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Research Article

Overcoming Student Misconceptions in Cell Division: Impact of Audio-Visual Tools on Conceptual Clarity

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ABSTRACT: Misconceptions in biological concepts have been identified as significant impediments to effective student learning. One such topic, 'cell division', has shown consistent areas of misconception among high school students. Misconceptions, as substantiated by several literatures, encompass a wide range of incorrect or oversimplified ideas formed from preconceived notions, non-scientific beliefs, and prior experiences. Previous studies have spotlighted these misconceptions in cell division, particularly concerning topics such as DNA, chromosomes, and the stages of mitosis and meiosis. The present study was conducted in one of the higher secondary schools in Samtse (southwest) district of Bhutan, targeting a class of 32 grade X students. Utilizing pre-test and post-test research design, this study aimed to identify prevalent misconceptions and their subsequent remediation through the utilization of audio-visual teaching aids such as animated videos and PowerPoint presentations. Pre-test data spotlighted several misconceptions, with a striking majority of students showcasing gaps in understanding cell division processes and events. Instructional interventions using audio-visual materials displayed potential in bridging these knowledge gaps. This research underscores the importance of evolving pedagogical strategies, advocating for the integration of contemporary audio-visual tools to enhance understanding and rectify longstanding misconceptions in biology education.

KEYWORDS: Misconceptions, Cell division, Mitosis, Audio-visual Aids, PowerPoint presentations, DNA.

INTRODUCTION

Misconceptions present a major obstacle to effective student learning, as they often stem from early experiences that shape incorrect understandings of scientific concepts. Dikmenli (2010) highlights that these misconceptions can arise from a range of sources, including preconceived notions, naive theories, and even simple misunderstandings, which may be further complicated by unscientific beliefs or mixed conceptions. These incorrect ideas can become deeply ingrained as students form them before or during their formative school years, and, concerningly, they may be reinforced by educators or textbooks, as noted by Bahar (2003). Consequently, identifying and addressing these misconceptions is essential to fostering accurate understanding and promoting more effective learning outcomes.

In the Bhutanese education system, misconceptions in biology are a common challenge that can impede students' understanding of key concepts. These misconceptions often arise from students' prior knowledge, everyday experiences, and cultural beliefs, which conflict with scientific explanations. For instance, students frequently hold incorrect beliefs about biological processes like photosynthesis, respiration, and reproduction, reflecting a broader issue seen in various educational contexts (Kaltakci-Gurel et al., 2016). The use of traditional, teacher-centered approaches in Bhutanese classrooms, which focus heavily on rote memorization and textbook-based learning, may exacerbate these misconceptions (Dorji, 2005). Furthermore, limited access to up-to-date educational resources, particularly in rural schools, contributes to students forming and retaining erroneous ideas about biological concepts (Sherab & Dorji, 2013). Addressing these misconceptions requires a shift toward inquiry-based learning and the integration of technology, both of which could help students visualize complex biological processes and engage more deeply with the subject matter.

This study aimed at identifying the prevalence of misconceptions of fundamental biological concepts, specifically ‘cell division’ held by high school biology students. It also aimed at assessing the effectiveness of intervention using audio-visual aids to address these misconceptions that would help students achieve an accurate understanding of the concepts in cell biology.

Specific study objectives include:

- To identify common misconceptions about cell division among Bhutanese grade X students.
- To assess the effectiveness of audio-visual aids in addressing these misconceptions.
- To evaluate the improvement in students' understanding of cell division following the intervention.

LITERATURE REVIEW

The term “misconception” has been described by many authors in different ways. For example, Modell et al. (2005) defined misconception as ‘a perception of phenomena occurring in the real world which is not consistent with the scientific explanation of the phenomena’ (p-20). Similarly, Abu-Hola (2004) discusses misconceptions in biology as difficulty in constructing an adequate mental representation of the phenomena and lack of prior learning experiences or failing to notice the relationships between various abstract natures of biological concepts. Other studies have reported the term “misconception” as an idea that provides incorrect understanding of concepts that are constructed based on a person’s experiences including preconceived notions, non-scientific beliefs, unexperienced theories, mixed conceptions, or conceptual misunderstandings (Shehu, 2015; Yasri, 2014).

