

UNIVERSITY OF EDUCATION, WINNEBA



**USING INTERACTIVE MULTIMEDIA INSTRUCTIONAL APPROACHES
TO IMPROVE ACADEMIC PERFORMANCE OF PRE-SERVICE SCIENCE
TEACHERS IN SOME SELECTED BIOLOGY CONCEPTS**

FRANCIS ARTHUR-BAIDOO

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TEACHERS IN SOME SELECTED BIOLOGY CONCEPTS**

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**A thesis submitted to the School of Graduate Studies
in partial fulfilment of the requirements for the award
of the degree of Doctor of Philosophy
(Science Education)**

**Department of Integrated Science Education
Faculty of Science Education**

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DECLARATION

Student's Declaration

I, **Francis Arthur-Baidoo**, declare that this dissertation, with the exception of quotations and references contained in published works, which have all been identified and acknowledged is entirely my own original work, and that, it has not been submitted either in part or in whole, for another degree elsewhere.

Signature:.....

Date:.....

Supervisors' Declaration

We hereby declare that the preparation and presentation of this thesis were supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

Prof. Yaw Ameyaw (Principal Supervisor)

Signature:.....

Date:.....

Prof. Charles Kwesi Koomson (Co Supervisor)

Signature:.....

Date:.....

DEDICATION

To my children: Benedict Arthur-Baidoo, Francisca Arthur-Baidoo and Michael Wiredu for their love, support and prayers throughout the study.

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ABSTRACT

This study assessed the effect of Interactive Multimedia Instructional Approaches (IMIA) on the learning outcomes of some biology concepts among pre-service science teachers at Wiawso College of Education in Ghana. The study employed an action research design with a convergent parallel mixed-method approach. Data was collected quantitatively and qualitatively and were analyzed using IBM SPSS version 27.0. The instruments used in the study were tests, questionnaires, and interviews. A total of 76 participants were involved, with a small subset (10 pre-service science teachers) selected for interviews. Purposive and convenience sampling techniques were used to select the participants for the study. The study revealed that the majority of respondents agreed they found it difficult to understand the different parts of cell and their functions, with a mean score of 4.75 and a standard deviation of 0.82. They also agreed that visualizing the three-dimensional structure of a cell was challenging, with the same mean value and standard deviation. Furthermore, most respondents indicated that technical difficulties hinder instruction, with a mean score of 4.28 and a standard deviation of 0.99. Finding appropriate multimedia instructional approaches that align with the curriculum was perceived as even more difficult, reflected by a mean score of 4.410 (standard deviation = 0.84). Limited access to technology and multimedia instructional approaches was another common concern, with a mean score of 4.21 (standard deviation = 0.83). The results, again, showed that a significant number of pre-service science teachers believed that integrating multimedia approaches effectively required additional time and effort, as indicated by a mean score of 3.880 (standard deviation = 1.30). Moreover, the study found that the pre-service science teachers' performance in the selected biology concepts improved significantly after being exposed to the IMIA interventions, with the average pre-test score increasing from 36.62 to an average post-test score of 71.89. Based on these results, the study recommends that Wiawso College of Education biology lecturers adopt and utilize the Interactive Multimedia Instructional Approach, to better support pre-service science teachers in learning abstract biology concepts like cell structure, cell division, and Mendelian genetics at the college level.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter presents the background to the study, the statement of the problem, and the purpose of the study. It also includes the objectives of the study, research questions, hypothesis and the significance of the study as well as delimitations and limitations that were identified. It also contains basic assumptions of the study, abbreviations and operational definitions of terms, list of abbreviations and finally, organisation of the study.

1.1 Background to the Study

Interactive Multimedia Approaches (IMA) are instruments used for communication, where by program output depends on the user's input, and the user input affect the output (Yang et al., 2022). Multimedia have the ability to improve educational instruction and management by making these services available at any time. The idea that multimedia may improve the quality of delivery systems and enable instructors to become better teachers have been underlined by Hall at al. (2022). To assist learning, multimedia instructional methods must be blended with educational programs as technology improves.

The use of sophisticated multimedia teaching methods in education has prompted scholars to investigate how these technologies influence learning (Ginting, & Linarsih, 2022; Way et al., 2022). Since content is presented in the form of videos or moving images coupled with sound, a multimedia teaching technique can pique students' interest in learning (Ollamina-Gerez & Dioso, 2023). They also claimed that multimedia instructional methods or learning processes in the classroom could be

viewed as an alternative educational instrument to encourage students to participate in scientific classes.

Furthermore, Winarni et al. (2022) argued that the direct use of multimedia instructional systems as part of education might impact student learning, when teachers utilize them to introduce new ideas and clarify concepts during main or close instruction. Multimedia instructional approach delivery in science teaching and learning, according to Mayer (2009), comprises the computer-controlled integration of text, graphics, drawings, still images, moving pictures, animation, and audio. Multimedia is a phrase that educational technologists regularly hear and debate about nowadays. Unless otherwise defined, the phrase can refer to a well-balanced mix of multiple mass media such as print, audio, and video, or it can refer to the creation of computer-based hardware and software packages that are mass-produced yet still allow for customized usage and learning.

In Biology, Adedamola (2018) evaluated how well students learned regulation of internal environment as a result of a variety of instructional approaches such as computer simulations and animation. The purpose of the computer simulation for all learners was to observe on screen text, graphic, still images, video packages and teacher's explanation on regulation of internal environment. The learners were given either graphical or written feedback. Furthermore, only half of the participants in the study got brief multimedia explanations of the biology involved, which were combined throughout the simulation. The in-writing feedback with multimedia explanation group had the highest performance. "The issue of how much learning occurs just by having participants view the explanations without engaging in the simulation is subject to dispute," the authors admitted in the absence of multimedia.

To Adedamola (2018), Biology is a science subject which explains the existence of life. It is a natural science which is concerned with the study of living organisms, their structures, forms and functions, heredity, cell division, etc. It is a fundamental science subject which serves as the basis for understanding the complexities of how the body parts of organisms' functions. Biology, according to Taiwo and Emeke (2014), is the subject that exposes the students to the world of knowledge of self, the immediate and distant environment. This may be the bases for its inclusion in the Senior High School (SHS) and College of Education (CoE) curricula in Ghana. Traditional college biology courses, on the other hand, only allow a limited number of biology experiments in the classroom, and students are unable to control them dynamically and intuitively in order to obtain a clear biological representation of the concept (Taiwo & Emeke, 2014). Despite the adoption of multimedia instructional approaches, they remain insufficient and therefore the multimedia approaches must be further developed and investigated to enhanced their application and methodology. In College biology classes, the effective use of multimedia approaches can minimize the amount of written and handwritten content.

Additionally, the quantity of blackboard drawings done by teachers is substantially decreased, allowing teachers to dedicate more time to the topic (Al Meajel & Sharadgah, 2018). The globe today is evolving at a rapid pace, as are the many areas of a nation's growth. Education, as one of these sectors and in reality, as the instrument of choice for national growth, follows this path by using technology and innovative ways to impact knowledge to students (Haddad & Draxler, 2002). Ways to improve biology teaching and learning should be a top priority for education stakeholders due to the importance of education to society (Penuel et al., 2020). This study, on the other hand, provided students a new viewpoint on the usage of interactive multimedia

instructional approach and their consequences on conceptual understanding and performance in teaching and learning of some biology concepts.

Practical laboratory exercises that demand a particular degree of psychomotor abilities are used to supplement the teaching and learning in multimedia education sessions. Practical content presentation to the learner can aid in the attainment of learning objectives and hence improve the learning environment. In view of this, it is clear that introducing interactive multimedia instructional approaches to students, such as virtual classrooms, distance learning, biology software (e.g., coach lab II), online concept teaching and learning, design experiments, and other approaches that are not as common as face-to-face education, helped them to improve their conceptual understanding and academic performance in cell structure, cell division and Mendelian genetics. Due to the fact that connection between a person and the learning environment are linked together, the interactive multimedia instructional approach can make learning process occur at any time, with anybody, and anywhere (Aljawarneh, 2020).

Conventional face-to-face instruction has its advantages; it does not impart the skills required in today's fast-paced economy (Aloraini, 2012). Choosing a good teaching approach is one of the problems that many instructors encounter when adding technology into the classroom. New technologies such as artificial intelligence, asynchronous computer conferencing, and interactive digital video and optical formats, according to Hannum et al. (2022), provide instructors with a new type of media. Abdulrahman et al. (2020) stated that integration of multimedia instructional approach in the learning process has been proved to improve students' engagement and performance in the classroom. The use of the most appropriate approach is crucial in attaining the intended learning outcomes, however tool selection and design are

frequently centred on the software's features, such as fancy special effects, rather than the approach's influence on learning.

1.2 Statement of the Problem

The cell structure, cell division and Mendelian genetics concepts has been part of the level 200 Biology Curriculum for the CoE affiliated to University of Education, Winneba and now affiliated to AAMUSTED for pre-service science teachers for quite some time now. In the Science Education Department at Wiawso College of Education, pre-service science teachers lack a strong conceptual understanding of these identified biology concepts. Again, they hold several misconceptions that are common among pre-service science teachers in many other Colleges of Education in Ghana. These misconceptions contribute to pre-service science teachers' poor performance in biology.

During a biology lesson somewhere in February, 2023 within the first semester, with the level 200 or second-year pre-service science teachers, 2022/2023 batch at Wiawso College of Education, it was observed that the level 200 pre-service science teachers have conceptual difficulties in learning cell structure, cell division and Mendelian genetics aspects of the Biology Curriculum. Persistent interactions with second-year pre-service science teachers revealed that almost all of them had learning difficulties in the three biology concepts identified. Several studies (Awang-Kanak et al., 2016; Borja & Mutya, 2024; Alberts, 2017; Çeliker, 2015) have attributed these conceptual difficulties to the theoretical and uninspiring lecture methods with little or no practical activities often used by biology lecturers in teaching these abstract biology concepts to these young and novice pre-service science teachers. This ineffective and obsolete theoretical lecture method used by the biology lecturer has made it difficult for pre-service science teachers to grasp the needed conceptual knowledge and skills embedded

the biology concepts understudy. This development had impacted negatively on the second-year pre-service science teachers' performance and attitude in Biology. This poor performance has led many pre-service science teachers to perceive biology - and science in general - as difficult, believing it is reserved for more gifted or academically strong students (Arthur-Baidoo et al., 2022).

There is an urgent need to adopt innovative instructional strategy in teaching biology concepts to the learners. The researcher found out that both pre-service science teachers and lecturers lacked the right attitude toward studying Biology. Many solutions implemented by researchers have had little impact on learners' conceptual understanding. Rote learning and memorization dominate, leading to misconceptions in topics such as cell structure, cell division, and Mendelian genetics. These issues affect both the effectiveness of biology teaching and students' understanding, resulting in the low performance of pre-service science teachers in Wiawso Colleges of Education in Ghana.

One research gap identified is the limited use of multimedia approaches to improve the teaching and learning of biology concepts like cell structure, cell division, and Mendelian genetics. Therefore, further research is needed to identify which multimedia approaches are most effective for teaching these specific biology concepts. The researcher has decided to undertake this study to improve the academic performance of pre-service science teachers in learning these essential biology concepts through the use of interactive multimedia instructional approaches.

1.3 Purpose of the Study

The purpose of this study was to use interactive multimedia instructional approaches to improve the academic performance of pre-service science teachers of Wiawso College of Education in some selected biology concepts.

1.4 Objectives of the Study

The objectives of the study were to:

1. Identify the students' challenges faced by pre-service science teachers in learning cell structure, cell division and Mendelian genetics.
2. Access the effect of interactive multimedia instructional approach on pre-service science teachers' performance in the learning of the following biology concepts: cell structure, cell division and Mendelian genetics.
3. Access the pre-service science teachers' difficulties, attitudes, and benefits to integrate the use of interactive multimedia instructional approach in their future classrooms.
4. Find out the effect of interactive multimedia instructional approach on pre-service science teachers' motivation and engagement in biology instructions.
5. Evaluate pre-service science teachers' perception on the effect of interactive multimedia instructional approach in teaching and learning of biology concepts.

1.5 Research Questions

The study was guided by the following research questions:

1. What are the pre-service science teachers' challenges in learning cell structure, cell division and Mendelian genetics?
2. What is the effect of interactive multimedia instructional approach on the improvement of pre-service teachers' performance in the learning of cell structure, cell division and Mendelian genetics?
3. What are the difficulties, attitudes, and benefits of the pre-service science teachers in the use of interactive multimedia instructional approach in classrooms?

4. What is the effect of interactive multimedia instructional approach on pre-service science teachers' motivation and engagement levels during biology instruction?
5. What are the pre-service science teachers' perceptions on the effectiveness of interactive multimedia instructional approach in biology lessons?

1.6 Hypothesis

The following hypotheses were formulated for the study:

H₀: There is no statistically significant difference between the mean of examination scores of the pre-test and post-test of pre-service science teachers.

H₁: There is a statistically significant difference between the mean of examination scores of pre-test and pot-test of pre-service science teachers.

1.7 Justification for the Study

One research gap was the limited use of interactive multimedia instructional approaches to improve the performance of pre-service science teachers in the teaching and learning of some biology concepts, such as, cell structure, cell division, and Mendelian genetics. Therefore, there is a need for more research on which types of multimedia approaches are most effective in teaching specific biology concepts. For example, interactive simulations may be more effective in teaching cell division, while digital storytelling may be more effective in teaching Mendelian genetics. Additionally, there is a need for research on how to effectively integrate interactive multimedia instructional approach into pre-service science teachers' educational courses, as well as, how to assess the impact of interactive multimedia instructional approach on pre-service science teachers understanding of biology concepts and pedagogical skills at Wiawso CoE in the Wiawso Municipality. Further research in these areas can help to identify best practices for using multimedia approaches to improve pre-service science

teachers' performance in teaching and learning of biology concepts, especially those in Wiawso Municipality.

1.8 Significance of the Study

The following are the significance of the study:

- Academic performance of the participants in this study will be improved.
- This study will provide guidelines or as a manual on how interactive multimedia instructional approaches can be used in many different ways to promote the teaching and learning of biology concepts in Wiawso College of Education.
- This study will again, promote active learning among second-year biology students at the Wiawso College of Education (WCoE).
- Furthermore, the study will contribute to practical knowledge of the roles of the teacher and student in using interactive multimedia instructional approach in teaching and learning of biology at WCoE.
- Finally, it will serve as an important source of literature for future studies that may investigate similar problems in other Colleges of Education in Ghana.

1.9 Limitations of the Study

The study was limited by:

- The production of interactive multimedia instructional approach coupled with the electronic devices and electricity needed to do the study, which makes it relatively expensive compared to other pedagogies.
- Student's application errors in using interactive multimedia instructional approach.
- Test anxiety on the part of the pre-service science teachers for the pre-and post-assessment results.

1.10 Delimitation of the Study

The study was delimited by the:

- Study's theoretical background, objectives, research questions, variables under study and study sample.
- The scope of study was second-year pre-service science teachers at Wiawso College of Education only.
- The following content areas only: cell structure, cell division and Mendelian genetics.

1.11 Basic Assumptions of the Study

This study was conducted with the assumptions that:

1. All the pre-service science teachers studying biology at Wiawso College of Education are computer literate.
2. There is availability of computer experts at the Wiawso College of Education where biology is taught.

1.12 Abbreviation

AAMUSTED	-	Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development
AR	-	Augmented Reality
AV	-	Audio-visual
CLT	-	Cognitive Load Theory
CoE	-	College of Education
IMA	-	Interactive Multimedia Approach
IMIA	-	Interactive Multimedia Instructional Approach
IMIAIS	-	Interactive Multimedia Instructional Approach Interview Schedule

Komenda CoE-		Komenda College of Education
Std. Dev.	-	Standard Deviation
SHS	-	Senior High School
UEW	-	University of Education, Winneba
WAEC	-	West African Examination Council
WCoE	-	Wiawso College of Education

1.13 Operational Definitions

Interactive multimedia instructional approach

Interactive multimedia instructional approach refers to instructional materials that integrate various forms of media, such as text, images, videos, animations, and interactive elements, to engage learners actively. When applied to biology education, interactive multimedia instructional approach can provide dynamic visualizations and simulations, enabling students to manipulate and explore complex biological concepts.

Cognitive Load Theory

Cognitive load theory focuses on the cognitive resources required to process information during learning. It suggests that the learning process can be optimized by managing the cognitive load imposed on learners. This theory identifies three types of cognitive load: intrinsic, extraneous, and germane. Effective instructional design should aim to reduce extraneous load and promote germane load to enhance learning outcomes.

Misconceptions

They are used to describe students' ideas or opinions which are different from the scientifically accepted views.

Performance

It is the learning outcome or attainment of pre-service science teachers who were taught cell structure, cell division and Mendelian genetics concepts using interactive multimedia instructional approach as expressed in examination scores in this study.

Practical Activities

They are “hands-on” and “mind-on activities” carried out on small scale basis (using compound light microscope to observe onion cell and cheek cells).

1.14 Organization/Structure of the Study

This study was organized into five (5) chapters. Chapter one presents the background to the study, statement of the problem, purpose of the study, objectives of the study, research questions, hypothesis, significance of the study, delimitations of the study, and limitations of the study. Also, included are operational definition of terms, list of abbreviations, and the organization of the study. Chapter Two describes the review of related literature that underpins the study. Various themes and sub-themes based on the objectives or research questions have been presented including theoretical and conceptual frameworks respectively. Chapter Three discusses the methodology employed in the study, and it includes research design, population, sample and sampling procedure, instruments, data collection procedure, and data analysis methods. Chapter Four presents the analysis of the results and discussion of the findings of the study in relation to the research questions. Finally, Chapter Five being the last chapter covers the summary of the study, conclusions, recommendations, and suggestions for further studies.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter reviews related information/materials of the present study. The review was organized under the following subheadings:

1. The theoretical Review
2. The conceptual framework
3. Meaning of multimedia
4. Components of Multimedia
5. Importance and Effects of Multimedia Instructional Approach
6. Interactive Multimedia Instructional Approach
7. Role of Multimedia Technology in Teaching and Learning
8. Disadvantages in the Uses of Multimedia Instructional Approach in Science Instruction
9. The Recommendations Made to Better the General Circumstances and Make Teachers Aware of the Functions of Multimedia Instructional Approach in Teaching
10. Difficulties/Barrier of Integrating Multimedia Instructional Approach in the Classrooms
11. Students' Difficulties in Learning Concept Cell Structure
12. Students' Difficulties in Learning Cell Division
13. Students' Difficulties in Learning Mendelian Genetics
14. Empirical Evidence of the Study
15. The Roles of the Teacher and the Student in Using Multimedia Instructional in Teaching and Learning of Biology.

16. The Perception of Students on the use of Multimedia in Teaching and learning of biology Concepts
17. Brief overview of cell, cell division and Mendelian genetics
18. Empirical Review
19. Impact on Student Motivation and Engagement in Biology
20. The Long-term Benefits of Interactive multimedia instructional approach Applications and Retention
21. Rationale of the Study
22. The Role of Multimedia in Biology Education

2.1 Theoretical Review Underpinnings the Study

The theories that underpinning the study were hinged on blended learning and cognitive load theory. Blended learning refers to a combination of various learning methods, which may include traditional classroom instruction, virtual classrooms, and independent e-learning formats (Al-Ani, 2013; Horton & Edwards, 2006). It is a style of education in which the students learn through electronic and online media as well as traditional face-to-face teaching (Trinder, 2016). Blended learning approach is believed to have an effect on students' achievement, motivation, collaboration and communication (Al-Ani, 2013). It can also be used to analyse obstacles faced by pre-service science teachers in using interactive multimedia instructional approach in blended learning environment (Sweller, Ayres, & Kaliyuga, 2011). There are many forms or types of blended learning but for the purpose of this research, the Researcher focused on flipped classroom method where pre-service science teachers are made to watch recorded lectures, videos, animations and PowerPoint presentation during the biology class.

According to Yeboah et al. (2020), the flipped classroom is an emerging instructional strategy that reverses traditional teaching methods by delivering instructional content, such as videos and readings, outside of class, while using classroom time for student-centered tasks. This shift allows teachers to act as facilitators, guiding students through interactive learning experiences, including problem-solving, collaborative work, and practical exercises. Such an approach encourages active participation and deeper engagement with content (Akçayır & Akçayır, 2018; Yeboah et al., 2020). The flipped classroom method of teaching has been implemented in high schools, colleges and universities around the world in disciplines such as Mathematics, Sciences and Humanities (Hao, 2016). Blended learning brings together multiple instructional strategies, combining conventional face-to-face teaching with digital tools and online engagement methods (Khalil et al., 2018). Rather than being grounded in a unique pedagogical model, this approach draws from foundational learning theories like behaviourism, cognitivism, and constructivism. Additionally, derivative frameworks such as social constructivism, activity theory, and situated cognition contribute valuable perspectives for designing student-centred blended environments. Reviewing these theoretical underpinnings is essential to provide a conceptual basis for this study.

