misconceptions may stem from inadequate instructional strategies or gaps in students' prior knowledge (Wahyono & Susetyarini, 2021).

To address these challenges, educators can employ various strategies. Interactive learning models and multimedia resources have proven effective in minimising misconceptions (Marisda & Handayani, 2020), while instructional videos enhance students' metacognitive skills (Susantini et al., 2019).

However, it is essential to recognise that misconceptions may persist despite effective instructional interventions. According to Halim et al. (2021), other factors such as ongoing assessment tools and feedback are crucial for identifying and addressing misconceptions. Additionally, incorporating narrative feedback and realistic video simulations can enhance the reduction of misconceptions and promote deeper conceptual understanding of biological concepts (Yuliasari et al., 2023).

On this note, the present study highlights the importance of effective educational interventions in addressing common misconceptions in biology education. By implementing evidence-based strategies, educators can foster a more accurate understanding of biological concepts among students.

**Effectiveness of Intervention (interactive video lessons)**

Based on the findings of the present research study, the effectiveness of the interactive video intervention in correcting misconceptions among high school biology students was evident. A paired samples t-test revealed a statistically significant difference between the pre-test *(M = 51.34, SD = 14.56)* and post-test *(M = 71.37, SD = 22.19)* results of the Experiment group, $t(114) = -8.451$, $p < .001$. This suggests that the intervention, consisting of interactive video lessons, effectively rectified the prevalence of misconceptions among the high school students following the intervention. This finding aligns with prior research indicating the potential of interactive educational tools, such as multimedia resources, in addressing misconceptions and enhancing conceptual understanding in biology education (Duda et al., 2020; Fan et al., 2018). By engaging students in active learning experiences and providing visual representations of complex concepts, interactive video lessons offer a promising approach to promoting conceptual change and fostering a deeper understanding of biological principles (Marisda & Handayani, 2020).

Moreover, an independent samples t-test revealed a statistically significant difference between the control and experiment groups, $t(226) = 13.278$, $p < .001$. This indicates that the experiment group, exposed to instructional interactive video lessons, demonstrated significantly better performance in rectifying misconceptions compared to the control group. This finding is consistent with prior research (Susantini et al., 2019), which similarly demonstrated that the experiment group, exposed to interactive instructional video lessons, exhibited significantly improved performance in rectifying misconceptions compared to the control group. By corroborating these findings, the present study underscores the potential of utilising instructional videos as standardised tools for imparting metacognitive skills within the realm of biology education (Susantini et al., 2019).

## Long-Term Retention of Corrected Knowledge

The comparison of post-test and post-retention test scores within the Experiment group revealed minimal differences. While the mean post-test score *(M = 22.83, SD = 7.10)* was slightly higher than the mean post-retention test score *(M = 22.713, SD = 7.28),* the paired samples test, as depicted in Table 6b in result section, showed no significant difference between the two scores $t(114) = .139$, $p > .05$). This finding implies the enduring impact of the Experiment (i.e. interactive video intervention) over time, suggesting no significant decline in the retention of corrected knowledge of biological concepts, specifically in plant photosynthesis and genes/chromosomes among students subsequent to the intervention. This discovery aligns with prior research, which similarly emphasised the efficacy of instructional interventions in rectifying misconceptions among students (e.g., Susantini et al., 2019). Their study also illustrated that students exposed to interactive instructional video exhibited notably enhanced performance in rectifying misconceptions compared to control group. Additionally, this study corroborates existing literature, consistently highlighting the effectiveness of interactive instructional methodologies in augmenting learning outcomes (Butler, Simmie, & O'Grady, 2015; Fan, Salleh, & Laxman, 2018).

The present study underscores the potential of leveraging instructional interactive video lessons as standardized tools for imparting the learning outcome of high school students in biology education. This aligns with the broader objective of addressing misconceptions and enriching conceptual understanding among students, as emphasised in previous research (Bahar, 2003; Gusmalini & Wulandari, 2020; Marisda & Handayani, 2020).

In summary, the analysis of post-retention test scores within the Experiment group suggests that the instructional intervention facilitated the sustained retention of corrected knowledge among students. This underscores the significance of implementing evidence-based instructional strategies to foster enduring conceptual understanding and alleviate misconceptions in biology education.

## Conclusion

This study highlights the prevalence of misconceptions among high school students regarding fundamental biological concepts such as photosynthesis and genes/chromosomes. The findings emphasise the crucial need for effective interventions to rectify these misconceptions as they can impede students' conceptual understanding and hinder scientific literacy.

The effectiveness of interactive video lessons as an intervention tool was evident in rectifying misconceptions among high school biology students. The significant improvement in post-test scores compared to pre-test scores within the experiment group, as well as the high performance of the experiment group compared to the control group, demonstrates the potential of interactive educational tools in promoting conceptual change and deeper understanding of biological principles.

Furthermore, the study demonstrates the enduring impact of the interactive video intervention, as evidenced by minimal differences between post-test and post-retention test scores within the Experiment group. This suggests that the corrected knowledge persisted over time, highlighting the importance of evidence-based instructional strategies in fostering enduring conceptual understanding and alleviating misconceptions in biology education.

In summary, the findings emphasise the significance of leveraging interactive educational tools and evidence-based instructional strategies to address misconceptions and promote accurate understanding of biological concepts among high school students. By doing so, educators can contribute to fostering scientific literacy and facilitating enduring conceptual understanding in biology education.

## Ethical Considerations

Prior to the commencement of the study, informed consent was sought from each student, detailing the purpose, procedures, and potential risks involved. Strict confidentiality measures were implemented to safeguard the privacy of participants, ensuring that their identities and responses remained anonymous throughout the research process. Furthermore, efforts were made to minimise any potential psychological or emotional discomfort that may have arisen from addressing misconceptions. In the dissemination of results, utmost care was taken to present findings responsibly, avoiding any stigmatization or misrepresentation of individuals or groups. The research strictly adhered to institutional and international ethical guidelines, promoting transparency, integrity, and respect for the participants' autonomy, dignity, and rights throughout the entire investigative journey.

## Significance of the Study

The study's significance lies in its contribution to the field of education and pedagogy, particularly in addressing a crucial gap in understanding and identifying misconceptions among secondary biology students. By utilising a three-tier diagnostic test, the research serves as a valuable diagnostic tool, refines assessment methods and facilitates a nuanced evaluation of students' conceptual understanding. Moreover, the study's emphasis on interactive videos as a corrective measure introduces an innovative remediation approach, especially relevant in the digital age where technology plays an integral role in education.

The implications of this research also extend beyond the classroom, potentially influencing curriculum development, teacher training, and educational policy. Early identification and rectification of misconceptions in students' academic journeys can contribute to a more solid foundation in biology, with potential long-term improvements in learning outcomes.

Ultimately, the significance of the research lies in its potential to elevate the quality of biology education, shape instructional practices, and contribute to a broader discourse on effective strategies for addressing misconceptions in science education.

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