Previous researches have highlighted that many secondary school students hold misconceptions regarding cell division. Some of the most prevalent misconceptions involve misunderstandings about DNA, chromosomes, chromatids, homologous chromosomes, and the distinction between haploid and diploid cells, as well as their interrelationships (Kindfield, 1994; Oztas et al., 2003; Chinnici et al., 2004). Dikmenli (2009) further revealed misunderstandings such as the belief that DNA replication occurs in the prophase of cell division, misinterpretations about the chromosome number in various stages of mitosis and meiosis, and confusion over the nature and number of chromatids during cell division. Dikmenli (2009) noted that students frequently mistake chromatids for chromosomes or conflate replicated with un-replicated chromosomes. Given these findings, it is clear that effective and timely instructional interventions are essential to address and rectify these misconceptions.

Various methods exist to assess students' understanding and misconceptions about cell division, including open-ended questions, two-tier diagnostic tests, interviews, and drawings (Dikmenli, 2009). To counter these misconceptions, educators often employ tools and strategies such as models (Clark & Mathis, 2000), animation-based instruction (Mustafa, 2023), conceptual maps, semantic feature analysis, conceptual change texts (Novak & Canas, 2007), and computer-based technology (Yesilyurt & Kara, 2007).

Instructional Strategy: Audio-Visual Aids

Teaching aids encompass materials that educators use to enhance the teaching and learning experience within the classroom. Among these, audio-visual aids stand out for their ability to engage both auditory and visual senses, offering an immersive learning experience. These aids, which include tools such as charts, maps, models, film strips, projectors, radios, and televisions (Rather, 2004), aim to captivate attention and simplify complex ideas, making education more impactful.

Traditional teaching methods have sometimes unintentionally introduced misconceptions among learners (Ashaver & Igyuve, 2013). Many studies underscore the transformative benefits of incorporating audio-visual materials in pedagogy. Quarcoo-Nelson et al. (2012) identified a marked rise in achievement scores when audio-visual aids were integrated into the curriculum alongside traditional teaching methods. Ouellette (2004) noted the efficacy of such aids in explaining scientific concepts. These tools have also been shown to improve academic performance among students with special needs or those classified as slow learners (Osokoya, 2007). Shabiralyani et al. (2015) further argued that audio-visual aids not only stimulate students' interest but also enhance memory retention.

In pursuit of a deeper understanding of cell division, audio-visual tools were employed as part of the intervention in this study. These tools aim to rectify existing misconceptions among grade X students in Bhutanese classrooms.

METHODOLOGY

Research area

A case study was conducted at a higher secondary school in Samtse district, Bhutan, accommodating 1224 students (631 girls and 593 boys) across grades nine to twelve. The school was selected for its proximity to the college campus, which provided logistical convenience for the study.

Participants

A single section of grade X was selected for the study using a simple random sampling method which ensured that every section had an equal chance of being chosen. The selected class comprised 32 students, including 18 females and 15 males. This gender distribution provided a balanced representation, allowing for an examination of understanding and potential misconceptions among both female and male students.

Research design

To assess the effectiveness of instructional strategy on students' understanding of mitosis and meiosis, a pre-test-post-test design was employed.

Pre-test Administration: Prior to the intervention, a pre-test was administered to identify existing misconceptions about cell division. The pre-test, consisting of five two-tier questions, was adapted from research on effective instructional methods (e.g., Mayer, 2009; Huddle & Pillay, 2006).), and the grade ten textbook (Royal Education Council [REC], 2017), reflecting the literature and common difficulties observed in students' understanding of cell division. These questions were reviewed and validated by a college tutor and biology teachers. The pre-test results provided baseline data for the study.

Intervention: Following the pre-test, an intervention using was conducted during a 45-minute biology class. The intervention utilized audio-visual aids, including animated videos and PowerPoint presentations, to address and correct misconceptions. The instructional materials—videos, PPTs, diagrams, and charts—were carefully designed to target specific misunderstandings identified in the pre-test.

Post-Test Administration: A post-test, consisting of the same five questions used in the pre-test, was administered three months after the intervention to evaluate the retention of knowledge and the long-term impact of the intervention.

Assessment Tools: The assessment tools used in this study included two-tier questions designed to identify and address students' misconceptions about cell division. These tools were validated through expert review and were intended to provide a comprehensive evaluation of students' conceptual understanding both before and after the intervention. However, the students' responses were assessed based on the assessment criteria adapted from Bayrak (2013).