2.1.1 The impact of new technologies on the characteristics of higher education students

Research suggests that an individual's intellectual growth can be influenced by their environment (Zajonc, 2001). Consequently, the fast pace of societal and technological evolution is likely to significantly shape how students think and learn. Neuroscience is increasingly contributing to educational insights. In the book *iBrain: Surviving the Technological Alteration of the Modern Mind*, by Small and Vorgan

(2009), it recognized authorities on brain function and behaviour and argue that frequent interaction with digital tools like the internet and smartphones can change the way the brain operates. They explain that the brain remains adaptable throughout life, continuously forming and reorganizing neural connections in response to new experiences and technological developments. Additionally, digital platforms such as blogs, wikis, and Twitter (now known as X) have become extremely popular, particularly among younger generations (Jones et al., 2015). These researchers suggest that growing up in a digitally interactive and socially connected world, as opposed to passive media like TV or traditional lectures, has significantly influenced students' characteristics, including their demographics, interests, expectations, learning preferences, and work habits.

In a study conducted by Lim et al. (2013), it was revealed that a considerable investment has been made to bring technology to schools and these investments have indeed resulted in many success stories. However, there are two significant gaps in educational uses of technology that must be addressed. The first is a usage gap, compared to how and how much today's students use technology outside school, in-school technology usage is much less intensive and extensive. The second is an outcome gap, compared with the outcomes achieved through investment in technology in sectors outside education, the gains in terms reduced costs and increased productivity achieved by schools is significantly smaller. Their study discussed the causes of these two gaps and provides suggestions for bridging them by engaging in discussions about effective teaching and committing to technology planning. According to Lim et al., (2013), since technology is deeply embedded in nearly every aspect of daily life, classrooms should mirror this reality. As such, schools are encouraged to close the gap between traditional educational settings and real-world experiences.

With the widespread availability of the internet and the rise of Web 2.0 social networking tools, learners are increasingly becoming what Mulaudzi (2021) describes as digital natives. These individuals seek continuous communication with their peers, prefer personalized instruction, and are drawn to learning environments that respond to their specific needs. More than ten years ago, a study conducted on the effects of mobile phones, social media, and the internet on American college students involved asking 250 participants to avoid all forms of media for a full day (Roberts et al., 2014). The study revealed that after spending twenty-four hours without media access, many participants experienced withdrawal symptoms, strong cravings, anxiety, and a general inability to function effectively without their usual digital and social connections. These reactions were comparable to those associated with substance dependence, such as drug or alcohol addiction. According to Lee (2015), today's generation of students has often developed technical competencies and digital literacy independently. They frequently use the internet, mobile phones, and instant messaging for social interaction, entertainment, and other purposes, viewing technology as a natural and integral part of their lives. Lee further asserts that these learners do not perceive technology as separate from their everyday experience. Therefore, excluding technology from the classroom setting is counterproductive, as students not only expect it but are also eager to engage with it in their learning. Given the profound influence of digital tools, many of today's students think and absorb information in ways that differ significantly from earlier generations. They tend to find traditional lecture-based instruction unsatisfying and are more inclined toward learning experiences that involve interaction with instructors, peer collaboration, and flexible, personalized environments where knowledge is co-constructed and shared.

Students today expect their instructors to be technologically proficient and to offer personalized and engaging forms of instruction in learning environments that cater to their individual needs. They also anticipate new models of learner support and increased access to technology-based courses (Mayer, 2020). However, Dey et al. (2009) noted a disconnect between students, who arrive on campus ready to engage with information in new ways, and faculty, who are often reluctant to change their traditional teaching methods. It is becoming more likely that students will question whether conventional teaching methods are effective in promoting critical and creative thinking. As a result, significant changes in Botswana's higher education system seem inevitable (Dey et al., 2009).

By integrating technologies that students are familiar with into the design of learning environments, educators can encourage greater involvement and facilitate experiential and meaningful learning. According to O'reilly (2010) and Andriole (2010), incorporating Web 2.0 concepts into both on-campus and online courses can increase student participation beyond standard reading and writing tasks, turning students into active participants. To keep up with societal changes and evolving workplace demands, classrooms must evolve to mirror the outside world (Bucheli & Galán, 2022). As Tapscott (2009) and Jones (2010) pointed out, students born between 1977 and 1997 are driving a shift from teacher-centered to student-centered methods of learning, focused on collaboration.

Dede (2009) observes that rapid advancements in information technology are significantly altering the learning preferences of students in higher education. As a result, these technological developments provide new opportunities for educational institutions, allowing emerging technologies to deliver instruction tailored to the needs of today's learners. For this reason, it is crucial for higher education institutions to

incorporate modern technologies in ways that foster and enhance learning. However, engaging students in meaningful and effective learning experiences within technology-supported environments remains a significant challenge for both researchers and educators. It is increasingly important for educators to understand their students and apply that knowledge in designing and implementing effective teaching and learning strategies. Unfortunately, many educators do not fully recognize the evolving characteristics and needs of the new generation of students. Gabriel (2021) highlights a common complaint among university instructors: many students today are perceived as unprepared for university, often due to their disinterest in participating in long, traditional lectures in a classroom setting.

2.1.2 From the perspective of technology as a cognitive tool

This study highlights the concept of learning as an intentional, constructive process that involves conscious cognitive efforts, with technologies being used as tools to enhance cognitive learning rather than as mere instructional media. This marks a clear departure from traditional views of technology, which were often employed for rote learning through repetitive drills and practice (Ro, 2018). The key difference between traditional uses of technology in learning and their application as cognitive tools is that the traditional perspective treats media as mere transmitters of information, expecting learners to be passive recipients rather than active creators of knowledge (Stewart et al. 2010). Over the past four decades, the literature on the use of computers as cognitive tools has evolved significantly (Zawacki-Richter & Latchem, 2018). According to these researchers, their study found that the literature has progressed through four key stages, each reflecting major advancements in educational technology and learning theories related to media: the growth of computer-based instruction (1976-1986), stand-alone multimedia learning (1987-1996), networked computers for

collaborative learning (1997-2006), and online learning in the digital era (2007-2016). Zawacki-Richter and Latchem (2018) concluded that mapping and analyzing literature from this and other areas of educational technology, including sources from non-English journals, books, and conference proceedings, can provide a valuable overview for global communities of practice and scholarly inquiry.

The term “mind tools” is often used interchangeably with “cognitive tools,” and both refer to similar concepts in this study. Kirschner and Erkens (2006) explain that when a computer-based application is used to complete a specific task during a learning activity, with the goal of enhancing effectiveness or efficiency, it is described as learning with the tool. In contrast, when the same application is used to improve the way learners think and operate, with effects that go beyond the immediate learning context, it is referred to as learning from the tool. Their work focused on this second perspective, emphasizing how mind tools in education support meaningful and professional ways of thinking and working. This is viewed as a core example of learning supported by digital technologies.

Mind tools and cognitive tools help learners express their understanding by transforming raw information into meaningful knowledge. These tools foster critical thinking and support the development of advanced cognitive skills. They can range from simple applications like email or online discussion boards to more complex systems such as argument mapping software or visualization tools. Kirschner and Erkens (2006) specifically highlighted conversation tools—a category of cognitive tools designed to create and support technology-enhanced communities of practice where collaboration and knowledge sharing can thrive.

According to Jonassen and Carr (2020), many studies have highlighted significant weaknesses in students’ thinking abilities across all levels of education.

They argue that one major reason for this is the widespread dependence on a single method of knowledge representation in assessment practices. Limiting how students express what they know restricts the range of cognitive skills being developed and assessed.

Limiting students to a single method of expressing their knowledge in instructional activities and assessments can restrict their understanding of the subject matter. For instance, in a physics course at Harvard, students were able to solve mathematical problems accurately using formulas and procedures. However, when tested on their conceptual understanding of those same problems, many failed to demonstrate a grasp of the underlying principles. This suggests that students had memorized formulas and techniques but lacked a true understanding of the physics concepts involved (Jonassen & Carr, 2020). As Wilson (2019) explains, technology should not be viewed merely as a physical tool, but as a cognitive resource that engages learners, supports critical thinking, and facilitates the construction of knowledge.

Jonassen and Carr (2020) explained that cognitive tools enhance human thinking, problem solving, and learning by supporting mental processes. Jonassen (2002) further highlighted that mind tools are intended to extend a learner's cognitive capacity during learning. These tools promote engagement, critical thinking, and the development of advanced learning skills, helping students become more analytical and reflective thinkers. Kim and Reeves (2007) describe cognitive tools as interactive technologies that learners use to support their own construction of knowledge. These tools allow learners to apply their expertise within a shared learning environment. Yson (2009) points out that, students do not learn directly from technology itself; rather, technology serves as a means of encouraging active engagement with content. By

prompting learners to think and work with information, technology supports the cognitive processes that lead to deeper learning.

Herrera et al. (2012) argued that computers can support and shape cognitive processes by helping learners develop dynamic mental models. This, in turn, encourages deeper mental engagement and improves learning outcomes. When technology is used as a cognitive tool within educational settings, it allows students and digital tools to work together as collaborative partners in the learning process. This partnership enables learners to overcome their natural cognitive limitations, such as challenges with memory, reasoning, and problem solving, by offloading routine tasks like calculations, data storage, and information retrieval to the computer. These forms of support allow learners to focus on more meaningful thinking tasks, encouraging articulation and reflection, both of which are essential to developing higher-level thinking skills and constructing new knowledge.

Jonassen (2002) emphasized that for students to use cognitive tools effectively; they must actively participate, think critically, and clearly express their understanding. With such technological support, learners are encouraged to build their own knowledge rather than simply recall and reproduce information. From the cognitive tool perspective, meaningful learning happens when students are immersed in complex environments that stimulate advanced thinking and problem-solving abilities (Jonassen & Carr, 2020). This view is supported by activity theory and the socio-cultural framework established by Vygotsky (1978), along with contributions from Pritchard et al. (2014). Vygotsky (1978) argued that tools play a central role in human development by enabling us to externalize and share our thoughts, thus enhancing social interaction and understanding. He identified two kinds of mediating tools essential for learning: physical tools (technical resources) and symbolic tools (such as language and signs).

In this context, the use of technology becomes especially relevant, as it can mediate human activity and support learning processes. Importantly, while learners engage in intellectual collaboration with technological tools, these tools are not meant to replace thinking. Instead, their purpose is to support and guide learners in developing their cognitive abilities. As Wegerif (2007) explains, computers do not teach content or thinking directly, but through interaction with them, students internalize the methods and structures that enhance their own thinking processes.

Jonassen and Carr (2020), along with Issroff and Scanlon (2002), asserted that computers should not be viewed as teachers or experts, but rather as tools that extend cognitive capabilities. Kennedy and McNaught (2001) suggest that well-designed computer-based cognitive tools can support learning by simulating complex environments or modelling expert strategies for solving problems. Decades earlier, Lajoie and Derry (1993) outlined several advantages of cognitive tools for learners: they support mental processes such as memory organization and self-regulation; they reduce the mental burden by handling basic tasks, thereby allowing learners to focus on more complex thinking; they enable engagement in intellectual tasks that might otherwise be too difficult; and they facilitate hypothesis generation and testing during problem-solving. According to Jonassen and Carr (2020), key characteristics of cognitive tools include being user-friendly, functioning effectively in constructivist settings, offering learners the chance to explore meaningful problems in real-world contexts, and providing relevant and timely feedback. These tools also promote student ownership of learning. The theoretical foundation of cognitive tools is rooted in constructivism, as emphasized by Yilmaz (2011), contrasting with traditional instruction models based on transmission of information. In today's educational environments, especially those rich in technology, constructivist approaches are

increasingly recognized as the most effective and widely endorsed (Oliveira et al., 2019).

2.1.3 From the perspective of learning as a social activity

Vygotsky (1978) emphasized that learning is inherently a social process. According to Msongole (2017), cognitive development is significantly shaped through social interaction, which fosters active engagement in learning. Hall and LeCavalier (2000) support this by arguing that human interaction is among the most powerful mechanisms for learning and the development of skills. Through such interactions, learners actively participate, leading to collaborative idea generation and shared understanding. It is within these social exchanges that information is transformed into knowledge. Social learning involves students working collaboratively, which helps them grasp how knowledge is constructed and evolves in contemporary society. In the context of the information age, where the volume of knowledge grows rapidly, expertise is no longer seen as residing in a single individual but within a broader network of socially connected individuals. Gijbels et al. (2021), proposed the situated learning theory, which views learning as a process of active participation within a community of practice. These communities often referred to as learning communities; serve as platforms for collective knowledge building. Wenger et al. (2002) noted that such communities are essential for facilitating the exchange and development of knowledge.

It is widely acknowledged that individuals acquire knowledge not only by generating and sharing information within a learning community but also through observation and imitation of others. In this regard, Salomon (2012) suggested that human thinking often occurs in collaboration with others and is supported by culturally available tools and resources. O'driscoll and Beehr (2000) defined learning as a lasting

change in an individual's performance or potential for performance that results from their interaction with the environment. Interaction, in fact, is a fundamental component of effective education, as highlighted by Chickering and Gamson's (1999) seven principles of good practice. According to their framework, key dimensions of interaction include communication, collaboration, and active participation in learning activities. Bernard et al. (2009) further emphasized the importance of three primary types of interaction in the learning process: interaction with the content, interaction with the instructor, and interaction among learners. They argued that meaningful learning requires students to engage actively with the course material, rather than simply being exposed to it. Berge (1999) combined the interaction between learners and instructors with peer-to-peer interaction under the broader category of interpersonal interaction. He argued that effective learning depends on students working collaboratively with one another and with instructors to co-construct meaning and develop a shared understanding of the subject matter.

Interpersonal interaction serves as a vital social framework for the shared development of understanding and has been shown to significantly influence the learning process (Andresen, 2009). In his study, Andresen explored learners' perceptions of interaction and satisfaction in a course delivered via interactive television. The participants included 123 teachers from kindergarten to sixth grade enrolled in a program on Developmental Approaches in Science and Health. Data were collected from three of the ten sessions in the course. The findings revealed strong correlations between learners' perceptions of both personal and overall classroom interaction. While perceptions of personal interaction moderately predicted learner satisfaction, the most influential factor was the overall perception of interaction within the class. The study concluded that students tend to be more satisfied with instruction

when they perceive a high level of classroom interaction. Interestingly, the broader dynamics of group interaction seemed to have a greater influence on satisfaction than individual participation. Observing interactions among classmates, referred to as vicarious interaction, can contribute more to learner satisfaction than direct engagement by each student. However, it was also observed that both perceived interaction and satisfaction tend to decline as learners gain more exposure to instruction via interactive television. According to Berge (1999), the social environment of learning plays a critical role in fostering motivation, critical thinking, and problem-solving skills. Many learners perform best when they are actively involved in collaborative learning activities. Salomon and Perkins (1998) noted that students' understanding is deepened when they engage in knowledge construction alongside their peers and instructors. As Pirtle and Tobia (2014) and Anderson (2004) also argue, the more opportunities students have for meaningful engagement, the more comprehensive their understanding becomes.

According to Bangert-Drowns and Pyke (2001), when learners are genuinely engaged, they are intrinsically motivated to undertake tasks and participate in activities. In any educational setting, engaged learners demonstrate behavioural, intellectual, and emotional involvement in their academic work. The advent of social networking and Web 2.0 technologies (Andriole, 2010) has further expanded the opportunities for interaction among students, instructors, and course content. These tools allow learners to collaborate beyond the confines of the traditional classroom, enhancing both the scope and depth of the learning experience. Collaborative learning enabled by these technologies encourages the development of innovative strategies aligned with the principles of social learning (Gillies & Ashman, 2003).

2.1.4 Traditional face-to-face versus online instruction and challenges

According to Bangert-Drowns and Pyke (2001), when learners are genuinely engaged, they are intrinsically motivated to complete tasks and participate in learning activities. In educational settings, such learners exhibit behavioural, intellectual, and emotional commitment to their academic work. The emergence of social networking and Web 2.0 technologies (Andriole, 2010) has further broadened the possibilities for interaction between students, instructors, and course materials. These technologies support collaboration beyond the traditional classroom, enriching the overall learning experience. The collaborative learning fostered by these tools promotes the development of new learning strategies that align with the principles of social learning (Gillies & Ashman, 2003).

The concept of knowledge and its nature have undergone significant transformation in recent years, particularly with the advent of the World Wide Web and the Internet (Pallen, 1995). Consequently, the skills students need to develop in order to be prepared for the workforce of the 21st century differ markedly from those of their predecessors. Over time, increasing demand for access to higher education, dwindling resources, and growing calls for better quality education have led universities to explore alternative teaching methods and course offerings (Alexander, 2020). As a result, the evolutionary transformation of teaching and learning in institutions is considered inevitable.

Gerbic (2011) distinguished between face-to-face and online instructional approaches in three major areas, highlighting the strengths and weaknesses of each in addressing learner needs. Despite the concerns about traditional face-to-face learning, it also has significant advantages, such as the possibility of strong human interaction,

which is generally more powerful than in the online setting due to the presence of visual cues (Singh et al., 2021).

While earlier studies suggested that distance and online learning courses were typically as effective as classroom-based instruction (Unal, 2005), a more recent detailed analysis by Howell et al. (2009) found that students who took all or part of their classes online not only performed as well as, but in fact, better on average than those taking the same course through traditional face-to-face instruction. They argued that unique strengths of online technology include its ability to expand instructional options and strategies, facilitate and extend interactions between students and teachers, resulting in personalized learning and support student collaboration through both synchronous (real-time) and asynchronous (delayed) methods.

Schoenfeld-Tacher et al. (2001) conducted a study examining the effects of distance delivery on student performance and classroom interactions in an upper-level science course, Histology. The outcomes were assessed by comparing performance on content pre- and post-tests for students enrolled in on-campus and online sections of the same course. Despite initial indistinguishable content knowledge between the groups, by the end of the semester, students in the online group significantly outperformed their peers in the on-campus section. The online setting facilitated a greater proportion of high-level interactions than the on-campus setting. The findings suggested that interactions in an online course may surpass those in traditional classroom settings. Interactions in technology-supported practices can include tutor-student communication via email, the development of communities of practice, online discussions, active learning engagement, and the provision of prompt and rich feedback-facilitating collaborative and cooperative learning (Schoenfeld-Tacher et al., 2001).

Although higher interaction is often assumed to be more feasible in face-to-face classrooms, this is not always the case. Interactions in traditional classrooms are often constrained by time, unlike in online environments where communication can occur anytime, anywhere (Freiermuth, 2001). According to Freiermuth (2001), another advantage of online technology is the increased time-on-task afforded by the availability of learning materials anytime and anywhere, combined with the use of asynchronous communication tools. The extended time for tasks enables deeper engagement with learning activities, fostering self-paced learning. The time lag in asynchronous communication (e.g., discussion forums and email) allows students to control the pace and timing of their learning, which encourages reflective learning and higher-level cognitive processes (Robertson, 2007). Therefore, both traditional face-to-face and online instruction offer unique strengths and weaknesses.

As Bowden (2022) argued that, a strong case is being made for a blended approach, where both online and face-to-face modes are integrated to maximize the strengths and minimize the weaknesses of both. The blended learning approach is considered the best way to unlock the educational potential of new technologies.

2.1.5 Constructivism versus traditional approaches and its practical challenges

Traditional lecture-based instructivist approaches struggled to stand the test of time, especially with the widespread shift toward constructivism in the 1990s (Stewart et al., 2010). According to them, the constructivist approach has become the most recognized and preferred method of instruction over the past three decades. Constructivism is a philosophy of learning that asserts knowledge is actively constructed by the individual through interactions with the environment, including other learners (Aljohani, 2017).

2.1.6 Constructivism and the new technology

There is a growing body of evidence (Pullano et al., 2005; Salinas, 2017; Nix et al., 2004) supporting the idea that traditional classroom instruction can be significantly enhanced through the use of web-based multimedia and communication tools. The role of technology in constructivist learning environments is increasingly recognized by all stakeholders in the educational sector. Several researchers (Mik-Meyer, 2020; Forster & Taylor, 2000; Nanjappa & Grant, 2003) agreed that technology is crucial in facilitating constructivist approaches. For them, both constructivism and technology focus on creating engaging and collaborative learning environments.

Winn (2013) argued that constructivism, combined with the integration of computer technology into the curriculum, offers significant promise for improving learners' achievement in core subject areas. He highlighted a mutualistic relationship between computer technology and constructivism, where each benefits the other. By developing constructivist course modules using technology as cognitive tools or mind tools, educators can offer more authentic content, learning activities, assessments, and enhanced interaction among students, content, and teachers. This, in turn, enriches knowledge construction opportunities. Such integration promotes increased motivation, knowledge construction, and the development of social and communication skills among learners (Schippers & Scheepers, 2020).