Table 1: Assessment criteria adapted from Bayrak (2013)

Responses	Marks awarded (point)
No answer	0
Both wrong answers	0
One correct answer	1
Two correct answers	2

RESULT

Baseline data analysis

Based on the pre-test data, significant misconceptions regarding cell division processes were identified among students (Table 2). A substantial proportion (40.63%) erroneously perceived interphase as a "resting phase," with this misunderstanding being more pronounced among females (50%) compared to males (28.57%). This highlights a critical area where instruction is needed to clarify that interphase involves active processes of cell growth and DNA replication, rather than being a period of inactivity. Furthermore, none of the students accurately recognized that chromosome numbers do not double during prophase of mitosis, indicating a widespread misunderstanding of chromosomal behavior during this phase. Only 34.38% of students correctly understood that mitosis produces two identical daughter cells, revealing a notable gap in their comprehension of mitotic outcomes. Conversely, the majority (96.88%) correctly identified that meiosis results in haploid cells, suggesting a strong grasp of this aspect of meiosis. Nonetheless, 65.63% of students incorrectly believed that meiosis occurs in all cells, underscoring a significant misconception regarding the specific contexts in which meiosis takes place. Notably, students accurately distinguished between chromosomes and chromatids, as evidenced by the absence of confusion in this area. These findings underscore the need for targeted instructional strategies to address and correct these misconceptions, thereby enhancing students' conceptual understanding of cell division processes.

Table 2: Pre-test student performance data before intervention

Sl.	Questions	N	Male (n=14)	%	Female (n=18)	%	Total (%)
1.	The Interphase is the "resting phase" of mitosis.	32	4	28.57	9	50.00	40.63
2.	Chromosome number is doubled in the prophase of mitosis.	32	0	0	0	0	0
3.	Mitosis produces two new identical daughter cells	32	4	28.57	7	38.88	34.38
4.	Meiosis occurs in all cells	32	9	64.29	12	66.67	65.63
5.	Diploid cells (2n) are produced during Meiosis.	32	14	100	17	94.44	96.88
6.	Chromosomes and chromatids are one and the same thing.	32	0	0	0	0	0

Endline data analysis

The post-test data reveals notable improvements in students' understanding of cell division processes following the intervention (Table 3). The percentage of students who mistakenly viewed interphase as a "resting phase" decreased significantly from 40.63% to 18.75%, indicating a successful correction of this misconception. Despite no change in the understanding that chromosome numbers do not double during prophase, there was a substantial increase in the proportion of students correctly identifying that mitosis produces two identical daughter cells, rising from 34.38% to 75.00%. Additionally, there was a reduction in the misconception that meiosis occurs in all cells, with the percentage decreasing from 65.63% to 28.13%. The understanding that meiosis produces haploid cells remained consistently correct at 100%, and confusion between chromosomes and chromatids persisted at 0%. These results demonstrate that the intervention effectively enhanced students' grasp of key concepts related to mitosis and meiosis, though further emphasis is needed on specific areas like chromosome dynamics during prophase.

Table 3: Post-test student performance data after intervention

Sl.	Questions	N	Male (n=14)	%	Female (n=18)	%	Total (%)
1.	The Interphase is the "resting phase" of mitosis.	32	2	14.3	4	22.2	18.8
2.	Chromosome number is doubled in the prophase of mitosis.	32	0	0	0	0	0
3.	Mitosis produces two new identical daughter cells.	32	10	71.4	14	77.8	75
4.	Meiosis occurs in all cells.	32	3	21.4	6	33.3	28.1

5.	Diploid cells (2n) are produced during Meiosis.	32	14	100	18	100	100
6.	Chromosomes and chromatids are one and the same thing.	32	0	0	0	0	0

Analysis of mean Performance: Pretest vs. Posttest

The overall analysis of pretest and posttest mean scores during pre-test and post-test events indicated a significant improvement in students' understanding of cell division. The average score increased from 4.81 on the pretest to 10.88 on the posttest (Figure 1), suggesting that the instructional interventions employed were effective in addressing common misconceptions and promoting learning. An inferential paired sample t-test revealed a significant difference between the pretest and posttest scores, $t(31) = -13.373$, $p < .001$ (see Table 4). On average, students scored 6.06 points higher on the posttest than on the pretest, indicating that the targeted instructional intervention was effective in enhancing students' grasp of complex biological concepts.