Proponents of constructivism have drawn connections between constructivist teaching and learning strategies and educational technology (Alanazi, 2016; Ladzik, 2012; MacLeod, Burm, & Mann, 2022; Nanjappa & Grant, 2003; Riegler, 2011). The richness of technology enables a more dynamic and engaging learning environment (Chaney-Cullen & Duffy, 1999). Nelson (2013) stated that such environments aim to introduce learners to constructivist practices through collaborative problem-solving

techniques and processes. His study revealed that in technology-supported collaborative learning environments, synchronous and asynchronous communication tools help facilitate dialogue, a key component of pedagogies based on socio-constructivist principles, which emphasize the co-construction of knowledge within a community of learners.

2.1.7 Cognitive load theory

Cognitive Load Theory (CLT), developed by Sweller (1988), explains how different mental demands during learning can impact student understanding and retention. The theory emphasizes that learners have a limited working memory capacity, and when instructional content is too complex or poorly structured, it can overwhelm this capacity and hinder learning. This has important implications for instructional design, particularly in the use of multimedia tools in education. CLT categorizes cognitive load into three types: intrinsic load, which relates to the inherent difficulty of the learning task; extraneous load, which results from ineffective or confusing instructional design; and germane load, which supports meaningful learning and schema construction (Sweller, 2010; Mayer & Moreno, 2003).

2.1.7.1 Intrinsic load

Intrinsic load refers to the cognitive demands inherent in the learning task itself and is determined by the complexity and interrelatedness of the material. Topics such as cell division or Mendelian genetics often impose a high intrinsic load due to their conceptual density. According to Sweller (2010), effective learning requires managing this load by providing well-structured and scaffold instruction. Strategies to reduce intrinsic load include breaking down complex information into manageable parts, offering clear examples, and using analogies to facilitate understanding.

2.1.7.2 Extraneous load

Extraneous load refers to the cognitive burden caused by elements in instructional materials that are not directly relevant to the learning objective (Sweller, 2010). For instance, decorative animations or superfluous visual effects may draw learners' attention but do not support meaningful understanding. Sweller (2010) emphasized that this type of load should be minimized to prevent unnecessary cognitive effort. Mayer and Moreno (2003), in their research on multimedia learning, found that extraneous information can hinder learning outcomes by overloading working memory. They recommend designing instructional materials that eliminate irrelevant content and minimize distractions to enhance cognitive efficiency and learning performance.

2.1.7.3 Germane load

Germane load refers to the cognitive effort dedicated to the construction of schemas and the development of meaningful mental representations (Sweller, 2010). It is closely linked to deep learning processes, such as integrating new information with prior knowledge and forming structured knowledge frameworks. Sweller (2010) emphasized the importance of optimizing germane load to support effective learning. Activities that promote reflection, problem-solving, and elaboration are essential for fostering deep understanding (Nelson, 2013). According to Janssen et al. (2010), encouraging active cognitive engagement-such as generating self-explanations or applying concepts in novel contexts-can enhance germane load and ultimately improve learning outcomes.

2.2 Conceptual Framework of the Study

The study adapted a conceptual framework grounded in blended learning and Cognitive Load Theory (CLT). When learners encounter challenging in abstract scientific concepts, such as cell division or Mendelian genetics, they often experience

confusion and cognitive imbalance (Loh & Lim, 2021). To address this, the Interactive Multimedia Instructional Approach (IMIA) serves as an effective approach. Delivered either collaboratively or individually, IMIA helps learners build new mental representations or adjust existing ones, thereby enhancing their understanding of complex biology concepts (Herrington et al., 2014).

Figure 1 illustrates the conceptual framework for this study, which integrates the Interactive Multimedia Instructional Approach (IMIA) with principles from Cognitive Load Theory (CLT) to improve student learning achievement in cell structure, cell division and Mendelian genetics. Rooted in the blended learning approach, the framework highlights how multimedia approaches can support cognitive processing to improve on challenges the pre-service science teachers faced during biology class. According to CLT, learning is affected by three types of cognitive load: intrinsic, extraneous, and germane (Sweller, 2010). Educators can use interactive multimedia instructional approach to reduce unnecessary cognitive burden (extraneous load) that is, difficulties they encountered and promote mental effort related to meaningful learning (germane load) which will motivate and engaged them in lesson delivery. When effectively implemented, this approach fosters enhanced academic performance, student engagement, collaboration, communication in mixed instructional settings and changed their perceptions toward the learning of the identified biology concepts (Al-Ani, 2013).

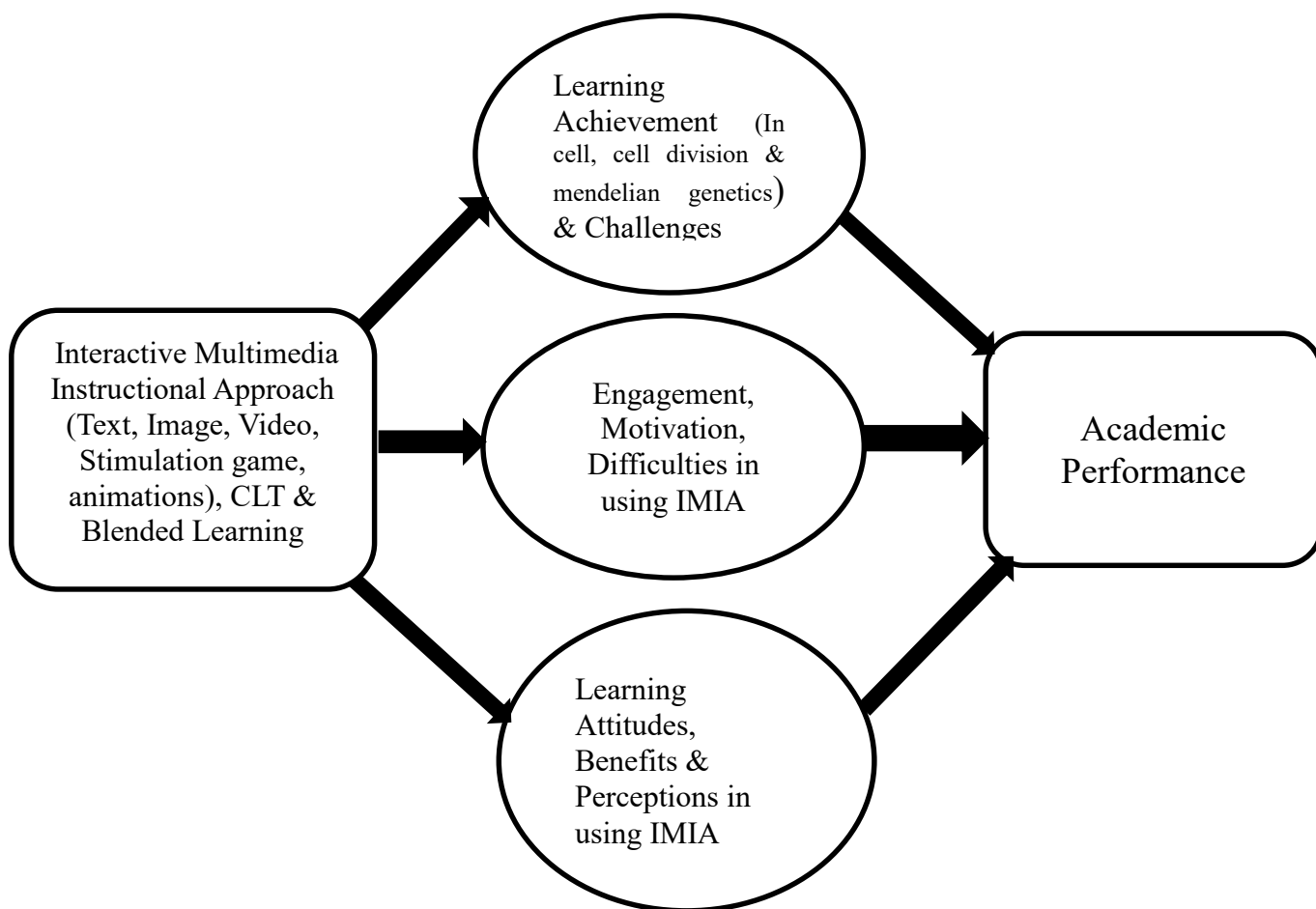


Figure: 1
Conceptual framework for enhancing learning through IMIA adapted from Al-Ani (2013)

2.2.1 Practical strategies to optimize learning through cognitive load theory

To optimize learning according to cognitive load theory, instructional materials should be designed or selected in a way that reduces extraneous cognitive load and maximizes germane cognitive load (Van Merriënboer & Sweller, 2010). Below are some of practical strategies that can be employed:

2.2.2 Multimedia principles

Mayer and Moreno (2003) proposed several principles for designing effective multimedia materials. These include the coherence principle-presenting information in a coherent and organized manner, the signalling principle-highlighting important information, and the multimedia principle-presenting information in both visual and

auditory formats (Mayer, 2017; Ofori, 2021). Following these principles can help reduce extraneous load and facilitate cognitive processing.

2.2.3 Scaffolding and guidance

Providing guidance and support during the learning process can help reduce the intrinsic load and facilitate schema acquisition. Scaffolding techniques, such as providing hints, step-by-step instructions, and worked examples, can effectively guide learners through complex tasks (Kirschner & Erkens, 2006).

2.2.4 Multimedia interactions and simulations

Interactive multimedia instructional approach such as simulations and virtual environments can provide learners with hands-on experiences and promote active engagement. These types of activities can increase germane load by allowing learners to explore, manipulate variables, and observe the outcomes of their actions (Höffler, 2010).

2.2.5 Prior knowledge activation

Activating learners' prior knowledge is important for reducing extraneous cognitive load. Connecting new information to existing knowledge structures can facilitate learning and increase germane load (Renkl, 2014). Activities like concept mapping or retrieval practice can help learners make connections between new and previous knowledge. Cognitive Load Theory provides a valuable framework for understanding how the cognitive demands of instructional materials impact learning (Sweller, 2010). Educators can design instructional materials that optimize cognitive processing and enhance learning outcomes by considering the intrinsic load, extraneous load, and germane load. Applying the principles of cognitive load theory in the design of multimedia materials for biology concepts like cell division and Mendelian genetics can promote effective learning experiences (Renkl, 2014). Cognitive Load Theory

which was coined in 1988 by John Sweller, suggested that our working memory is only able to hold a small amount of information at any one time and that instructional approaches should avoid overloading it in order to maximise learning (Sweller, 1988; Williams, 2023).

2.2.6 Why have I chosen to build my conceptual framework from this theory?

We all have been in learning sessions where the teacher has whizzed through the content, leaving us with little to remember. We have also been in sessions where the content was so complex that we leave more confused than when we entered. Cognitive Load Theory goes some way to explaining why this happens and what we, as teachers (Williams, 2023), can do to maximise the learning of individuals within our classrooms. Building on the work of Baddeley and Hitch (1974), Cognitive Load Theory views human cognitive architecture as the working memory and long-term memory. Put simply, the working memory has a limited capacity and consists of multiple components that are responsible for directing attention and coordinating cognitive processes. Long-term memory, on the other hand, has an endless capacity for storage and works with working memory to retrieve information (Baddeley, 2003). It was upon this basis that I chose to build my conceptual framework from the Cognitive Load Theory for the study with the pre-service science teachers to overcome the extraneous loads to understand the abstracts, complex and confusing nature of cell structure, cell division and Mendelian genetics concepts in biology class.

2.2.7 What can teachers do to reduce cognitive load?

Educators must activate students' prior knowledge before introducing new information, as this process enhances learning and comprehension. According to Sweller (2010), long-term memory contains organized patterns of knowledge known as schemas, each of which functions as a single unit within working memory. This allows

learners to process complex information more efficiently by integrating new content with existing cognitive structures. Activating prior knowledge helps students retrieve relevant information from long-term memory, making it accessible for processing in working memory. Techniques such as quizzes, visual aids, and guided discussions serve to stimulate recall and facilitate the assimilation of new knowledge (Baddeley, 2003; Gill, 2007; Williams, 2023). Marzano et al. (2000) found that student achievement significantly improves when instruction is connected to existing knowledge. Moreover, retrieval practice has been shown to reinforce long-term retention, making it a powerful strategy for both teaching and learning (Williams, 2023).

2.2.8 Long term memory working memory

Long-term memory interacts with working memory, which utilizes both visual and verbal channels to process and present information to learners (Cowan, 2008). This dual-channel approach should not be confused with the widely debunked concept of learning styles. Instead, empirical research supports the idea that working memory has two distinct modalities for processing input: one for auditory information and another for visual information (Baddeley, 2020). When instructional materials align these channels, such as combining narration with relevant imagery, the cognitive burden on working memory is reduced, thereby enhancing comprehension and learning efficiency. This integration minimizes cognitive overload by distributing information processing across both modalities rather than overloading a single channel.

2.2.9 Working memory

Sweller and Chandler (1991), in their influential article Evidence for Cognitive Load Theory published in *Cognition and Instruction*, presented a substantial body of evidence demonstrating the effectiveness of worked examples in enhancing learning outcomes. To Clark et al. (2006), a worked example is a step-by-step demonstration of

how to perform a task or solve a problem. These structured examples serve as cognitive scaffolds, providing learners with clear guidance that facilitates the development of mental models (Baddeley, 2012). By offering a concrete representation of problem-solving processes, worked examples reduce the cognitive demands on learners, allowing them to focus on understanding rather than problem generation.

In contrast, discovery or problem-based learning can place a heavy burden on working memory, particularly for novices who lack sufficient prior knowledge to support their learning (Kim, 2017). The cognitive strain associated with processing large volumes of information independently may hinder learners' ability to focus and apply strategies effectively (Wickens, 2020). As learners become more proficient, elements of the worked examples can be gradually withdrawn, a strategy known as "fading", to encourage autonomy and reinforce independent problem-solving skills.

Ultimately, regardless of one's educational philosophy, it is vital for educators to understand both the benefits and limitations of different instructional methods. As William (2023) argued, teachers should be equipped with a foundational understanding of Cognitive Load Theory and its practical applications. The insights provided by CLT and related empirical research enable educators to design instruction that aligns with how students most effectively process, organize, and retain information (Plass et al., 2010).

2.2.10 The relationship between cognitive load theory and interactive multimedia instructional approach

Interactive multimedia instructional approach, when designed with cognitive load theory (CLT) in mind, can be used to optimize cognitive load and improve learning outcomes (Mutlu-Bayraktar et al., 2019). CLT, developed by John Sweller, explains the impact of cognitive load from instructional materials on student learning (Sweller,

1988). It argues that learners have a limited capacity in working memory and that instructional design should aim to reduce extraneous cognitive load while increasing germane cognitive load (Sweller, 2010). Interactive multimedia instructional approach involves digital content that enables users to engage actively with the material, such as through simulations, interactive exercises, or multimedia presentations (Mutlu-Bayraktar et al., 2019).

When multimedia approaches are designed with CLT principles, they can help manage cognitive load by offering opportunities for active engagement, allowing learners to manipulate information and receive prompt feedback (Paas et al., 2004). For instance, a study by Mayes and de la Rosa (2012) explored the effect of interactive multimedia instructional approach on cognitive load and learning performance. The study showed that learners who used multimedia with both visual and verbal explanations, which reduced extraneous cognitive load, performed better on a transfer test than those who only received verbal explanations. This research highlights how interactive multimedia instructional approach can enhance learning by optimizing cognitive load. Additionally, Paas et al. (2004) introduced the cognitive load theory of multimedia learning," suggesting that instructional approaches should combine visual and verbal content and include interactive components to foster active learning. This approach underscores the importance of designing multimedia approaches that align with cognitive load principles to support effective learning (Paas et al., 2004).

2.3 Meaning of Multimedia

Computer technology has significantly transformed information production in the latter half of the twentieth century (Campbell-Kelly et al., 2023). Initially, personal computers were primarily text and data-focused until the 1980s, when graphical environments started emerging. During the 1990s, the ability to process and handle

various forms of media rapidly grew, turning personal computers into multimedia machines and marking the onset of the multimedia technology era (Ramaiah, 2005). Research in computer technology has shown that people typically remember 20% of what they see and 30% of what they hear, but they retain 50% of what they both see and hear (Dizon, 2016).

Multimedia technologies allow users to combine and manipulate data from diverse sources such as text, images, audio, video, graphics, and animation on a single platform (Raper, 2020). According to Raper, multimedia have become a significant cultural phenomenon in the information sector. The rapid growth of multimedia technologies in recent years has brought about profound changes in computing, entertainment, and education (Dizon, 2016). This expansion has presented new opportunities and challenges to the computerized society (Aart, 2004). The popularity of multimedia technology continues to rise due to its effectiveness in various aspects of human life (Shuib et al., 2015; Xu et al., 2021). The advancement of multimedia applications has led to a fundamental shift in how information is transferred and presented.

The term multimedia combines two components: “multi” (meaning many, at least two) and “medium,” which refers to forms of storage, transmission, communication, and presentation (Zin, et al., 2013). Medium can also encompass basic information types such as text, graphics, audio, animation, and video (Parekh, 2006). Thus, multimedia refers to the integration of multiple media types within a single medium, creating a cohesive unit of information.

According to the Columbia Encyclopaedia, multimedia in personal computing refers to software and applications that blend text, high-quality sound, two- and three-dimensional graphics, animation, images, and full-motion video (Furht, 2008).

Mukherjee (2018) defines multimedia as a blend of text, sound, animation, and video, delivered through computers or other digitally manipulated means. Islam (2020) describes multimedia as a woven combination of digitally manipulated text, photographs, sounds, graphic art, and video elements. Williams and Newton (2009) describe multimedia as the combination of various media types to communicate information between users and their computers, typically incorporating voice, sound processing, and image processing.

Dhiya Eddine and Abdelfettah (2020) highlighted multimedia as a fusion of previously separate technologies, integrating text, graphics, sound, and still or motion pictures to effectively present information. The merging of print, telecommunications, video, broadcasting, and computers has resulted in the multimedia we recognize today (Dhiya Eddine & Abdelfettah, 2020). Hassoun (2014) defines multimedia as the simultaneous use of multiple forms of media, including text, graphics, animation, sound, and video, for effective communication. Terms like graphics, digital or analog video, animation, virtual reality, and electronic books have all been associated with multimedia (Hassoun, 2014). In essence, multimedia is a technology that uses a variety of media, such as text, audio, video, graphics, and animation, either separately or in combination, to communicate ideas or disseminate information via computers.

2.4 Components of Multimedia

The five core elements of multimedia are text, sound, images, animation, and video. Each contributes uniquely to creating interactive and compelling multimedia experiences. Explanation of these components as outlined by Vaughan (2016).

2.4.1 Text

Text, or written language, is one of the most common and fundamental forms of communication, particularly in multimedia. Initially, it was primarily associated with printed media such as books and newspapers, which used various typefaces to display characters, numbers, and symbols. While multimedia products incorporate pictures, audio, and video, text often remains the most prevalent data type found in multimedia applications. Additionally, text offers the potential to extend traditional communication by linking it to other media, thereby creating an interactive experience.

Static Text: Static text refers to words that are carefully arranged to blend seamlessly with the surrounding graphics. In this format, the text is integrated into the design, much like how text and visuals are presented in a printed book, making the information easy to read and accessible. This format allows learners to view both images and text on the same screen simultaneously (Myhill, 2005).

Hypertext: Hypertext systems consist of interconnected nodes that contain text and links between them. These links define the non-sequential paths users can follow to access information, creating a web of related meanings and concepts. The author of the system typically creates this structure, although advanced hypertext systems often allow users to define their own navigation paths. Hypertext offers users the flexibility to explore material at their own pace and in a non-linear manner.

When using text in multimedia products, it is essential to ensure that it conveys clear and necessary information, placed appropriately within the design. Proper formatting, including well-structured sentences and paragraphs, spacing, and punctuation, is crucial for readability. Additionally, choosing the right fonts and styles helps enhance the communication of the message and improves overall user experience (Zammit, 2011).

2.4.2 Image

Images are a key element in multimedia, and they can be generated in two primary forms: bitmap (or raster) images and vector images.

Raster or Bitmap Images: Bitmap images are the most common form of image storage on computers. They are made up of a matrix of tiny dots called pixels (Ogli & Dilshod, 2021). Each pixel can have two or more colours, and the number of colours in an image is determined by the colour depth, which is measured in bits. For instance, one bit represents two colours, four bits give 16 colours, eight bits provide 256 colours, and so on, up to millions of colours depending on the system's capabilities. Bitmap images are designed to look as close to the original object or scene as possible, and factors like size, colour, proportion, and texture need to be accurate. Common bitmap formats include Windows Bitmap (BMP), Device Independent Bitmap (DIB), and Windows Run Length Encoded (RLE) (Kuo et al., 2005).

Vector Images: Unlike bitmap images, vector images are based on geometric shapes like lines, circles, and rectangles to form an image. The key advantage of vector images is their ability to be much smaller in file size since they rely on a set of drawing commands rather than individual pixels. As a result, vector images require less memory to store. However, the truth is that vector images may not convey as much detail as bitmap images. The most commonly used vector format in Windows operating systems is the Windows Metafile. Compression techniques like GIF, TIFF, and JPEG are often used to reduce image file sizes, which are particularly helpful for storing large numbers of images and speeding up transmission in networked environments (Moxey et al., 2003).