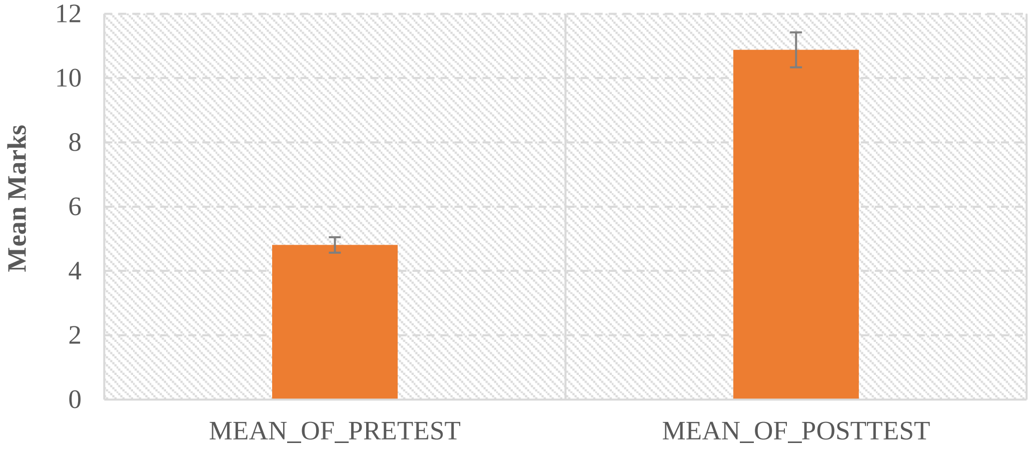

Figure 1: Overall mean of students' performance in pre-test and post-test events

Table 4: Paired samples t-test between pretest scores and posttest scores

Pair1	Mean	Std. Deviation	t-value	df	p-value
Pretest scores - Posttest scores	-6.06250	2.56449	-13.373	31	0.000

Gender-wise performance

The chart below (Figure 2) shows that both male and female students had a good understanding of the subject matter. However, female students performed slightly better than male students on both the pre-test and post-test. Despite this trend, the difference in performance between genders was not statistically significant. This observation may suggest potential gender-related differences in factors such as study habits, motivation, or prior knowledge.

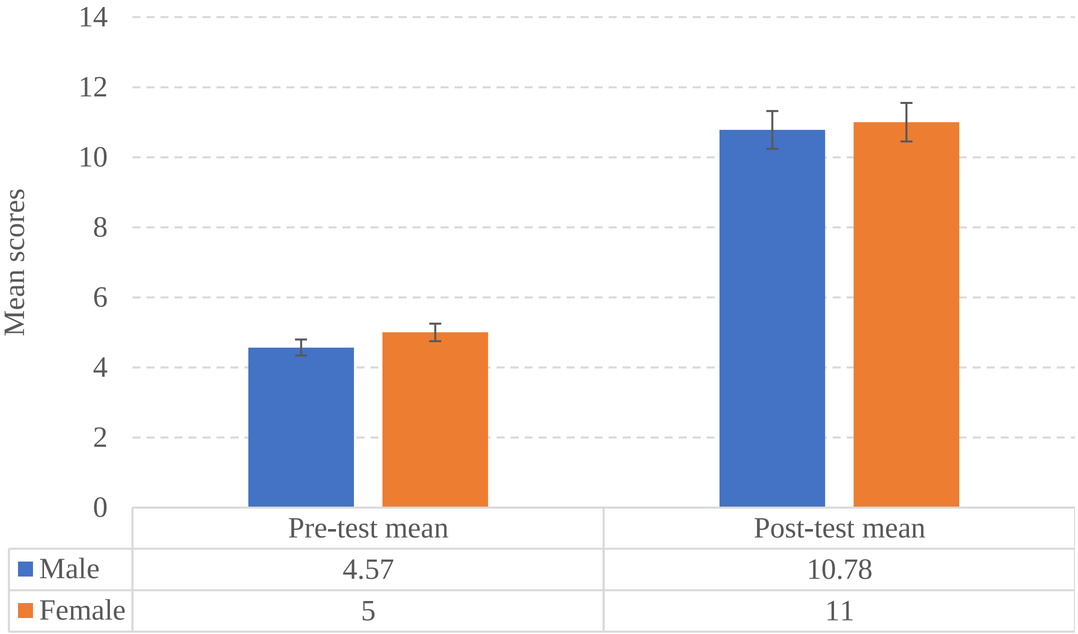

Figure 2: Gender-wise performance in pretest and post-test

DISCUSSION

Prevalence of misconceptions

The present study indicated that students struggled to grasp fundamental concepts of mitosis and meiosis. Notably, none of the students correctly identified that chromosomes and chromatids are distinct entities, and many believed that meiosis occurs in all cells. These finding is consistent with earlier research by Dikmenli (2009), who reported that students frequently confuse the stages of cell division, chromosome replication, and the roles of chromatids and chromosomes. Similar misconceptions were noted by Kindfield (1994), who found that students often have difficulty understanding the relationship between DNA, chromosomes, and chromatids during cell division.