Animation: Animation involves displaying a series of still images so quickly that they appear to move continuously. In animations, the screen object is typically a

vector image (Tversky et al., 2002). The movement of objects in animation is achieved by applying numerical transformations to their coordinates. For smooth animation, the frame rate must be at least 16 frames per second, while 25 frames per second is typically needed for natural-looking motion. Animations can be either two-dimensional (2D) or three-dimensional (3D) (Siyao, et al., 2021). In 2D animation, the movement occurs along the X and Y axes, while in 3D animation, movement takes place across all three axes, X, Y, and Z, and is typically rendered using high-end 3D software. There are two main types of animations: path animation and frame animation (Parent, 2012).

Path Animation: Path animations involve moving an object along a fixed path on the screen with a static background. For example, a cartoon character may move across the screen without altering the background (Parent, 2012; Gómez-Albarrán, 2005). **Frame Animation:** In frame animations, multiple objects can move simultaneously, and both the objects and the background can change. Frame animation is particularly useful for demonstrating processes or changes, as it allows learners to visually follow complex transformations (Wells, 2011). Unlike digital video, which requires more memory, animation is a memory-efficient alternative, especially when moving visuals are necessary but digital video would be too resource-intensive or unnecessary.

2.4.3 Sound

Sound is one of the most immersive elements in multimedia, capable of conveying meaning through speech, enhancing enjoyment through music, providing impactful sound effects, or establishing atmosphere through background audio (Mayer, 2017). Mayer emphasized that sound not only adds emotional depth to content but can also humanize a digital space, such as by featuring a speaker's voice on a website or helping learners with pronunciation in language learning.

Musical Instrument Digital Interface (MIDI): MIDI, developed in the early 1980s, is a protocol for communication between electronic musical instruments and computers (Frid, 2019). It serves as a compact digital notation for music, representing musical events numerically. MIDI is highly efficient for creating original soundtracks for multimedia, requiring sequencing software and a sound synthesizer. A MIDI keyboard can assist in composing by making musical input more intuitive. However, the audio quality produced by MIDI depends heavily on the instruments used and the specifications of the playback system, making it device-dependent (Kerr, 2009).

Digital Audio: Watkinson (2013) described digital audio as sound that has been captured and stored through sampling, a process where snapshots of sound are taken at precise intervals and converted into digital data. The clarity and fidelity of the recorded sound are influenced by two main factors: how frequently samples are taken (sampling rate) and how detailed each sample is (bit depth). The higher these values, the more accurately the sound is represented (Painter & Spanias, 2000). In addition, the original sound quality, recording equipment, software, and playback hardware all affect the final audio experience (Watkinson, 2013). One of the advantages of audio in multimedia is that it uses a separate communication channel from visuals, allowing for layered information delivery (Pohlmann, 2000). However, its use must be balanced carefully to avoid overwhelming the user (Kefauver & Patschke, 2007). In multimedia, digital audio is commonly used for narration, instructional content, and sound effects that signal transitions or actions within an application (Pohlmann, 2000). Common sampling rates include 44.1 kHz (CD quality), 22.05 kHz, and 11.025 kHz. Audio is also a crucial element in digital video (Hussain, 2020)

2.4.4 Video

Video refers to the visual representation of real-life events displayed on a screen, similar to a television (Woolfitt, 2015). Integrating video into multimedia platforms is a highly effective method for delivering content, offering a personal touch that is often absent in other forms of media (Aart, 2004). The presence and expression of a presenter can be visually communicated through video (Korkut, 2022). Jack (2011) classified video into two types: analogue and digital.

Analogue Video: This type refers to video content stored on non-digital media like tapes, laserdiscs, or film. It is categorized into composite and component formats. In composite analogue video, various elements such as brightness, colour, and synchronization are merged into one signal. However, this integration leads to lower quality, with issues such as colour bleeding, reduced clarity, and significant quality degradation when copied, known as generational loss (Jack, 2011). This format was typical of consumer video systems like VHS and Betamax and was not considered suitable for high-quality multimedia use (Liang et al., 2017).

Digital Video: Digital video is considered one of the most engaging components of multimedia, effectively bridging users with real-world experiences (Tekalp, 2015). Despite its advantages, it is storage-intensive; for example, a single high-resolution frame may consume over a megabyte of memory. Displaying smooth motion requires at least 30 frames per second, equating to around 30 megabytes of storage per second of video. Watkinson (2012) emphasized that higher frame rates yield better quality, but also demand higher bandwidth, particularly for network streaming. Advances in compression technology have significantly addressed these challenges.

Several standards exist for video compression, such as MPEG, JPEG, Cinepak, and Sorenson (Haskell et al., 2007). Additionally, streaming platforms like Adobe

Flash, QuickTime, Real Player, and Windows Media have made it possible to transmit acceptable-quality video over limited bandwidth. Among digital formats, composite digital video encodes visual data into binary form but still suffers some limitations of analogue formats. In contrast, component digital video maintains high image quality without compression, although it is typically costly. Well-known formats in this category include Digital Betacam, D-5 (developed in 1994), and DVCAM (introduced in 1996) (Jon Fauer, 2013).

Digital video broadcasting also adheres to international standards. ATSC is used in North America and South Korea, DVB is prevalent in Europe, and ISDB is Japan's digital broadcasting standard for radio and television (Jon Fauer, 2013). Videos are particularly useful in educational and cultural contexts where dynamic visual representation improves understanding. For instance, demonstrating cultural dance movements is more effectively done through video than static images or animation (Duranti & Thibodeau, 2006).

2.5 Importance and Effects of Multimedia Instructional Approach

The roles and effectiveness of multimedia systems have been widely examined in academic research. One of the standout features of well-designed multimedia courseware is user interactivity. According to Guan et al. (2018), numerous studies underscore the significance of multimedia technologies in education and highlight their broad integration into learning environments. This widespread adoption stems from the numerous advantages multimedia applications offer (Almarabeh et al., 2015). Some key benefits of multimedia approaches in teaching and learning include:

- Transforming abstract concepts into tangible and understandable content
- Delivering large volumes of information efficiently in a short time with reduced effort

- Enhancing student engagement and interest in learning
- Enabling teachers to better assess student comprehension and learning progress
- Cultivating a sense of anticipation and curiosity among students energize or relax students for learning exercise
- Draw on students' imagination
- Improve attitudes toward content and learning
- Build a reference to other students and instructor
- Increase the memory of the content
- Increase students understanding
- Foster creativity
- Stimulate the flow of ideas
- Foster deeper learning
- Function as vehicle for collaboration
- Inspire and motivate students
- Make learning fun
- Set an appropriate mood or tone
- Decrease anxiety and tension on scary topics/concepts and make memorable visual images.

The significance of multimedia technologies and applications in education, both as teaching aids and learning tools, is widely acknowledged and supported by numerous studies. Research has consistently highlighted the positive impact of multimedia on the educational process. For instance, Milovanović et al. (2013) emphasized the effectiveness of multimedia approaches in enhancing students' understanding, particularly in mathematics instruction. A substantial body of literature confirms that multimedia fosters improved learning outcomes (Aloraini, 2012; Al-Hariri & Al-

Hattami, 2017; Barzegar et al., 2012; Chen & Xia, 2012; Dalacosta et al., 2009; Jian-hua & Hong, 2012; Keengwe et al., 2008b; Kingsley & Boone, 2008; Shah & Khan, 2015; Taradi et al., 2005; Zin et al., 2013).

Multimedia instructional approach simplifies complex or abstract concepts, accommodates diverse learning styles, and presents multiple forms of content with cohesive visual and conceptual coordination (Aloraini, 2012). Al-Hariri and Al-Hattami (2017) noted that computer-based tools, when designed with appropriate fonts and styles, serve as an effective interface between learners and educational content, contributing meaningfully to the teaching and learning experience. Nonetheless, some challenges remain in using multimedia for educational purposes. Interactive multimedia instructional approach empowers users with features like linking, sorting, searching, and annotating, which help reinforce intellectual development and support meaningful learning. These tools meet cognitive needs by enabling immediate exploration of curiosity-driven paths and facilitating the simultaneous comparison of various information formats (Barzegar et al., 2012).

Interactive multimedia instructional approach programs usually integrate some combination of orientation tools, like timelines, graphs, glossaries, and other pedagogical guides and these types of tools further point to a different major advantage of multimedia: The personalization or individualization of the training experience. By allowing users to manage the sequence and also the pacing of the materials, Multimedia packages facilitate greater individualization in learning, allowing students to proceed at their own pace during a tailored learning environment (Chen & Xia 2012). In other words, object-oriented database management system, properly developed and properly implemented, could reform education.

According to Roschelle et al. (2000), reform or change in education system is also a touch optimistic, multimedia system may be a promising medium for reinforcing, extending, and complementing what goes on within the classroom with print materials, lectures, and classroom discussions. Research has shown that interactive learning environments contribute significantly to the development of effective instructional and learning systems (Dalacosta et al., 2009; Jian-hua & Hong, 2012; Shinde, 2003). Notably, Richard Mayer's extensive work over the years supports the conclusion that multi-modal instruction, using more than one type of media, is more effective than relying on a single mode of delivery (Mayer, 1997; Mayer, 2005; Norhayati & Siew, 2004). His findings suggest that the medium of instruction can influence learning outcomes by enabling different educational possibilities. For example, video, which provides both visual and auditory input, is generally more effective for learning than audio-only media like radio.

Visual representations of concepts are especially beneficial, as they enhance comprehension and support the learning process (Mayer, 2005). Multiple studies reviewed by different scholars indicate that learners exposed to computer-based multimedia instructions often outperform those taught through conventional classroom methods, particularly in test scores (Keengwe et al., 2008b; Kingsley & Boone, 2008; Shah & Khan, 2015; Taradi et al., 2005; Zin et al., 2013).

Further research by Bayhan et al. (2002) highlighted the use of computers at home to develop mathematical thinking, noting the potential of computer games to facilitate such learning. Similarly, Charp (2003) reported that children with access to personal computers and the internet at home are better positioned to grasp foundational academic skills, such as basic mathematics and literacy. Early exposure to technology presents new opportunities for both young children and the teaching strategies used in

early childhood education. Scholars have coined terms such as ‘Generation Y’ (Eckleberry-Hunt & Tucciarone, 2011; Charp, 2003), ‘Digital natives’ (Marc, 2001), and ‘Millennials’ (Gorman et al., 2004; Kurz, Li & Vine, 2019) to describe the current generation raised in a technology-rich environment.

Today’s homes are filled with digital devices like TV remotes, programmable microwaves, wireless phones, computers, and gaming systems like PlayStation and Xbox, that provide new forms of play beyond those found in non-digital settings (Zevenbergen, 2007). As a result, educators must continually adapt and upgrade their skills to integrate technology into their teaching, regardless of their subject area. Studies support the effectiveness of digital tools in education. For example, Nocek (2015) found that animation enhances the teaching of biology, while Ward (2013) emphasized that interactive animations with features like hotkeys and rollovers significantly improve learning outcomes. Stith (2004) also showed that animations combined with audio, video, and motions are more effective than static images in teaching cell biology. Cronje and Fouche (2008) studied differences in mental models between learners and instructional designers by examining how six high school students learned electrical principles. Their findings revealed that students and designers often conceptualize information differently. Additionally, Nusir et al. (2013) found that allowing advanced learners to freely navigate multimedia content accelerates their learning.

Holzinger et al. (2009) compared the effectiveness of simulations and traditional text-based lessons in teaching complex physiological concepts to medical students. They found both methods equally effective, though adding guided support to the simulations further improved learning. Finally, Kamat and Shinde (2009) conducted tests on various hypermedia packages for students in grades I to IV, further supporting the value of interactive multimedia instructional approach in education. Kamat and

Shinde (2009) concluded that multimedia packages are commonly used in subjects such as science, mathematics, geography, and history. They emphasized that interactive multimedia instructional approaches are significantly more effective than traditional teaching methods that rely on lectures and chalk-and-talk strategies. One innovative application of multimedia in education is through educational computer games. Ke (2008) conducted a study to investigate the effects of such games on fourth and fifth-grade students' mathematics learning. The study assessed cognitive achievement in mathematics, metacognitive awareness, and attitudes toward learning. Findings revealed that educational games positively influenced student engagement and interest in mathematics during the initial five weeks of use.

Similarly, Liu et al. (2009) supported previous research by confirming the positive impact of media-rich e-learning systems on users' intentions to adopt and engage with them. Their study showed that e-learning platforms incorporating a combination of text, audio, and video led to higher perceived usefulness and learner concentration compared to systems using fewer media types (Jenkinson, 2017). Evans and Gibbons (2007) explored the effects of adding interactivity to computer-based learning modules in business and management education. They studied a small sample of undergraduate students (22 males and 11 females), randomly divided into interactive and non-interactive groups. Their results reaffirmed that interactive visualizations enhance learning depth and conceptual understanding. Nusir et al. (2013) also found that the dynamic elements of multimedia help children develop mental models more effectively and improve comprehension. In their study on using multimedia programs to teach basic math skills, they concluded that on-going technological advancements offer new opportunities to enrich instructional approaches. Specifically, multimedia

approaches can enhance educators' ability to deliver content in an engaging, interactive format that surpasses traditional approaches.

These multimedia-based teaching approaches can assist students by presenting information through multiple channels that are often easier to understand, engage with, and retain. Offering alternative instructional approaches is particularly beneficial for children, individuals with special needs, or students in rural areas, where they can have access to qualified instructors, especially for core subjects, may be limited. The purpose of the study by Nusir et al. (2013) was to investigate the impact of multimedia technologies on enhancing teaching effectiveness among early primary school students in Jordan. To achieve this, a specialized program was developed to assess students' comprehension of basic mathematical concepts and skills. Two groups from a local school were selected based on their existing classroom distribution. One group was taught using the multimedia-based program, while the other group received instruction through traditional teaching approaches.

Upon analyzing the collected data, results indicated that multimedia-enhanced teaching approaches, particularly those incorporating cartoon characters were effective in capturing students' attention and engagement. However, the study also revealed no statistically significant difference in knowledge acquisition or learning skills based on gender; both boys and girls performed similarly in terms of understanding and retaining basic mathematical skills. Roschelle et al. (2000) emphasized that effective learning environments are characterized by active engagement, collaboration, frequent feedback, and connections to real-world contexts. They criticized traditional teaching approaches for lacking these essential components and argued that innovative computer-based approaches better support these attributes. Furthermore, they advocated for the integration of entertainment within educational practices to enhance

student participation. Incorporating familiar and enjoyable elements such as games or social media platforms into classroom instruction can make learning more appealing and effective. Similarly, Mustafa and Sharif (2011) asserted that well-designed hypermedia e-learning systems have the potential to draw learners toward more in-depth exploration of content. Supporting this, Said (2007) highlighted that building a foundational design model for multimedia systems in e-learning environments can significantly promote active learner engagement, which is critical for improving educational outcomes.

2.6 Interactive Multimedia Instructional Approach

The term Interactive Multimedia Instructional Approach has been a very trendy and meaningful concept for a long time (Gitelman, 2008). Interactivity, in the term adopted here, means the potential of technical devices for maintaining a human-digital relationship with the required aspect of participation and interaction (Sundar & Limperos, 2013). In turn, the concept of interaction in the teaching process itself is understood as the kind of interaction between a teacher-educator and a student or a group of learners (Khoza, 2024). The technological interaction is also mentioned which is related to the impact of technical means and innovative communication methods (Siemieniecka et al., 2017). In information technology, interaction means the mode of operation consisting in alternating exchange of information between the user and the computer, the user issues commands to the computer, whose effects can be monitored and used to make further decisions (Fischer, 2011; Gill, 2007). Human interaction with the computer becomes a key mechanism for acquiring knowledge, education, and furthering education, developing interests and passions, and realizing the idea of lifelong education (Ala-Mutka, 2009; Solomon, 2013).

The long-term empirical research on the use of media and digital technologies has confirmed the need to use activation methods with a high level of interaction (Pimmer, et al., 2016). According to researchers, multimedia or digital learning approaches assist learners in developing effective mental representations through the use of different media elements that support information processing. These approaches typically present content and learning activities using a combination of text, images, video, and audio. Research has shown that learners who study with both pictures and words achieve better outcomes than those who study with words alone (Chen & Liu, 2008; Mayer, 2008). Eady and Lockyer (2013) explained that digital resources support various teaching approaches. In their work, they demonstrated how educators used these approaches to introduce new concepts, provide demonstrations, stimulate group discussions, offer access to different types of texts, and engage students in an interactive way. Generally, multimedia technologies used in education can be categorized based on whether they support teaching or learning. Eady and Lockyer (2013) identified a variety of digital resources applied in educational settings. Additionally, Guan et al. (2018) noted that several studies have confirmed the value of multimedia technologies in education and have documented their widespread use. This growing adoption of multimedia tools is largely due to the numerous benefits they offer for improving teaching and learning (Almarabeh et al., 2015).

According to the researchers, some of the benefits of multimedia application tools for teaching and learning are summarized as follows:

1. The ability to turn abstract concepts into concrete content.
2. The ability to present large volumes of information within a limited time with less effort.
3. The ability to stimulate students' interest in learning.

4. The ability to provide teachers with insight into students' progress in learning.

Multimedia designed for learning refers to the process of building mental representations from words and pictures in various contexts. These approaches are designed to assist learning through presentations, classroom or laboratory settings, simulations, e-learning, computer games, and virtual reality, allowing learners to process information both in verbal and pictorial forms (Alemdag & Cagiltay, 2018). Effective multimedia learning requires an understanding of certain theories, such as the cognitive theory of multimedia learning, which postulates three assumptions describing how people learn from instructional multimedia approaches. These assumptions include dual-channel, limited capacity, and active processing (Alemdag & Cagiltay, 2018). The dual-channel assumption suggests that learners have separate channels for visual and auditory information. The limited capacity assumption indicates that there is a limit to the amount of information that can be processed in each channel. Understanding these principles helps prevent overwhelming learners with excessive information while enabling them to recognize their information-processing limitations. Active processing proposes that humans actively manage the selection, organization, and integration of the information they interact with.

The appropriate use of information and communication technology (ICT) in teaching transforms the learning environment from being teacher-centered to being learner-centered (Coleman et al., 2016), just as it is transforming all aspects of human life (Guan et al., 2018). Coleman et al. (2016) emphasized that shifting from teaching to learning creates a student-centered environment where teachers act as facilitators rather than traditional figures of authority. In this context, the role of the teacher changes from a knowledge transmitter to that of a facilitator, knowledge navigator, and co-learner. Keengwe et al. (2008a) concluded that the application of multimedia

technologies ensures highly productive, engaging, motivating, and interactive classroom instruction while addressing the diverse needs of learners.

2.7 Role of Multimedia Technology in Teaching and Learning

Technology is constantly evolving, and scholars in the fields of Information Technology (IT) and educational technology continue to explore how multimedia technologies can enhance teaching and learning (Laurillard et al., 2009). Software tools can be used to expand teaching and learning across various fields, providing students with practical experience in many areas. The importance of multimedia technologies and applications in education, as both teaching and learning tools, cannot be overstated. Several studies have investigated the impact of multimedia technology on the education system, confirming that multimedia significantly enhances students' learning (Aloraini, 2012; Al-Hariri & Al-Hattami, 2017; Barzegar et al., 2012; Chen & Xia, 2012; Dalacosta et al., 2009; Jian-hua & Hong, 2012; Keengwe et al., 2008b; Kingsley & Boone, 2008; Shah & Khan, 2015; Taradi et al., 2005; Zin et al., 2013).

Additionally, Abdulrahaman et al. (2020) demonstrated in their study that the use of multimedia approaches in Mathematics classes greatly enhances students' learning. Multimedia communication shares similarities with face-to-face communication, allowing for the simplification of abstract content, accommodating individual differences, and offering diverse perspectives. The use of computer-based techniques as an interface between students and the content they are learning, with appropriate fonts and design, can be very valuable. Multimedia technology clearly contributes to improvements in teaching and learning. However, there are some limitations to its use in educational settings, such as unfriendly programming or user interfaces, limited resources, lack of necessary knowledge and skills, limited time, and high maintenance costs, among others (Aljazzaf, 2020; Putra, 2018).

Multimedia approaches are becoming increasingly accessible and are widely appreciated by language instructors, who incorporate them into their lessons and assessments through video, film, and computer-based learning methods. These approaches enhance the effectiveness of teaching by providing students with exciting and innovative ways to learn a language. In today's technology-driven world, where students are constantly surrounded by digital approaches, the integration of multimedia in education offers a powerful approach to language learning. Technological advancements in schools are providing educators with the necessary approaches to foster effective teaching practices (Healey, Hegelheimer et al., 2008). By leveraging multimedia, teachers can seamlessly integrate technology into their courses, enhancing their instructional methods.

Rana (2013) highlights several key advantages of using multimedia technology in education. One of the major benefits is its ability to motivate students. Humans are naturally visual creatures, and what we see often influences our judgments. By incorporating visual elements into learning, multimedia makes lessons more engaging and significantly more effective than traditional lecture-based methods. Furthermore, multimedia approach facilitate easier access to information about the culture of the target language, creating an immersive, real-life speaking environment that sparks curiosity and boosts students' interest in language acquisition. This approach allows learners to break free from the constraints of time and space, offering a dynamic learning experience (Kumar, 2021). Another benefit of multimedia is its role in enhancing communicative skills. The integration of multimedia technology supports a more comprehensive approach to education, motivating students to succeed and preparing them for the competitive job market (Healey et al., 2008). By combining the instructor's guidance with multimedia approaches, students' critical thinking is

stimulated, and their motivation is further encouraged. Hossain (2021) also emphasizes the importance of multimedia technologies in breaking the monotony of traditional classroom teaching. By incorporating engaging tools like PowerPoint, educators can enhance students' understanding of the subject matter and develop their critical thinking abilities. Additionally, multimedia fosters an environment conducive to group discussions, debates, and the exchange of ideas, offering more opportunities for students to engage in communication. Hossain concluded that multimedia tools are integral in nurturing students' communicative abilities and improving their overall learning experience.

Multimedia approaches are also closely associated with enhancing students' understanding of the target culture. These approaches help students access information about cultural backgrounds and real-life experiences, motivating them to learn (Dema & Moeller, 2012). Additionally, multimedia approaches contribute to increased teacher efficiency. They supplement teaching materials and facilitate best practices, ultimately improving teaching effectiveness. Unlike traditional teaching methods, which focus primarily on instructors, multimedia approaches enhance language learning by enabling more interactive and personalized learning experiences. These approaches overcome the limitations of crowded classrooms and large course sizes, offering one-on-one participation and helping extend learning beyond the classroom setting. This flexibility allows for more realistic learning environments and provides students with additional knowledge and practice opportunities. Furthermore, multimedia approaches enhance teacher-student engagement. According to Motteram (2013), technology use can improve physical classroom settings by promoting active student involvement and fostering stronger teacher-student connections. The teacher's role as a facilitator becomes increasingly important in this context. Multimedia technologies encourage

information sharing and emphasize the importance of meaningful, real-world interactions, creating a more collaborative learning environment (Warschauer & Meskill, 2013). This approach enhances the traditional teaching model, shifting away from passive learning and toward more engaged participation.

Lastly, the integration of multimedia approaches in schools helps create a conducive teaching and learning environment, particularly in science education. Healey et al. (2008) emphasized that while technology alone cannot improve teaching, its proper use can support students in achieving their learning objectives. Multimedia approaches, with their vibrant and visible features, actively engage both students and instructors, particularly in science education, where visual and auditory elements can enhance the learning experience.

2.8 Weaknesses in the Uses of Multimedia Instructional Approach in Biology Instruction

2.8.1 Dependence on supplementary tools

Multimedia can be a valuable teaching approach, but if instructors rely solely on it, they may lose their ability to effectively facilitate students' learning. Over-dependence on multimedia devices can limit teachers from fulfilling their essential role as guides and mentors (Kumar et al., 2021). While many educators use multimedia technology in their lessons, they may not always be adequately trained to utilize these tools effectively (Bray & Tangney, 2017). One concern is that the use of multimedia in the classroom can reduce interaction between teachers and students. Effective communication activities are essential in language courses, and teachers must help students improve their pronunciation, understanding of phrases, thinking skills, and ability to express their learning (Kumar, 2021).

Kumar also points out that when multimedia technology is implemented, it often leads to a lack of interaction both among students and between teachers and students. The auditory, visual, and textual elements may capture students' attention, but they can replace direct teacher instruction with computer-generated sound and visuals, leaving little room for student interaction. Without opportunities for logical and abstract thinking, students may absorb information quickly but lack the development of critical thinking skills (Marton & Pang, 2015).

Learning involves progressing through stages of perception followed by rational development, which fosters critical thinking and independent learning, while also encouraging positive interactions (Healey et al., 2008). Therefore, teachers need to understand that knowledge plays a critical role in bridging perceptual and cognitive learning. Nowadays, students are increasingly concerned about the decline in effective learning methods due to limited access to technology (Liu et al., 2018).

2.8.2 Expensive Education on Multimedia Technology

The implementation of multimedia technologies in science education can be an expensive and underutilized approach to conducting lessons (Panthee, 2012). While it can enhance educational efficiency, it often leads to increased costs. These expenses typically cover hardware, software, personnel, and training, especially when setting up a networked computer laboratory that both teachers and students can access. According to Healey et al. (2008), the ability to work with computers and other digital technologies, as well as the global connectivity enabled by the internet, has significantly advanced language learning. However, the rapid pace of technological advancements has made it challenging for many educators and administrators to effectively integrate computers into their teaching practices. Despite this, many countries have modernized

their equipment and successfully demonstrated the positive impacts of integrating technology into education (Liu et al., 2018).

2.9 Precaution to the use and Function of Multimedia Instructional Approach in Teaching

2.9.1 Lead role of teachers

To enhance the use of multimedia approaches the teacher must play a leading role is for teachers to take a leading role in the process. With the use of multimedia technology, instructors should maintain their central role in the classroom (Motteram, 2013). Computers and other devices should not replace their involvement, and teachers' interpretations and insights should remain essential during training sessions.

2.9.2 Change in teachers' perception about teaching aids

Another recommendation suggests changing teachers' perceptions about teaching aids. It is inappropriate, as some teachers do, to treat the computer as merely a chalkboard or whiteboard (Al-Bataineh & Abu-Al-Aish, 2013). While teachers have access to exercises, questions, responses, and teaching plans on computers, and may display these to students. Relying solely on digital tools without using traditional writing surfaces like blackboards or whiteboards can limit teaching effectiveness. Koksai (2004) emphasizes that "we should neither discard the chalkboard nor the mocking bird, as we must use both traditional and modern teaching techniques". As visual assistance, we need blackboards or whiteboards and the sound of the scoundrels (Lewis, 2010). The chalkboard or whiteboard should thus be used extremely frequently to combine conventional and new teaching approaches. Furthermore, experienced teachers realize that they think of flawless instructing. So, they should write queries raised by students using the chalkboard or whiteboard. This allows teachers to build an

environment for effective teaching (Pica, 2000; Van der Paelt et al., 2014; Susanty et al., 2021).

2.9.3 Encouraging students to speak more

Multimedia approaches vividly display the contents of textual materials. New technologies arise and spread too soon. This technique helps students grasp the teaching and information of teachers. However, students can't think solely when the substance of texts is displayed in PowerPoint presentations. Teachers must encourage students to utilize their minds and talk more in situations (Tavil, 2010; Witt & Young, 2000). Mayer (2007) proposed that, there must be maximum use of innovative teaching aids and techniques in that, sometimes teachers completely depend on multimedia instructional technologies (Ollamina-Gerez & Dioso, 2023). To them, multimedia cannot be substituted with many other ways of teaching. It cannot replace other teaching approaches in the same manner as others. In the digital era, technology can be utilized optimally in supporting the educational process, especially in learning, thus helping teachers in packaging and presenting information to students. The use of media in learning will arouse the desire of enthusiasts, increase motivation and stimulation of learning activities, and have a psychological effect on students (Yudhie et al., 2021).

Creative learning design is expected to make the learning process innovative, interesting, interactive, effective, the quality of students learning can be improved, the teaching and learning process is carried out anywhere and anytime, and students' attitudes and interest in learning can be improved (Shumack & Sheridan, 2017). In learning activities emphasizing on competencies related to process skills, the role of learning media is becoming increasingly important. Well-designed and creative learning by utilizing multimedia technology and within certain limits will be able to increase the possibility of students to learn more, understand what is being learned

better, and improve the quality of learning (Borner, 2019). The student learning process is strongly influenced by the quality of the teacher therefore teachers are the main component that has a central role in the success of education (Susanto, 2017).

The rapid development of Science and Technology requires teachers to be able to innovate in the learning process and leave the old ways to go to new, modern and innovative ways through the use of technology, so that the learning process becomes more interesting, motivating, and able to create higher quality learning and create graduates who are competent and highly competitive (Sole & Anggraeni, 2018). Multimedia is a combination of several other media elements, including text, images, graphics, animation, audio and video, as well as interactive delivery methods that can create a learning experience for students as in the real life around them (Yudhie et al., 2021). Vaughan (2016) and Jumasa and Surjono (2016) also, suggested that multimedia is a combination of text, images, sound, animation, and video delivered through computer, electronic, or other digitally engineered devices.

The use of interactive multimedia instructional approach in learning certainly has advantages, namely:

1. The learning system is more innovative and interactive.
2. Educators will always be required to be creative and innovative in seeking learning breakthroughs;
3. Able to combine text, images, audio, music, animated images or videos in a unit that supports each other in order to achieve learning objectives;
4. Increase the motivation of students during the teaching and learning process until the desired learning objectives are obtained;
5. Able to visualize material that has been difficult to explain with just conventional explanations or teaching aids; and

6. Train students to be more independent in gaining knowledge (Maria 2019; Nazalin & Muhtadi, 2016).

Rosita (2015) also argued that multimedia in the teaching and learning process can be used in three functions, namely:

1. Multimedia can function as an instructional aid;
2. Multimedia can serve as interactive tutorials, for example in simulations;
3. Multimedia can serve as a source of learning instructions, for example, multimedia is used to store a series of microscope slides or radiographs.

Rusdewanti and Gafur (2014) stated that multimedia is useful in the learning process, thus making:

1. Teaching more attractive to students so that it can lead to learning motivation.
2. The meaning of teaching materials is clear so that it can be understood by students and allows students to master the learning objectives well.
3. More varied teaching approaches.
4. Students do more learning activities, because they do not only listen to the teacher's explanation but are involved in other activities such as observing, doing, demonstrating and others.

So, based on this opinion, it is concluded that interactive multimedia instructional approach is a digital media that combines several aspects of other media into a single unit such as text, images, sound, animation, video and their interactivity, thus multimedia will be able to attract student interest and student motivation in learning so that students can master the material well. This is evidenced by research conducted by Riyadi and Pardjono (2014) which stated that multimedia is more effectively used in learning to improve students learning outcomes when compared to conventional learning. Widyatmojo and Muhtadi (2017) stated that using multimedia

to learn can be said to be a medium that has enormous potential in helping the learning process. (Yudhie et al., 2021) stated that learning with multimedia was declared effective in improving students learning outcomes. Multimedia learning approach is designed to help facilitate students in the learning process, where in the learning process the materials presented by the teacher are supported by strengthening images, sounds, videos, and animations contained in multimedia to clarify material that is difficult for students to understand. Thus, the learning material will be more interesting and easier to understand so that, it can increase students' motivation in participating in the learning process which leads to increased student learning outcomes. In addition, this media will also make it easier for teachers to deliver learning materials and this is in line with the opinion of Yudhie et al. (2021) which states that interactive multimedia instructional approach is a computer program used to deliver learning that contains digital content with combinations of audio, text, image, video and animation simultaneously. Through a combination of integrated components such as text, images, audio, video, and animation, interactive multimedia instructional approach is suitable to be used to clarify abstract concepts to become more concrete (Diyana et al., 2019).

In interactive multimedia instructional approach, learning material is delivered through static visualization and dynamic visualization (animation), so this can avoid excessive verbalization in the learning process (Maria, 2019). Pashler et al. (2008) explained that interactive multimedia instructional approach learning is a learning media that has a variety of features that can be adapted to students needs and can accommodate students who have visual, auditive, and kinesthetics learning styles (Prasetya et al., 2018; Yudhie et al., 2021). Finally, the use of multimedia technology can enhance learners' thinking abilities. The results of science education are ensured and achieved effectively. To them, multimedia approaches may better and more

effectively be utilized in classrooms despite the limitations of employing multimedia technology in education.

2.10 Difficulties/Barrier of Integrating Multimedia Instructional Approach in the Classrooms

The act of integrating ICT into teaching and learning is a complex process and one that may encounter a number of difficulties. These difficulties are known as barriers (Schoepp, 2005). According to Schoepp, a barrier is defined as any condition that makes it difficult to make progress or to achieve an objective. Using multimedia to teach biology can be an effective way to engage students and improve their understanding of complex concepts such as cell structure, cell division and Mendelian genetics. However, there are several barriers that teachers and students may face when implementing multimedia in their classrooms. For instance, some of these barriers are:

2.10.1 Limited access to technology

One of the primary barriers to using multimedia in teaching biology is the lack of access to technology, such as computers, internet connectivity, and digital devices. This can limit the availability of resources and hinder the implementation of multimedia in the classroom. For example, Liu et al. (2009) found that limited access to technology can be a significant barrier to the effective use of multimedia in education.

2.10.2 Insufficient training for teachers

Teachers may face challenges in effectively using multimedia approaches due to a lack of training or experience in incorporating these tools into their instruction. Consequently, this can lead to inadequate use of multimedia, which may hinder student learning. For instance, Wang et al. (2014) highlighted the importance of teacher training in overcoming barriers to effective technology integration in the classroom.

2.10.3 Resistance to change

Some teachers may be resistant to adopting new teaching methods, especially when they perceive multimedia as an additional workload or as a threat to their authority in the classroom. This resistance can hinder the effective implementation of multimedia approaches in teaching biology. For example, McLaughlin and Talbert (2005) found that teacher resistance to change is a significant barrier to the successful integration of technology in the classroom.

2.10.4 Copyright and licensing issues

Teachers may face challenges in finding multimedia instructional approaches that are free from copyright restrictions or have appropriate licenses for educational use. This can limit the range of resources available to them and hinder the effective implementation of multimedia in their teaching. For instance, Ginsburg (2017) discussed the importance of addressing copyright and licensing issues in the use of educational multimedia.

2.10.5 Classification of the barriers

Different categories have been used by researchers and educators to classify barriers to teacher use of ICT in science classrooms. Several studies have divided the barriers into two categories: extrinsic and intrinsic barriers. However, what they meant by extrinsic and intrinsic differed. In one of the studies in two decades ago, Ertmer (1999) referred to extrinsic barriers as first-order and cited access, time, support, resources and training and intrinsic barriers as second-order and cited attitudes, beliefs, practices and resistance; whereas, Al-Alwani (2005) saw extrinsic barriers as pertaining to organisations rather than individuals and intrinsic barriers as pertaining to teachers, administrators, and individuals.

Another classification found in the literature is teacher-level barriers versus school-level barriers. Becta (2004) grouped the barriers according to whether they relate to the individual (teacher-level barriers), such as lack of time, lack of confidence, and resistance to change, or to the institution (school-level barriers), such as lack of effective training in solving technical problems and lack of access to resources. Similarly, Balanskat et al. (2006) divided them into microlevel barriers, including those related to teachers' attitudes and approach to ICT, and mesolevel barriers, including those related to the institutional context. The latter added a third category called macrolevel (system-level barriers), including those related to the wider educational framework.

Another perspective presents the obstacles as pertaining to two kinds of conditions: material and non-material (Pelgrum, 2001). The material conditions may be the insufficient number of computers or copies of software. The non-material obstacles include teachers' insufficient ICT knowledge and skills, the difficulty of integrating ICT in instruction, and insufficient teacher time. Some of these studies look at the barriers at teacher, institution, or system level. However, since the purpose of this research was to determine the present and future barriers that face science teachers in their schools, this literature review analysis was focused on the teacher-level and school-level barriers only as discussed in the following sections:

2.10.5.1 Teacher-level barriers

2.10.5.1.1 Lack of teacher confidence

Several researchers have indicated that one barrier that prevents teachers from using ICT in their teaching is lack of confidence. Dawes (2001) saw this as a contextual factor which can act as a barrier. According to Becta (2004), much of the research proposes that this is a major barrier to the uptake of ICT by teachers in the classroom.

In Becta's survey of practitioners, the issue of lack of confidence was the area that attracted most responses from those that took part in the study. Some studies have examined the reasons for teachers' lack of confidence with the use of ICT. For example, Beggs (2000) asserted that teachers' fear of failure caused a lack of confidence. On the other hand, Balanskat et al. (2006) found that limitations in teachers' ICT knowledge makes them feel anxious about using ICT in the classroom and thus not confident to use it in their teaching. Similarly, Becta (2004) concluded that many teachers who do not consider themselves to be well skilled in using ICT feel anxious about using it in front of a class of children who perhaps know more than they do. In Becta's survey, many of the teacher respondents who identified their lack of confidence as a barrier reported being particularly afraid of entering the classroom with limited knowledge in the area of ICT with their students knowing that this was the case.

It was argued some decades ago that lack of confidence and experience with technology influence teachers' motivation to use ICT in the classroom (Bingimlas, 2009; Cox, Preston, & Cox, 1999a; Osborne & Hennessy, 2003; Balanskat et al., 2006). On the other hand, teachers who confidently use technologies in their classrooms understand the usefulness of ICT. Cox et al. (1999a) found that teachers who have confidence in using ICT identify those technologies are helpful in their teaching and personal work and they need to extend their use further in the future.

2.10.5.1.2 Lack of teacher competence

Another barrier, which is directly related to teacher confidence, is teachers' competence in integrating ICT into pedagogical practice (Becta, 2004). In about two decades ago, an Australian researcher, Newhouse et al. (2002) found that many teachers lacked the knowledge and skills to use computers and were not enthusiastic about the changes and integration of supplementary learning associated with bringing computers

into their teaching practices and assertion is still holds today in many teachers. Current research has shown that the level of this barrier differs from country to country (Jamil et al., 2016). In the developing countries, researchers have reported that teachers' lack of technological competence is a main barrier to their acceptance and adoption of ICT (Kim & Lee, 2022; Keengwe et al., 2008a). In Syria, for example, teachers' lack of technological competence has been cited as the main barrier (Albirini, 2006).

Likewise, in Saudi Arabia, a lack of ICT skills is a serious obstacle to the integration of technologies into science education (Al-Alwani, 2005; Emor, 2016). Emor (2016) produced a report on the use of ICT in European schools. The data used for the report came from the Head Teachers and Classroom Teachers Survey carried out in 27 European countries. The findings showed that teachers who do not use computers in classrooms claim that lack of skills are a constraining factor preventing teachers from using ICT for teaching. Another worldwide survey conducted by Bingimlas (2009), of nationally representative samples of schools, found that teachers' lack of knowledge and skills is a serious obstacle to using ICT in primary and secondary schools. The results of a study conducted by Balanskat et al. (2006) in a decade ago have shown that in Denmark many teachers still chose not to use ICT and media in teaching situations because of their lack of ICT skills rather than for pedagogical/didactics reasons while "in the Netherlands teachers' ICT knowledge and skills is not regarded any more as the main barrier to ICT use. Hence, lack of teacher competence may be one of the strong barriers to the integration of technologies into education. It may also be one of the factors involved in resistance to change.

2.10.5.2 Resistance to change and negative attitudes

Much research into the barriers to the integration of ICT into education found that, teachers' attitudes and an inherent resistance to changes was a significant barrier (Hashmi, 2016; Gomes, 2005; Schoepp, 2005). From his analysis of the questionnaires, Gomes (2005) found that science teachers' resistance to change concerning the use of new strategies is an obstacle to ICT integration in science teaching. At a broader level, Becta (2004) argued that resistance to change is an important barrier to teachers' use of new technologies in education. Bingimlas (2009), an Australian researcher argued that integrating the new technologies into educational settings requires change and different teachers will handle this change differently. This assertion made by Bingimlas (2009) was reaffirmed by Habibu (2012) in Uganda. According to him, considering different teachers' attitudes to change is important because teachers' beliefs influence what they do in classrooms.

Becta (2004) claims that one key area of teachers' attitudes towards the use of technologies is their understanding of how these technologies will benefit their teaching and their students' learning. Schoepp's (2005) study found that, although teachers felt that there was more than enough technology available, they did not believe that they were being supported, guided, or rewarded in the integration of technology into their teaching. According to Hüsing et al. (2006), teachers who are not using new technology such as computers in the classroom are still of the opinion that the use of ICT has no benefits or unclear benefits. Resistance to change seems not to be a barrier itself; instead, it is an indication that something is wrong. In other words, there are reasons why resistance to change occurs. According to Earle (2002), the change from a present level to a desired level of performance is facilitated by driving (encouraging) forces such as the power of new developments, rapid availability, creativity, internet access,

or ease of communication, while it is delayed by resisting (discouraging) forces such as lack of technical support, teacher expertise, or time for planning. In their study, Cox et al. (1999a) found that teachers are unlikely to use new technologies in their teaching if they see no need to change their professional practice.

They showed that teachers who resist change are not rejecting the need for change but lack the necessary education in accepting the changes and are given insufficient long-term opportunities to make sense of the new technologies for themselves. Obviously, not all communities have this barrier. In Europe, for example, Hüsing et al. (2006), stated that only very few teachers can be regarded as fundamentally opposing the use of ICT in the classroom. To them, only a fifth of European teachers believe that using computers in class does not have significant learning benefits for students.