In addition to this confusion, students demonstrated misconceptions about the stages of mitosis. Specifically, more than half of the students incorrectly believed that the interphase is the "resting phase" of mitosis. Such pervasive misconceptions underscore the need for targeted interventions to clarify these complex processes.

Effectiveness of audio-visual aids

The post-test data showed a marked improvement in students' understanding after the intervention using audio-visual aids, including animated videos and PowerPoint presentations. This improvement is consistent with the finding of Shabiralyani et al. (2015), who demonstrated that visual aids not only enhance student engagement but also improve memory retention and conceptual understanding. The use of animated videos, in particular, helped students visualize the dynamic processes of cell division, thereby reducing confusion about the roles of chromosomes and chromatids.

Research by Ashaver and Igyuve (2013) supports the notion that audio-visual materials are effective in simplifying complex biological concepts. In this study, these materials facilitated students' understanding of the intricate details of mitosis and meiosis, which are often challenging to convey through traditional methods or textbook illustrations. By engaging multiple senses, audio-visual aids enabled students to develop a more comprehensive grasp of the cell division process. For instance, the effectiveness of these aids was evident in the overall improvement in students' performance. Both male and female students demonstrated a significant increase in their scores following the intervention. However, the data did not indicate any substantial difference in the extent of benefit between male and female students, suggesting that the audio-visual aids were equally effective for both genders in enhancing their understanding of cell division concepts. This finding aligns with Quarcoo-Nelson et al. (2012), who reported that audio-visual tools can enhance academic performance in science subjects regardless of gender.

Addressing persistent misconceptions

Despite the success of the instructional intervention, some misconceptions persisted, particularly regarding the doubling of chromosome numbers during the prophase of mitosis and the distinction between chromatids and chromosomes. These findings suggest that while audio-visual aids are helpful, they may not be sufficient on their own to fully eliminate deep-seated misconceptions. Bahar (2003) highlighted that misconceptions can be reinforced by educators or textbooks, which suggests that simply presenting the correct information through new mediums may not be enough to overcome existing misunderstandings.

To address these persistent misconceptions, future instructional strategies should incorporate more interactive approaches, such as conceptual maps and hands-on models, as suggested by Novak and Canas (2007). These tools can provide students with opportunities to actively engage with the material, thereby reinforcing correct understanding. Additionally, integrating formative assessments throughout the learning process could help educators identify misconceptions in real-time and adjust their teaching strategies accordingly (Dikmenli, 2009).

Significance of the study

This study offers valuable insights into addressing common misconceptions about mitosis and meiosis, demonstrating the effectiveness of audio-visual aids in enhancing students' understanding of complex biological concepts. The research confirms that visual aids, such as animated videos and PowerPoint presentations, significantly improve conceptual clarity and engagement, providing evidence for their integration into educational practices. By identifying persistent misconceptions, the study highlights the need for comprehensive instructional strategies that go beyond traditional methods. The findings contribute to the field by offering practical solutions for improving science education and informing future research on effective teaching interventions in biology.

CONCLUSION

The present study highlights significant student misconceptions about mitosis and meiosis, including confusion between chromosomes and chromatids and incorrect beliefs about meiosis occurring in all cells. These findings corroborate earlier research by Dikmenli (2009) and Kindfield (1994), which identified similar misunderstandings. The use of audio-visual aids, such as animated videos and PowerPoint presentations, notably improved students' understanding, consistent with Shabiralyani et al. (2015) and Ashaver and Igyuve (2013). The aids effectively enhanced conceptual clarity and engagement across genders, as supported by Quarcoo-Nelson et al. (2012). Despite these improvements, some misconceptions, particularly regarding chromosome doubling during prophase and the distinction between chromatids and chromosomes, persisted. This indicates that while audio-visual aids are beneficial, they may not fully resolve deep-seated misunderstandings. Future instructional strategies should integrate interactive tools and formative assessments to address and correct persistent misconceptions, aligning with the recommendations of Novak and Canas (2007) and Dikmenli (2009).

Limitations

The sample size was limited to only 32 grade ten students, where very small sample size may reduce the reliability and validity of the data. Additionally, the research was conducted in a single educational setting, which may not fully represent other contexts. The study focused exclusively on audio-visual aids, potentially overlooking other effective instructional methods. Despite improvements observed in students' understanding, some misconceptions persisted, indicating that the intervention may not have fully addressed all misunderstandings.

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