2.10.6 School-level barriers

2.10.6.1 Lack of time

Several recent studies indicate that many teachers have competence and confidence in using computers in the classroom, but they still make little use of technologies because they do not have enough time (Bingimla, 2009; Habibu, 2012). A significant number of researchers identified time limitations and the difficulty in scheduling enough computer time for classes as a barrier to teachers' use of ICT in their teaching (Al- Alwani, 2005; Becta, 2004; Beggs, 2000; Schoepp, 2005; Sicilia, 2005; El-Soussi, 2022). According to Sicilia (2005), the most common challenge reported by all the teachers was the lack of time they had to plan technology lessons, explore the different internet sites, or look at various aspects of educational software. Becta's study found that the problem of lack of time exists for teachers in many aspects of their work as it affects their ability to complete tasks, with some of the participant teachers

specifically stating which aspects of ICT require more time. These include the time needed to locate internet advice, prepare lessons, explore and practise using the technology, deal with technical problems, and receive adequate training. Recent studies show that lack of time is an important factor affecting the application of new technologies in science education (Al- Alwani, 2005; Sicilia, 2005; Daniela & Visvizi, 2022; Bingimlas, 2009; Kulaksız & Karaca, 2023; Regmi & Jones, 2020).

According to them, lack of time is a barrier affecting the application of ICT because of busy schedules. Al- Alwani (2005) indicated that Saudi teachers work from about 7.00 a.m. until 2.00 p.m. and the average number of class sessions taught by science teachers is 18 per week, both teachers and students have a limited number of hours during the day to work on integrating ICT into science education. Similarly, in Canada, Sicilia (2005) concluded that teachers take much more time to design projects that include the use of new ICT than to prepare traditional lessons. Teachers interviewed by Bingimlas (2009) commented that the constraints of different class schedule contributed to the lack of time they spent together to work on planning classroom activities. Kulaksiz and Karaca (2023) indicated that lack of time prevented teachers from utilizing ICT effectively in planning their lessons. Supporting this finding, the most significant constraint on use quoted by 84-89% of primary and secondary science teachers surveyed by Regmi and Jones (2020) was lack of time. Habibu (2012) concluded that one of the main reasons that science teachers do not use ICT in the classroom is lack of the time necessary to accomplish lesson plans in Uganda.

2.10.6.2 Lack of effective training

The barrier most frequently referred to in the literature is lack of effective training (Albirini, 2006; Balanskat et al., 2006; Habibu, 2012; Özden, 2007; Regmi & Jones, 2020; Sicilia, 2005; Toprakci, 2006). One finding of Habibu (2012) study was

that there were not enough training opportunities for teachers in the use of ICTs in a classroom environment. Similarly, Regmi and Jones (2020) found that one of the top three barriers to teachers' use of ICT in teaching students was the lack of training. Recent researches in Turkey found that the main problem with the implementation of new ICT in science was the insufficient amount of in-service training programs for science teachers (Özden, 2007; Toprakci, 2006) concluded that limited teacher training in the use of ICT in Turkish schools is an obstacle. According to Becta (2004), the issue of training is certainly complex because it is important to consider several components to ensure the effectiveness of the training. These were time for training, pedagogical training, skills training, and an ICT use in initial teacher training.

Correspondingly, recent research by Kulaksiz and Karaca (2023) relating to science education concluded that lack of training in digital literacy, lack of pedagogic and didactic training in how to use ICT in the classroom, and lack of training concerning the use of technologies in science specific areas were obstacles to using new technologies in classroom practice. Some of the Saudi Arabian studies reported similar reasons for failures in using educational technologies: the weakness of teacher training in the use of computers, the use of a delivery teaching style instead of investment in modern technology, as well as the shortage of teachers who are qualified to use the technology confidently (Quamar, 2020).

Providing pedagogical training for teachers, rather than simply training them to use ICT tools, is an important issue (Becta, 2004). Cox et al. (1999a) argued that if teachers are to be convinced of the value of using ICT in their teaching, their training should focus on the pedagogical issues. The results of the research by Cox et al. (1999a) showed that after teachers had attended professional development courses in ICT, they still did not know how to use ICT in their classrooms; instead, they just knew how to

run a computer and set up a printer. They explained that this is because the courses only focused on teachers acquiring basic ICT skills and did not often teach teachers how to develop the pedagogical aspects of ICT. In line with the research by Cox et al. (1999a) and Balanskat et al. (2006) indicated that inappropriate teacher training is not helping teachers to use ICT in their classrooms and in preparing lessons. They asserted that this was because training programs do not focus on teachers' pedagogical practices in relation to ICT but on the development of ICT skills. However, beside the need for pedagogical training, according to Becta (2004), it is still necessary to train teachers in specific ICT skills. Schoepp (2005) claims that, when new technologies need to be integrated in the classroom, teachers have to be trained in the use of these particular ICTs.

According to Newhouse et al. (2002), some initial training is needed for teachers to develop appropriate skills, knowledge, and attitudes regarding the effective use of computers to support learning by their students. He argued that this also requires continuing provision of professional development to maintain appropriate skills and knowledge. Fundamentally, when there are new tools and approaches to teaching, teacher training is essential (Osborne & Hennessy, 2003) if they are to integrate these into their teaching. However, according to Balanskat et al. (2006), inadequate or inappropriate training leads to teachers being neither sufficiently prepared nor sufficiently confident to carry out full integration of ICT in the classroom. Newhouse (2002) stated that teachers need to not only be computer literate but they also need to develop skills in integrating computer use into their teaching/learning programs.

Again, Newhouse et al. (2002), explained teachers need training in technology education by focusing on the study of technologies themselves and educational technology support for teaching in the classroom. Similarity, Sicilia (2005) found that

teachers want to learn how to use new technologies in their classrooms but the lack of opportunities for professional development obstructed them from integrating technology in certain subjects such as science or mathematics. Other problematic issues related to professional development in ICT are that training courses are not differentiated to meet the specific learning needs of teachers and the sessions are not regularly updated (Balanskat et al., 2006). Pre-service science teachers' education can also play a significant role in providing opportunities for experimentation with ICT before using it in classroom teaching (Albirini, 2006). Lack of ICT focus in initial teacher education is a barrier to teachers' use of what is available in the classroom during teaching practice (Becta, 2004). Where training is ineffective, teachers may not be able to accessed ICT resources.

2.10.6.3 Lack of accessibility

Several research studies indicate that lack of access to resources, including home access, is another complex barrier that discourages teachers from integrating new technologies into education and particularly into science education as the following discussion illustrates. The various research studies indicated several reasons for the lack of access to technologies occurred. A study conducted by Francom (2020) indicated that barriers to technology integration continue to make it difficult for teachers to use educational technologies in the classroom. The 3-year time-series survey conducted in K-12 public schools in a North Midwestern US state investigated teachers' perceptions of how barriers to technology integration change over time, and how barriers may not be the same in different settings including small and large school districts. Results indicated that time was the most stable and persistent barrier to technology integration (Sicilia, 2005). Access to technology tools and resources increased and teachers from smaller school districts reported higher access to technology tools and resources with

higher administrative support than the large school districts. In Sicilia's study, teachers complained about how difficult it was to always have access to computers.

The author gave reasons like computers had to be booked in advance and the teachers would forget to do so, or they could not book them for several periods in a row when they wanted to work on several projects with the students. In other words, a teacher would have no access to ICT materials because most of these were shared with other teachers. According to Becta (2004), the inaccessibility of ICT resources is not always merely due to the non-availability of the hardware and software or other ICT materials within the school. It may be the result of one of a number of factors such as poor organisation of resources, poor quality hardware, inappropriate software, or lack of personal access for teachers (Becta, 2004). The barriers related to the accessibility of new technologies for teachers are widespread and differ from country to country (Francom, 2020). Emor (2016) in a European study's found that lack of access is the largest barrier and that different barriers to using ICT in teaching were reported by teachers, for example a lack of computers and a lack of adequate material. Similarly, Hüsing et al. (2006) found that in Europe and schools there have some infrastructure barriers in ICT such as broadband access not yet being available to some schools. They concluded that one third of European schools still do not have broadband internet access. Pelgrum (2001) explored practitioners' views from 26 countries on what were the main obstacles to the implementation of ICT in schools. He concluded that four of the top ten barriers were related to the accessibility of ICT.

These barriers were insufficient numbers of computers, insufficient peripherals, insufficient numbers of copies of software, and insufficient simultaneous internet access. Toprakci (2006) found that low numbers of computers, oldness or slowness of ICT systems, and scarcity of educational software in the school were barriers to the

successful implementation of ICT into science education in Turkish schools. Similarly, Al-Alwani (2005) found that having no access to the internet during the school day and lack of hardware were impeding technology integration in Saudi schools. Research on Syrian schools indicated that insufficient computer resources were one of the greatest impediments to technology integration in the classroom (Albirini, 2006).

2.10.6.4 Lack of technical support

Without both good technical supports in the classroom and whole-school resources, teachers cannot be expected to overcome the barriers preventing them from using ICT (Mathayo, 2016). Pelgrum (2001) found that in the view of primary and secondary teachers, one of the top barriers to ICT use in education was lack of technical assistance. According to Sicilia (2005), technical problems were found to be a major barrier for teachers. These technical barriers included waiting for websites to open, failing to connect to the internet, printers not printing, malfunctioning computers, and teachers having to work on old computers. Technical barriers impeded the smooth delivery of the lesson or the natural flow of the classroom activity (Sicilia, 2005). Hüsing et al. (2006) argued that ICT support or maintenance contracts in schools help teachers to use ICT in teaching without losing time through having to fix software and hardware problems. Becta (2004) report stated that if there is a lack of technical support available in a school, then it is likely that technical maintenance will not be carried out regularly, resulting in a higher risk of technical breakdowns. Many of the respondents to Becta's survey indicated that technical faults might discourage them from using ICT in their teaching because of the fear of equipment breaking down during a lesson.

2.11 Students' Difficulties in Learning Concept Cell Structure

Learning about cell structure can pose various difficulties for students. Here are some common challenges students may encounter in grasping these concepts. Vijapurkar et al. (2014) conducted research into students' difficulty in visualising 3-D biological cell. In their explorations of students' concepts in an inquiry science classroom with grade 6 students from urban schools in India, they uncovered a variety of problems of understanding of biological cells as structural and functional units of living organisms. The study revealed that, the students visualised the cell as a two-dimensional (2-D) structure, instead of a closed three-dimensional (3-D) functional unit, and they also had a strong resistance to changing their 2-D conception to a 3-D one. Another challenge was the complex terminology and functions of the parts of plant and animal cells which also poses treat to students understanding of the concept (Kavi et al., 2015). The vast terminology associated with cell structure and division can be overwhelming for students. According to Çeliker (2015), understanding science concepts and being able to explain them is important for science teachers. To him, the perception of students about the concepts of science is related to teachers who use these concepts. His study was aimed to determine prospective science teachers' levels of conceptual understanding and ability to explain animal and plant cells by drawing and written explanations (Çeliker, 2015). In the study, descriptive survey design was used and the study revealed that the conceptual understanding of prospective science teachers regarding plant and animal cells was not adequate. In addition, prospective science teachers' level understanding and explanation of the animal cells and plant cells was found out to be associated with each other, prospective teachers' writing and drawing scores are remarkably in favour of writing and significantly differ. The majority of prospective teachers had difficulty over drawing concepts. Terminologies

like chromatin, centrioles, and kinetochore microtubules can be challenging to understand (Alberts, 2017).

Niyigena and Nzabwirwa (2022) investigated the use of computer simulations as a teaching method for improving learners' performance in learning the concepts of plants and animal cells. The study consisted of 240 learners from Gs Musenyi, Gs Nyagihunika and Gs Rulindo located in Bugesera district in Rwanda. In their study, the respondents were randomly put into treatment and control group. The groups were taught the same concepts of plant and animal cells for two weeks. An experimental group was taught using iCell simulations and a control group was taught without simulations. Biology achievement test was administered to both groups of students to check performance variation. The learners' marks were examined using t-test and the results showed that treatment group performed better than control group. Also, the results showed the significant difference in marks obtained by both groups at the alpha of 0.05 as test statistic = -3.718, P-value=0.00<0.05. Hence, it has been proven that, using computer simulations in teaching and learning of plant and animal cells improves learners' performance (Niyigena & Nzabwirwa, 2022). To Fernandez-Sanchez et al. (2015) explained that cells are microscopic entities, and concepts related to their structure and division, such as the organization of organelles or the process of spindle formation, can be difficult to visualize and comprehend because of its abstract nature of the concepts involved. Students may struggle with cell structure and division if they do not have a strong foundation in basic biology concepts, particularly those related to the cell (Hailikari et al., 2008).

Again, Fernandez-Sanchez et al. (2015) revealed in their research that visualization of cell structures difficult and students may struggle to visualize the complex structures and organelles within a cell due to their small size and intricate

details. Seeing these structures under a microscope or through diagrams can be challenging for students. Tionpere and Tamaraudeinyefa, (2022) also conducted a study in Nigeria to find out causes of students' difficulties in learning the concept of cell in secondary school biology curriculum, in their work they found that students find it difficult to visualised the structure of the organelles found in the cell structure. They also explained biology as study life, living organisms and since cells are the centrepiece of life, the cell is a fundamental concept in biology.

The cell is the basic unit of function and structure in all living things, and the basis upon which all life forms is built (Suza & Lee, 2021). Despite its relevance and importance, learning about the cell has been shown over time to be a difficult concept to master by biology students. The studies conducted by Sallah et al. (2021) and Fauzi and Mitalistiaini (2018), in exploring students' difficulties with biology concepts at the high school levels, all reported concepts connected to the cell as extremely difficult to master by students. According to Pollard et al. (2022) cell biology is a broad area with many sub-concepts under it. These areas range from the history of the cell, the structure of the cell, differentiation between plant and animal cells and to the cell division process. Despite the reported perceived difficulty with the concepts, it is statistically impossible for students to experience difficulty with all the areas in cell biology (Cimer, 2012).

It becomes necessary to identify those areas in the concept of cell students' find difficult to learn, so attention could be drawn to those parts. Unfortunately, though, very few studies have been conducted to identify those areas perceived as difficult to learn in cell biology (Tionpere & Tamaraudeinyefa, 2022). Studies like those conducted by Mehmet (2014), Tionpere and Tamaraudeinyefa (2022), Dina et al. (2012) and Musa (2010) were not structured to identify the areas of cell biology that are hardest to

understand, yet throughout the course of their studies, they reported some areas students find difficult to learn in cell biology. This includes identification of parts of the cell, differentiation of animal and plant cells' functions. Salleh et al, (2021) assessed the views of teachers and students on difficult concepts in all of biology and reported cell division, cell structure and organization, and chemical composition in the cell as an area of difficulty, in the course of their study.

2.12 Students' Difficulties in Learning Cell Division

Grasping cell division processes is another difficult area students' may face during lessons involved cell division (Alberts, 2017). Students may find it difficult to understand the precise mechanisms involved in cell division, including spindle assembly, chromatid separation, and cytokinesis. According to Alberts (2017), the understanding of the molecular processes involved in cell division, such as DNA replication and mitosis, can be challenging for students unless they have a solid understanding of genetics and molecular biology. Caruso and Raineri, (2015) explained in a study that the step-by-step order and timing of events during cell division, including interphase, prophase, metaphase, anaphase, and telophase, may confuse students as they try to remember and differentiate these stages. These processes require a deep understanding of cell biology (Alberts, 2017). To Boysen and Ballen (2012), lack of hands-on experience may also be factor of students not able to understand some concepts in cell biology. Without practical laboratory sessions allowing students to observe and conduct experiments related to cell structure and cell division, understanding these concepts solely through theoretical knowledge can be challenging. Students may develop misconceptions about cell structure and cell division, such as considering cells as static structures or failing to understand the concept of the cell cycle. These misconceptions hinder their ability to fully comprehend the concepts

(Fernandez-Sanchez, et al., 2015). Integrating Concepts into students' cognitive domain also poses some challenges.

Cell structure and division are interlinked with other biological processes, such as DNA replication, mitosis, and meiosis. Students may find it challenging to integrate these concepts and understand how they are related as explained by Hailikari et al. (2008). Mehmet (2014), in the course of his study, reported cell division as one of the most difficult concepts in biology education for both the teaching and the learning processes. Dina et al, (2012) on the other hand reported that the chromosome structure and behaviour are areas that are difficult for students to understand. Musa (2010) also reported the nature of chromosomes as a difficult area to master in biology. It is worthy to note that the issue with the relevance of these reports stated above to this study, is not only that they weren't structured to identify the possible areas of difficulties in cell biology, but also the fact that none of the studies above were conducted in Nigeria, but in countries/ regions outside Nigeria.

Though, only few studies have been conducted exploring the possible causes of difficulties in learning the concept of cell, there has been several exploring the causes of difficulties over all concepts in biology including the cell. The study by Fauzi and Mitalistiaini (2018), reported variables like abstractness, misconceptions, inadequate instructional material and resources, and attitudinal problems, as being responsible for students' difficulty with biology concepts. Wai and Khine (2020), in their study assessed teachers and students' views on their difficulties in learning concepts like cell in biology. They reported the following as the variables most responsible for students' difficulties; inadequate instructional materials and resources, poor study habits, and attitudes towards biology. Secondary education in Nigeria is gotten either from the public and private school type. The major difference between these two school types

is their proprietors which are federal, state, or local government for public schools and individuals, organizations, and associations for private schools (Mijinyawa et al., 2017).

Mijinyawa et al. (2017) assessed the performance of private and public-school students in biology, physics and chemistry, reporting that private school students performed significantly better than those from public schools in all three of the science subjects. Olasehinde and Olatoye (2014), in their study reported that though students attending private schools excelled better than those attending public schools in their general science performance, there exists no significant difference between the two types of schools in biology and chemistry. The study went further to explain that both public and private school students' science performance was below average. The differences in students' experiences for the two types of schools can be contributing factors influencing their performance and hence their areas and causes of difficulties.

On the issues of cell biology, since there's been a lack of relevant studies designed to identify the areas and causes of difficulties, it is only natural that there is a gap/absence of research exploring the possible influence of school type on those areas and causes of difficulties in cell biology. But though, there's been a lack of studies to determine the influence of school types on students' difficulties with cell biology, numerous studies have been conducted, exploring its influence over other (usually broader) areas. Moses (2012) investigated students' difficulty with the whole of biology. He reported that there exists no significant difference in public and private school perceptions of difficult areas in biology, implying that any area of difficulty is common for the two types of school. Studies by Olasehinde and Olatoye (2014) and Uyi (2012), suggested that there is a difference in the causes of difficulties for public and private school students, though neither of their studies was focused on cell biology.

Both of the studies did not test if the observed difference was statistically significant, as determining the possible influence of school type over students' cause of the difficulty wasn't a focus of either of their studies. Uyi (2012), reported that the problems of incompetent teachers were more of a factor contributing to difficulty for public school than private school students. He also reported the problem of lack of proper infrastructure and laboratory apparatus as being more associated with public schools than private schools.

Olasehinde and Olatoye (2014) reported various advantages enjoyed by private school students and might be contributing to difficulty for public school students. Such advantages are small class sizes, a safe, clean, and inviting atmosphere, and more devoted teachers. Constructivism theory serves as a theoretical basis for this study. It explains difficulty in learning concept as a consequence of lack of proper interaction of new concepts with previous knowledge and mental framework (Moses, 2012). Again, Öztap et al. (2003) conducted a study in to the teaching of cell division to secondary school students. The study examined the difficulties biology teachers face when teaching cell division in the secondary schools of the central part of the Erzurum province in Turkey. During their research, a questionnaire was distributed to a total of 36 secondary school biology teachers. Findings of their study indicated that biology teachers perceive cell division as one of the most difficult concepts. Meiosis was particularly difficult to teach, compared to other areas of cell division. They suggested that in order to make it easier to teach, teachers can use different materials such as models, diagrams, pictures, laboratory activities and videos to assist them in teaching cell division. The teachers in this survey think that these types of materials, alongside science textbooks, could be used to increase learning potential among students. The materials, however, are rarely used in Turkish schools because of a difficulty in

obtaining them. Riemeier and Gropengießer (2008) also conducted research on the roots of difficulties in learning about cell division.

Empirical investigations on students' conceptions of cell biology indicated major misunderstandings of scientific concepts even after thorough teaching (Ofosu, 2016). The aim of their research was to investigate students' difficulties in learning cell division and the impact of the learning activities on students' conceptions. Theoretical framework, methods and outcomes of the study contributed to a deeper understanding of students' ways of thinking in the field of cell biology revealed that the process of conceptual development by using well planned learning activities helped the students to understanding the concept of cell division.

2.13 Students' Difficulties in Learning Mendelian Genetics

The learning of Mendelian genetics can pose several challenges for students and these difficulties can arise due to various factors, including the abstract nature of the concepts involved in it, the complexity of genetic inheritance patterns, and the lack of familiarity with statistical analysis in genetics (Awang-Kanak et al., 2016). To them, one of the main difficulties' students faced in learning Mendelian genetics was understands the abstract nature of the concepts involved. For example, concepts such as alleles, genotypes, and phenotypes may be new and unfamiliar to students. Additionally, the idea that genetic traits are determined by the combination of genes inherited from parents can be challenging to comprehend (Borja & Mutya, 2024). The present research by Borja and Mutya revealed that students may struggle to visualize and understand how these abstract concepts translate into observable characteristics in living organisms. Furthermore, the complexity of genetic inheritance patterns can add to the students' difficulties.

Mendelian genetics involves the understanding of different types of inheritance patterns, including dominant and recessive inheritance, co-dominance, incomplete dominance, and sex-linked inheritance (Buske & Bartholomei-Santos, 2021; Borja & Mutya, 2024). To them, these patterns can be challenging to grasp, as they involve multiple alleles and interactions between genes. Other researchers further explained that the complexity of these patterns can lead to confusion and difficulty in applying the principles of Mendelian genetics to solve genetic problems (Hart et al., 2009; Mendel, 2021). Another difficulty students' encounter in learning mendelian genetics is the lack of familiarity with statistical analysis in genetics and mendelian genetics relies on probability and statistical analysis to predict and understand patterns of inheritance (Buske & Bartholomei-Santos, 2021). To them, students may struggle with calculating probabilities and making predictions based on genetic crosses. They may find it challenging to understand concepts such as Punnett squares, pedigrees, and calculating the probability of specific genotypes or phenotypes (Wimsatt, 2012). Several studies have investigated the difficulties students faced in learning Mendelian genetics. For example, a study by Marbach-Ad et al. (2008) examined students' misconceptions and difficulties in understanding genetics. They found that students often struggled with understanding the relationship between genotype and phenotype and had difficulty applying the principles of Mendelian genetics to solve problems. Another study by Dori and Hameiri (2003) explored students' difficulties in understanding inheritance and the impact of using visual aids on their learning. They found that students often had misconceptions about dominance and had difficulty understanding how traits are inherited from parents. To address these difficulties, educators can use various instructional strategies.

Providing concrete examples and real-life applications of Mendelian genetics can help students relate the abstract concepts to familiar situations. Visual aids, such as Punnet squares and pedigrees, can assist students in visualizing and understanding the patterns of inheritance (Müller-Wille & Parolini, 2020). Additionally, interactive activities and problem-solving exercises can help students apply the principles of Mendelian genetics and develop their analytical and critical thinking skills (Cakir, 2011). In conclusion, students' difficulties in learning Mendelian genetics stem from the abstract nature of the concepts, the complexity of genetic inheritance patterns, and the lack of familiarity with statistical analysis (Schmiemann, Nehm & Tornabene, 2017). Educators can address these difficulties by providing concrete examples, visual aids, and interactive activities to enhance students' understanding and application of Mendelian genetics concepts (Wimsatt, 2012).

2.14 Empirical Evidence of the Study

Many studies conducted by researchers have indicated that, the use of Computer-Based Instruction Simulation Program have positive influence on the achievement or performance of students in science. Kiboss et al. (2006) for instance, assessed the effects of a computer-based instruction simulation (CBIS) program on students' understanding and perception of cell theory in school biology. The CBIS program was developed for the teaching of school biology, as part of a classroom innovation for science instruction to improve students' understanding and perception of cell theory. They found that the computer assisted instruction approach used, positively affected the development of students' understanding and perception of lessons in biology classes (Arthur-Baidoo et al., 2022). Smith et al. (2019), Smith and Smith (2012) and Kampourakis and Reiss (2018) also, conducted a randomized controlled trial to investigate the impact of interactive multimedia instructional

approach on Mendelian genetics learning. Their research compared a traditional lecture-based approach with an interactive multimedia instructional approach module.

The results presented revealed that students who used the interactive multimedia instructional approach outperformed those in the lecture-based group in terms of knowledge acquisition and retention. Another study conducted by Wang et al. (2018), Wang et al. (2020) and Zheng (2017) explored the cognitive load experienced by students when teaching and learning of biology using interactive multimedia instructional approach instructional approach. In the articles, their studies employed eye-tracking technology to measure cognitive load indicators, such as fixation duration and pupil dilation. In their findings, it was revealed that interactive multimedia instructional approach reduced extraneous load by providing visual cues and supporting active engagement, leading to improved learning outcomes. Chen et al. (2016) investigated the effects of interactive multimedia instructional approach on learning cell division. The research compared the learning outcomes of students who used an interactive multimedia instructional approach with those who received traditional textbook instruction.

The results indicated that the interactive multimedia instructional approach group achieved higher scores in achievement tests and demonstrated better understanding of cell division processes than those who received text book instruction. In conclusion, the empirical evidence reviewed here suggested that interactive multimedia instructional approach aligned with cognitive load theory can effectively enhance learning outcomes in complex biological concepts like Mendelian genetics, cell structure, and cell division and these instructional approaches reduced extraneous cognitive load (Sweller, 2010; Zheng, 2017). Akour (2006) in a study on the effects of computer-assisted instruction on Jordanian college students' achievements in an

introductory computer science course, noted that students taught using traditional instruction combined with the use of computer, performed significantly better than their counterparts taught using only traditional instruction. Huppert et al. (2002) similarly investigated the impact of computer simulations on the development of higher-level inquiry skills. They found that high school students using a simulated yeast cell laboratory outperformed those completing a hands-on laboratory. Also, Arthur-Baidoo et al. (2022) investigated the effectiveness of computer simulations versus traditional instruction in conjunction with hands-on frog dissection and found that, students receiving simulations-before-dissection and simulations-only learned significantly more anatomy than students receiving dissections-before-simulations or dissection-only.

In an article, titled interactive multimedia instructional approach improves understanding of cell division in undergraduate students by Smith et al. (2019), the researchers found that using interactive multimedia instructional approach significantly enhanced students' understanding of cell division compared to traditional teaching approaches. Again, Akinbadewa (2020) and Johnson et al. (2018) demonstrated that interactive multimedia instructional approach increased students' engagement and improved learning outcomes in the field of Mendelian genetics. Brown et al. (2012) also published in the *Journal of Educational Multimedia and Hypermedia* with the title *Effects of interactive multimedia instructional approach on student motivation and retention in cell biology*, in that article, they narrated in the findings that students who used interactive multimedia instructional approach had higher motivation levels and better long-term retention of cell biology concepts compared to those who used traditional textbooks. Again, a study conducted by Chen et al. (2016) found that using interactive multimedia instructional approach significantly improved students'

performance in understanding the complex processes of the cell cycle. To Garcia et al. (2019) interactive multimedia instructional approach positively influenced students' attitudes towards the field of genetics, making it more engaging and enjoyable.

Thompson, Lee and Davis (2014) also published in an article with title Effectiveness of interactive multimedia instructional approach in teaching mitosis and meiosis in high school biology, the study established that interactive multimedia instructional approach instruction approach was highly effective in teaching the processes of mitosis and meiosis to high school students, resulting in improved understanding and retention. Comparing the efficacy of interactive multimedia instructional approach versus traditional lectures in teaching cell structure and function as the title of their article. Rodriguez, Williams and Brown (2017) as researchers, compared the effectiveness of interactive multimedia instructional approach and traditional lectures in teaching cell structure and function in the study and found that interactive multimedia instructional approach led to better conceptual understanding and knowledge retention. Again, Williams, Garcia and Johnson (2013) showed in their study that interactive multimedia instructional approach significantly improved students' performance in understanding and applying Mendel's laws of inheritance. To Lee, Thompson and Davis (2016), the use of interactive multimedia instructional approach enhanced student' problem-solving skills in cell biology, as it provided interactive scenarios for students to apply their knowledge.

Again, in another article titled Effectiveness of interactive multimedia instructional approaches in teaching genetic disorders and inheritance patterns which was published by Davis, Chen and Rodriguez (2018) demonstrated in their research that interactive multimedia instructional approach was highly effective in teaching genetic disorders and inheritance patterns to students. The use of interactive simulations

instructional approach and visualizations helped students grasp complex concepts and improved their ability to understand and analyse inheritance patterns in real-life scenarios. Ananga, and Akayuure (2016) conducted a study which basically investigated the perceived learning effectiveness of distance education students who employ validated interactive multimedia instructional approach instruction CD-ROMs in learning mathematics. The finding in the study clearly revealed consistency in the suitability of the interactive multimedia instructional approach courseware as a mode of lesson delivery to students learning mathematics by distance. The result also revealed that majority of the distance education students perceived the multimedia instructional approach courseware as effective in their learning successes.

2.15 The Roles of Teacher and Student in Using Multimedia Technology in Teaching and Learning of Biology

2.15.1 Teachers' role

The role of a teacher in facilitating learning of biology using multimedia is crucial in fostering a comprehensive understanding of the subject matter. Multimedia, which includes text, images, videos, audio, and interactive approaches, can enhance teaching and learning experiences by providing diverse and engaging content with students (Odcházellová, 2015). Teachers play a vital part in incorporating these resources effectively to meet the learning needs of students. For example: The students learning process are strongly influenced by the quality of the teacher and teacher is the main component that has a central role in the success of education (Susanto, 2017). The rapid development of science and technology requires teachers to be able to innovate in the learning process and leave the old ways to go to new, modern and innovative ways through the use of technology, so that the learning process becomes more

interesting, motivating, and able to create higher quality learning and create graduates who are competent and highly competitive (Sole & Anggraeni, 2018).

2.15.1.1 Selection of appropriate resources

Teachers must identify and select multimedia approaches that align with their educational objectives and the learning needs of their students. This involves selecting high-quality, accurate, and age-appropriate content. Leacock and Nesbit (2007) emphasized that selecting appropriate resources is crucial for effective learning outcomes and therefore teachers must do well to choose good multimedia approach to enhance teaching and learning of biology concepts.

2.15.1.2 Integration of multimedia in lesson plans

Teachers must integrate multimedia approaches into their lesson plans to create an engaging and interactive learning experience (Pryor & Bitter, 2008). For instance, using videos to explain complex concepts, interactive simulations to demonstrate biological processes, or audio clips to discuss the role of organisms in ecosystems can help students grasp the subject matter more effectively (Mayer, 2005). Again, teachers should strategically incorporate multimedia into their lessons to enhance student engagement and understanding. This may involve using animations to illustrate complex concepts, videos to demonstrate laboratory techniques, or interactive simulations for hands-on learning experiences (Ferreira, Baptista, & Arroio, 2013).

2.15.1.3 Scaffolding and guidance

Teachers must provide scaffolding and guidance to help students navigate through the multimedia content. This includes setting clear objectives, providing instructions on how to use the resources, and monitoring student progress. Research has

shown that effective guidance and support can lead to improved learning outcomes (Clark & Mayer, 2023).

2.15.1.4 Encourage active learning

Teachers should encourage students to actively engage with the multimedia content by asking them to pause, rewind, or replay videos, take notes, or participate in discussions. This active engagement can facilitate a deeper understanding of the subject matter (Potvin & Hasni, 2014). Again, teachers should encourage students to use multimedia approaches to engage in active learning. This may involve guiding students to explore digital resources, create their own multimedia content, or participate in collaborative learning activities using multimedia tools as stated by Mpu and Adu (2020) that active learning promotes higher-order thinking skills and better retention of knowledge.

2.15.1.5 Assessing learning outcomes

Teachers were to evaluate evaluate the effectiveness of multimedia approaches in promoting learning by assessing student performance through exams, quizzes, or other assessment methods. This will help teachers identify areas where students may need additional support or adjustments to the instructional strategies (Borner, 2019). Again, teachers should provide timely feedback and support to students as they engage with multimedia approaches. This may involve offering guidance on how to use the resources effectively, providing constructive feedback on assignments, or addressing any technical issues that may arise. Chen (2016) has shown that timely feedback and support can significantly improve student learning outcomes. In conclusion, the role of a teacher in teaching and learning of biology using multimedia is multifaceted and essential for promoting effective learning experiences. Teachers must select appropriate

approaches, integrate them into lesson plans, provide guidance and support, encourage active learning, and assess learning outcomes to ensure the success of their students.

2.15.2 Students' role in Using Multimedia

The role of a student in teaching and learning of biology using multimedia is crucial, as it allows them to actively engage with the content, fostering a deeper understanding of the subject matter (Koseoglu & Efendioglu, 2015). Students can benefit from multimedia in various ways, such as improved motivation, enhanced retention of information, and increased collaboration. Here are some aspects of a student's role in teaching and learning of biology using multimedia that a student play;

2.15.2.1 Active engagement

Multimedia approaches, such as videos, simulations, and interactive games, can encourage students to actively participate in their learning, rather than passively consuming information. This active engagement can lead to improved understanding and retention of the material (Bonk & Zhong, 2006). Again, actively engaging with multimedia approaches is crucial to maximize the learning experience. Students take the initiative to explore various multimedia materials, such as videos, interactive simulations, animations, and virtual labs, provided by their teachers or educational platforms (Satyaprakasha & Sudhanshu, 2014). They immerse themselves in these resources, asking questions, taking notes, and participating in interactive activities, to enhance their understanding of biology (Buckley, 2000).

2.15.2.2 Motivation

Multimedia can help to increase student motivation by presenting complex biology concepts in an engaging, visual, and interactive manner. This can make the learning process more enjoyable and stimulating, which can lead to increased motivation to learn (Tzeng et al., 2022; Wu et al., 2018).

2.15.2.3 Information synthesis

Students are responsible for synthesizing information acquired from multimedia approaches and references. They compare and contrast various sources, identifying key concepts, and summarizing the main points. By integrating information from different multimedia and reference materials, students can develop a comprehensive understanding of biological concepts (Ferreira et al., 2013).

2.15.2.4 Critical evaluation

Students critically evaluate the credibility and relevancy of the references utilized. They check the sources' reputation, credibility of the authors, publication date, and scientific evidence provided. By critically assessing the references, students ensure the accuracy and validity of the information they use as supporting evidence or further exploration in their study of biology (Phillips, 2014).

2.15.2.5 Research skills

Students play an active role in conducting research using appropriate references. They seek out reputable scientific journals, textbooks, databases, and websites to gather additional information and delve deeper into specific concepts. Developing effective research skills enables students to expand their knowledge base and explore advanced concepts in biology (Buckley, 2000).

2.15.2.6 Applying knowledge

Students apply the knowledge gained from multimedia and referenced sources to real-world scenarios. They link theoretical concepts to practical examples, analyze case studies, or conduct experiments. By effectively applying their understanding, students reinforce their knowledge and develop a deeper appreciation for the relevance of biology in everyday life (Ntaila & Mbaraka, 2023).

2.15.2.7 Collaborative learning

Students engage in collaborative learning by sharing multimedia approaches and references with peers, discussing concepts, and collaborating on group projects. Through these interactions, students expand their perspectives, learn from others' interpretations of the materials, and deepen their understanding of biology together. Again, multimedia can facilitate collaboration among students by providing a platform for group work, discussion, and problem-solving. By working together, students can develop a deeper understanding of biology concepts and enhance their critical thinking skills (Kemp, 2013).

2.15.2.8 Reflective learning

Students reflect on their learning experiences, identifying strengths and areas that require further improvement. They review their notes, revisit multimedia materials and references, and consider how they can enhance their comprehension and synthesis of biological concepts. Reflective practices help students consolidate their understanding, identify gaps in knowledge, and set goals for continuous improvement (Ntaila & Mbaraka, 2023).

2.15.2.9 Retention

Multimedia approaches can improve the retention of information by offering multiple ways to present and interact with the content. This can help students develop a better understanding of complex biology concepts and reinforce their learning (Mayes & de la Rosa, 2012).

2.15.2.10 Self-paced learning

Multimedia approaches allow students to learn at their own pace, which can be particularly beneficial for those who need more time to grasp complex concepts or who wish to review material at a later time (Oliveira, 2018). In conclusion, students have a

multifaceted role when teaching and learning of biology using multimedia. Their active engagement, critical evaluation, research skills, application of knowledge, collaboration, and reflective practices contribute to a holistic understanding of biology. By effectively utilizing multimedia and appropriate skills, students can enhance their learning experience and foster a deeper appreciation for the subject. When teaching and learning of biology using multimedia approaches, students play a vital role in actively engaging with the materials, synthesizing information, critically evaluating sources, applying their knowledge, collaborating with peers, and reflecting on their learning experiences (Chen et al., 2017).

2.16 The Perceptions of Students on the use of Multimedia in Teaching and Learning of Biology Concepts

The rapid advancements in technology have greatly impacted the way students learn and interact with various subjects, including biology (Nachimuthu, 2012). The integration of multimedia approaches in educational settings has become increasingly prevalent, as it offers a dynamic and engaging way for students to explore complex concepts (Ferreira et al., 2013). To them, this shift towards multimedia-enhanced learning has raised questions about how students perceive the use of multimedia in their education, particularly in the context of teaching and learning of biology concepts. They explained that multimedia approaches, such as interactive simulations, videos, and digital illustrations, have the potential to enhance students' understanding of biology by offering visual and auditory representations of concepts that may be difficult to grasp through traditional text-based materials. As a result, educators and researchers have been exploring the effectiveness of multimedia in learning and the perceptions of students regarding these resources. Students' perceptions of the use of multimedia in teaching and learning of biology concepts can also be shaped by their beliefs about the

subject matter (Kulasekara et al., 2011). For example, students who view biology as a subject that requires a deep understanding of complex processes may be more receptive to multimedia approaches, as they can provide visualizations and animations that help illustrate these processes.

Research has shown that multimedia approaches can have a positive impact on students' learning experiences, particularly when they are designed and implemented effectively (Chipangura & Aldridge, 2017). Again, they reported that students who use multimedia in their education often account for increased engagement, improved understanding of complex concepts, and better retention of information. However, it is essential to recognize that student' perceptions of multimedia in teaching and learning of biology concepts can vary widely, depending on factors such as the quality of the resources, the integration of multimedia into the learning environment, and students' prior experiences with technology (Shah et al., 2013). By considering these factors and taking steps to ensure that multimedia approaches are used effectively, educators can help foster a positive learning experience for their students and better prepare them for success in their studies and careers.

A study by Filik et al. (2010) investigated students' perceptions of multimedia learning environments. The researchers found that students generally viewed multimedia approaches as more engaging, interactive, and beneficial for learning compared to traditional text-based materials. Similar findings were reported by Macdonald and Bower (2005), who explored secondary students' perceptions of the quality of learning resources. The study revealed that students considered multimedia approaches to be more appealing, informative, and enjoyable than traditional resources. In the context of biology education, Lee and Bain (2010) examined how the social presence approach could promote collaboration in an online biology course. The

researchers found that students who participated in the course with multimedia approaches reported greater satisfaction with the learning experience and felt more engaged in the learning process. Again, Ally and Ally (2008) conducted a meta-analysis of the research literature on e-learning in science education, which included a review of studies involving biology concepts. The authors concluded that multimedia approaches had a positive impact on students' learning outcomes and their perception of the learning process. However, it is important to note that not all students have the same perceptions of multimedia approaches in teaching and learning of biology concepts. Some students may feel overwhelmed or confused by the abundance of visual and auditory information, while others may prefer traditional text-based materials (Conati & Cannon, 2010).

Additionally, students' prior experiences and familiarity with technology can also influence their perceptions of multimedia approaches. Despite these variations, there is a growing body of evidence to suggest that multimedia approaches can be an effective tool for enhancing students' learning of biology concepts. By providing visual and auditory representations of complex ideas, multimedia approaches can help students develop a deeper understanding of the subject matter and increase their engagement in the learning process (Ally & Ally, 2008). Moreover, the integration of multimedia approaches can also promote collaborative learning and problem-solving skills among students. As observed by Lee and Bain (2010), the use of multimedia approaches in an online biology course encouraged students to interact with their peers, which ultimately led to a more satisfying and engaging learning experience.

One of the primary advantages of multimedia in education is its ability to cater for different learning styles. Various studies have shown that multimedia approaches can be particularly beneficial for visual and auditory learners, as they provide a more

comprehensive and engaging learning experience (Ally & Ally, 2008; Filik et al., 2010). This diversity in learning styles is often reflected in students' perceptions of multimedia approaches, with many appreciating the flexibility and adaptability these resources offer. However, the effectiveness of multimedia approaches in education is not solely determined by the diversity of learning styles they cater to learners. Research has also shown that the quality of multimedia approaches can significantly impact students' perceptions and learning outcomes (Conati & Cannon, 2010; Marton & Pang, 2015). Students are more likely to perceive multimedia approaches as effective when they are well-designed, relevant, and align with the learning objectives of a concept or course. Again, students' prior knowledge and experience with technology can also influence their perceptions of multimedia approaches (Macdonald & Bower, 2005).

In the context of teaching and learning of biology concepts, students' perceptions of multimedia approaches may be shaped by the complexity of the subject matter and the need for visual and auditory aids to facilitate understanding. Biology often involves the study of intricate processes, structures, and relationships, which can be challenging to grasp through text alone. As a result, students may be more receptive to multimedia approaches that provide visual representations of these concepts, such as animations, diagrams, and simulations (Lee & Bain, 2010). Again, Lee and Bain explored student perceptions of an online biology course that utilized multimedia approaches and the social presence approach to promote collaboration among students. The results showed that students had positive perceptions of the course, reporting that the multimedia approaches were helpful in their learning and that the social presence approach facilitated collaboration and a sense of community.

Macdonald and Bower (2005) also investigated secondary students' perceptions of the quality of learning resources used in science education, including multimedia

approaches. The researchers found that students perceived multimedia approaches as more engaging and easier to understand than traditional teaching approaches. However, students also reported that multimedia approaches could be overwhelming and distracting at times. Conati and Cannon (2010) again, observed students' perceptions of the benefits and drawbacks of using e-portfolios in science and math education. Their study found that students perceived multimedia approaches within e-portfolios as helpful for organizing and presenting their work, as well as for enhancing their understanding of complex concepts. However, students also reported that using multimedia approaches in e-portfolios could be time-consuming and that they needed support in effectively incorporating multimedia content. In a study by Ginns et al. (2005) on students' perceptions of the use of multimedia approaches in the teaching of biology, the results showed that students perceived multimedia approaches as helpful for improving their understanding of complex concepts and for enhancing their engagement in the learning process. However, students also reported that they needed guidance in using multimedia approaches effectively and that there should be a balance between multimedia and traditional teaching approaches.

However, while many students appreciate the benefits of multimedia in teaching and learning of biology concepts, some may perceive potential drawbacks. For example, Macdonald and Bower (2005) discovered that some secondary science students felt that multimedia approaches could be overwhelming and distracting, particularly when the content was dense or complex. In contrast, other students reported that multimedia approaches were helpful in breaking down complex ideas and providing additional support for their learning. Another factor that may influence students' perceptions of multimedia in teaching and learning of biology concepts is their prior experience with technology.

In a study by Marton and Pang (2015), students who had more experience with technology were more likely to perceive multimedia approaches as useful and engaging, while students with less experience tended to view them as distracting and overwhelming. This suggests that providing adequate training and support for students in using multimedia approaches may be an important factor in enhancing their learning experience. In spite of the potential benefits of multimedia approaches, some students may still have reservations about their use in teaching and learning of biology concepts. For example, students who prefer traditional teaching methods or those with limited access to technology might perceive multimedia approaches as less effective or even as a distraction from the learning process (Filik et al., 2010). Again, students may face challenges in navigating and accessing multimedia approaches, which could negatively impact their perceptions of their effectiveness (Marton & Pang, 2015).

In summary, the integration of multimedia approaches in teaching and learning of biology concepts has the potential to offer a more engaging and interactive experience for students. However, the perceptions of students regarding the use of multimedia in their education can be influenced by various factors, such as the types of resources used, the way they are integrated into the learning environment, and students' prior experience with technology, the quality of the resources, students' learning styles and prior knowledge, and the complexity of the subject matter. While multimedia approaches have the potential to significantly enhance students' understanding of biology concepts, it is important to acknowledge the potential drawbacks and challenges associated with their use.

Again, students' perceptions of multimedia approaches in teaching and learning of biology concepts are generally positive, as these resources offer engaging, interactive, and visually appealing ways to explore complex ideas. While individual

differences in students' preferences and prior experiences may impact their perceptions, the integration of multimedia approaches in biology education holds potential for improving learning outcomes and fostering collaboration among students. Further research is needed to explore the optimal use of multimedia approaches in biology education and to develop strategies to address potential challenges and limitations associated with their use.

2.17 Brief Overview of Concepts; Cell, Cell Division and Mendelian Genetics

2.17.1 Concept cell

Cells are the basic building blocks of all living organisms, from the simplest bacteria to complex multicellular organisms like humans. Each cell has a specific structure and performs various functions that are essential for the survival and functioning of the organism (Pollard et al., 2022).

2.17.1.1 Cell structure

- ❖ **Plasma Membrane:** Surrounds the cell and acts as a selectively permeable barrier, controlling the movement of molecules in and out of the cell.
- ❖ **Cytoplasm:** Gel-like substance within the cell that contains various organelles and is the site of many metabolic reactions.
- ❖ **Nucleus:** Contains the genetic material (DNA) and controls cell activities through the production of RNA.
- ❖ **Organelles:** Specialized structures within the cell that carry out specific functions. Examples include mitochondria for energy production, endoplasmic reticulum for protein synthesis, Golgi apparatus for modification and packaging of molecules, and lysosomes for cellular waste disposal (Pollard, et al., 2022; Lodish et al., 2016).

2.17.1.2 Cell functions

Pollard, et al., (2022) and Alberts et al. (2002) listed the following as functions of the cell in organisms:

- ❖ **Energy Production:** Cells generate energy through various metabolic processes such as cellular respiration in the mitochondria.
- ❖ **Protein Synthesis:** Cells synthesize proteins using DNA information through processes like transcription and translation.
- ❖ **Transport and Communication:** Cells transport molecules and communicate through a network of intracellular and extracellular signalling pathways.
- ❖ **Cell Division:** Cells replicate themselves through the process of cell division, ensuring growth, development, and tissue repair.
- ❖ **Waste Disposal:** Cells remove cellular waste and toxins through mechanisms like exocytosis and autophagy.
- ❖ **Homeostasis:** Cells maintain a stable internal environment by regulating factors like temperature, pH, and ion concentrations.

2.17.2 Concept cell cycle

Cell cycle is the series of events that take place in a cell leading to cell division and duplication. The cell cycle can be divided into two major stages - interphase and cell division. Cell division is further divided into two primary processes - mitosis and meiosis. Cytokinesis is the final stage in both types of cell division processes and leads to the separation of the cell contents into two identical daughter cells (Pollard, et al., 2022; Lodish, et al., 2016).

2.17.2.1 Interphase

Interphase is the longest phase of the cell cycle and is divided into three sub-phases - G1, S, and G2. G1, S, and G2 are the three different sub-phases of interphase, the longest stage of the cell cycle. Interphase is the stage of the cell cycle when the cell is growing, replicating its DNA, and preparing for cell division.

G1 (Gap 1): This is the first growth phase of interphase where the cell grows in size and increases its organelles in preparation for DNA replication. During this phase, the cell actively synthesizes RNA and proteins required for DNA replication.

S (Synthesis): This is the DNA synthesis phase where the cell replicates its DNA. During the S phase, the cell's DNA is duplicated, and the chromosomes, which were single-stranded, become double-stranded.

G2 (Gap 2): This is the second growth phase of interphase, where the cell continues to grow and prepare for cell division. During this phase, the cell synthesizes proteins required for cell division and prepares to enter the next stage, which is mitosis or meiosis. After G2, the cell enters into the second stage of the cell cycle, which is cell division. Cell division is further divided into two processes: mitosis and meiosis. During mitosis, somatic cells of the body divide and produce two identical daughter cells, while during meiosis, germ cells divide, and produce four haploid daughter cells (Alberts, et al., 2002).

2.17.2.2 Concept cell division

2.17.2.2.1 Mitosis

Mitosis is a process by which the nucleus of a eukaryotic cell is divided into two identical daughter nuclei. Mitosis is divided into five stages - prophase, pro-metaphase, metaphase, anaphase, and telophase. During prophase, the chromosomes condense and the spindle fibers form. In pro-metaphase, the nuclear membrane breaks

down and the spindle fibers attach to the chromatids. During metaphase, the chromosomes align on the metaphase plate. In anaphase, the spindle fibers pull the chromatids apart towards the opposite poles of the cell. Finally, during telophase, the chromosomes reach the poles and the nuclear membrane reforms around each group of chromosomes to form two nuclei (Dominguez-Brauer et al., 2015).

2.17.2.2.2 Meiosis

Meiosis is the process of cell division that occurs in the germ cells and results in the production of gametes. Meiosis involves two successive divisions, known as meiosis I and meiosis II, which produces four haploid daughter cells from one diploid parent cell. Meiosis I is similar to mitosis and involves prophase I, metaphase I, anaphase I, and telophase I. However, unlike mitosis, homologous chromosomes pair up during prophase I and exchange genetic material in a process known as crossing over. In meiosis II, chromatids separate into individual chromosomes, leading to the formation of four haploid daughter cells (Hillers et al., 2017; Wilkins & Holliday, 2009).

2.17.2.2.3 Cytokinesis

Cytokinesis is the final stage of the cell cycle, which involves the separation of cytoplasmic contents into two identical daughter cells. Cytokinesis in animal cells involves the formation of a cleavage furrow, which is deepened by the contractile ring made of actin and myosin molecules. In plant cells, cytokinesis involves the formation of a cell plate that grows from the center towards the cell walls. The cell cycle involves the replication of DNA followed by cell division, which can occur in either mitosis or meiosis. Cytokinesis eventually leads to the formation of two identical daughter cells. These processes ensure that genetic information is duplicated and distributed equally to daughter cells (Alberts, et al., 2002).

2.17.2.2.4 The in-depth discussion of each phase, highlighting key events and their molecular mechanisms

G1 phase

According to Wilkins and Holliday (2009), this is the first growth phase of interphase. During G1, the cell grows in size, increases its organelles in preparation for DNA replication, and synthesizes RNA and proteins required for DNA replication. G1 is an important phase in the cell cycle because it is the most highly regulated stage, and if the cell receives signals to enter the cell cycle, it progresses through the rest of the stages. If the cell does not receive these signals, it can remain in G0 phase, a quiescent phase where the cell is alive but not actively dividing.

Key Events:

- ❖ In G1, cells monitor their environment to determine if they should divide. This is regulated by tumour suppressor genes and oncogenes, which control the cell cycle and prevent uncontrolled cell division.
- ❖ The G1/S checkpoint is the most important checkpoint of the cell cycle because it determines whether the cell is ready to commit to DNA replication or not. The checkpoint is regulated by a protein complex called cyclin-dependent kinase 4/6 (CDK4/6), which must be activated by the presence of cyclin D before progression into S phase.
- ❖ G1 also involves the replication of organelles, such as mitochondria and ribosomes, in preparation for cellular division.

S phase

This is the phase of the cell cycle where DNA replication takes place. During S phase, the cell's DNA is duplicated, and the chromosomes, which were single-stranded,

become double-stranded. The process of DNA replication is highly regulated to prevent errors and ensure the accurate copying of genetic material.

Key Events

- ❖ The initiation of DNA replication is regulated by the origin recognition complex (ORC), which binds to specific sites on the DNA and recruits other proteins in preparation for replication.
- ❖ The active DNA replication process involves the unzipping of the DNA molecule by a helicase enzyme, with each strand acting as a template for the synthesis of new strands.
- ❖ Each new complementary strand is synthesized by DNA polymerase, which adds nucleotide bases to the growing DNA strand in a 5'-3' direction.
- ❖ Once replication is complete, the DNA helix is completely replicated, and each daughter cell will receive an identical copy of the genetic material.

G2 phase

This is the second growth phase of interphase, where the cell continues to grow and prepare for cell division. During G₂, the cell synthesizes proteins required for cell division and prepares to enter the next stage, which is mitosis or meiosis.

Key Events

- ❖ During G₂, the cell carefully monitors the completion of DNA replication and undergoes a checkpoint to verify that the replicated DNA is intact before the cell commits to mitosis.
- ❖ During G₂, several proteins required for the progression of the cell cycle, such as cyclin B1 and CDC2, are synthesized in preparation for entry into mitosis.
- ❖ G₂ is highly regulated by checkpoint kinase 1 (CHK1) and checkpoint kinase 2 (CHK2), which are activated in response to DNA damage during G₂. The

checkpoint arrest gives the cell the time required to repair damage before entering mitosis.

In conclusion, the cell cycle is a complex process that involves several tightly regulated events and checkpoints that ensure genomic stability and maintain cell integrity. The interphase stage of the cell cycle is particularly critical, as it plays a pivotal role in the accurate duplication of DNA before cell division (Alberts, et al., 2002).

2.17.3 Concept Mendelian genetics

The fundamental principles of Mendelian genetics are based on the work of Gregor Mendel, a 19th-century scientist known as the “Father of Genetics.” Gregor Mendel, an Austrian monk, conducted a series of ground-breaking experiments between 1856 and 1863 on the inheritance of traits in pea plants. His meticulous work laid the foundation for modern genetics and resulted in the formulation of Mendel’s Laws of Inheritance (Olby, 1994; Mendel, 1996; Mendel, 2008). Mendel’s experiments on pea plants yielded three foundational principles that explain the transmission of genetic traits from parents to offspring. These principles include the law of segregation, the law of independent assortment, and the law of dominance (Mendel, 2021).

2.17.3.1 Law of segregation

This principle states that during the formation of gametes (sex cells), the two alleles (alternative forms of a gene) segregate or separate from each other. As a result, each gamete carries only one allele for a particular trait. When fertilization occurs, the two alleles from the parents combine, determining the genotype of the offspring (Mendel, 2008).

2.17.3.2 Law of independent assortment

This principle states that alleles for different traits segregate independently during the formation of gametes. In other words, the inheritance of one trait does not affect the inheritance of another unrelated trait. This principle suggests that traits are inherited randomly and independently of each other (Mendel, 2008).

2.17.3 Law of dominance

According to this principle, one allele in a pair of alleles (the dominant allele) has the ability to mask the expression of the other allele (the recessive allele). When an individual has at least one dominant allele, the dominant trait will be displayed in the phenotype (observable characteristics), regardless of whether the second allele is dominant or recessive. The recessive trait will only be observable if both alleles are recessive (Hart et al., 2009). To understand these principles, it is essential to be familiar with some core genetics vocabulary such as:

2.17.4 Alleles

Alleles are alternative forms of a gene that occupy the same position (locus) on a pair of homologous chromosomes. They are responsible for the variation in a particular genetic trait. For example, for the gene determining flower colour in pea plants, the gene could have two alleles: one that codes for purple flowers and another for white flowers (Hart et al., 2009).

2.17.4.1 Allele morph

Allele morph refers to the term coined by Mendel, which is now more commonly known as an allele. It represents one of the possible variations of a gene. For instance, the allele morphs of the flower colour gene could be the purple allele and the white allele (Mendel, 2021).

2.17.4.2 Phenotype

Phenotype refers to the observable physical or biochemical characteristics of an organism, resulting from the interaction between its genotype and the environment. For example, in the pea plant, the phenotype could be either purple or white flower colour.

2.17.4.3 Genotype

Genotype refers to the genetic makeup of an organism. It represents the combination of alleles present in an individual for a particular trait. Using the flower colour gene as an example, an individual can have a genotype of either PP (homozygous dominant for purple flowers), Pp (Heterozygous, with one dominant and one recessive allele), or pp (homozygous recessive for white flowers). These fundamental principles and vocabulary are crucial for understanding the inheritance patterns and genetic variability observed in species. Mendelian genetics laid the foundation for further advancements in the field of genetics (Mendel, 2008).

2.17.4.4 Mendel's experiment

2.17.4.4.1 Selection of pea plants

Mendel chose the garden pea plant (*Pisum sativum*) for his experiments due to its easily observable traits, short life cycle, and ability to self-fertilize or cross-fertilize (Mendel, 1996; Mendel, 2008). He selected seven pairs of contrasting traits, such as tall vs. short plants, smooth vs. wrinkled seeds, yellow vs. green seeds, etc., as the basis for his investigations (Mendel, 2008).

2.17.4.4.2 Artificial pollination

To control the process of fertilization, Mendel performed artificial pollination. He manually removed the male reproductive organs (anthers) of one plant to prevent self-fertilization and then transferred pollen from another plant (with desired traits) to

the stigma of the first plant. This process allowed him to ensure specific crosses between different individuals (Mendel, 2008).

2.17.4.4.3 Controlled breeding

To study the inheritance patterns of traits, Mendel performed controlled breeding experiments over several generations. He carefully tracked the parent plants and the traits they exhibited to determine how these traits were passed on to future generations (Mendel, 2008).

2.17.4.4.4 Generation terminology

Mendel classified the generations into the P, F1, and F2 generations. The P generation represented the parental generation, in which two pure-breeding plants with contrasting traits were crossed. The resulting offspring from this cross were called the F1 generation. Lastly, the F2 generation was obtained by self-fertilizing the F1 plants or crossing them with each other (Mendel, 2008).

2.17.4.4.5 Law of segregation

According to Jayakody (2019), Mendel's most significant finding was the Law of Segregation. He observed that for each trait, one form (allele) appeared dominant over the other, which was recessive. When two hybrid plants (F1 generation) with the dominant phenotype were crossed, the recessive trait reappeared in some of the F2 offspring. Mendel concluded that factors responsible for each trait separate during gamete formation and only recombine during fertilization.

2.17.4.4.6 Law of independent assortment

To Jayakody (2019), Mendel also discovered the Law of Independent Assortment through his experiments. He studied the inheritance of multiple traits together and found that the inheritance of one trait did not influence the inheritance of

another. This principle demonstrated that different traits were inherited independently of each other, contradicting the assumption of blending inheritance prevalent at that time.

2.17.4.4.7 Quantitative analysis

Mendel quantitatively analysed the observed ratios of different trait combinations in the offspring. He derived a set of mathematical ratios, known as Mendelian ratios, such as the 3:1 ratio for the F₂ generation of monohybrid crosses and the 9:3:3:1 ratio for the F₂ generation of dihybrid crosses. Mendel's experiments and subsequent publications on his findings went relatively unnoticed during his lifetime. It was only after his death that his work gained recognition, eventually leading to the development of the field of genetics (Mendel & Bateson, 2023; Mendel, 1996). Mendel's experiments are considered a cornerstone of modern biology, providing fundamental insights into the way traits are inherited and passing on the legacy of a scientific pioneer.

2.17.5 Integration of cell division and Mendelian genetics

Cellular processes of mitosis and meiosis play a crucial role in Mendelian genetics by ensuring the proper distribution of genetic material during cell division. This ensures the transmission of genetic information from one generation to the next and the inheritance of traits in a predictable manner. According to Hartwell et al. (2010), mitosis is the process of cell division that occurs in somatic cells, resulting in the production of two identical daughter cells. It is responsible for growth, repair, and asexual reproduction. During mitosis, the replicated chromosomes are evenly distributed between the daughter cells, ensuring that each cell receives a complete set of genetic material. In the context of Mendelian genetics, mitosis contributes to the inheritance of traits by maintaining the constant number of chromosomes in each

generation. This means that the offspring inherit the same number of chromosomes as their parents, ensuring that the genetic information is preserved. This is essential for the transmission of alleles, which are alternative forms of a gene, from one generation to the next according to Mendel's laws (Jayakody, 2019). Meiosis, on the other hand, is a specialized form of cell division that occurs in germ cells, resulting in the formation of gametes (sperm cells and egg cells). Unlike mitosis, meiosis involves two rounds of cell division, resulting in the production of four non-identical daughter cells with half the number of chromosomes as the parent cell.

Meiosis is crucial for Mendelian genetics as it introduces genetic variation through the process of recombination and independent assortment. Recombination occurs during the first division of meiosis when homologous chromosomes exchange genetic material, resulting in new combinations of alleles. This shuffling of genetic material contributes to the diversity of traits observed in offspring (Hartwell et al., 2010). Independent assortment occurs during the second division of meiosis when the homologous chromosomes separate randomly, leading to the independent distribution of alleles. This means that the combination of alleles inherited by an offspring is not solely determined by the combination present in their parents but is a result of chance. Independent assortment further contributes to the diversity of traits and allows for the expression of different combinations of alleles. The cellular processes of mitosis and meiosis are essential for Mendelian genetics. Mitosis ensures the preservation and transmission of genetic information, while meiosis introduces genetic variation through recombination and independent assortment. These processes contribute to the inheritance and expression of traits in a predictable manner, as described by Mendel's laws.

2.17.6 Explanation of how genetics information is passed from parental cells to daughter cells during mitosis and meiosis

During mitosis, genetic information is passed from parental cells to daughter cells in a process called cell division. Mitosis is responsible for the growth and repair of tissues, as well as asexual reproduction in some organisms. The process of mitosis consists of several stages: prophase, metaphase, anaphase, and telophase. During prophase, the genetic material in the form of chromosomes condenses and becomes visible. The nuclear envelope also breaks down, and the centrosomes move to opposite poles of the cell, forming spindle fibers. In metaphase, the chromosomes line up at the center of the cell, forming a metaphase plate. The spindle fibers attach to the centromeres of the chromosomes, ensuring their proper alignment. During anaphase, the spindle fibers contract, pulling the sister chromatids apart. Each chromatid, now referred to as a chromosome, moves towards opposite poles of the cell. Finally, in telophase, the chromosomes reach the poles, and a new nuclear envelope forms around each set of chromosomes (Wang, 2014). The chromosomes de-condense, and the cell starts to divide into two daughter cells through a process called cytokinesis. During meiosis, genetic information is passed from parental cells to daughter cells in a specialized type of cell division that leads to the formation of gametes (sperm and eggs).

Meiosis involves two rounds of division, known as meiosis I and meiosis II, resulting in the production of four haploid daughter cells. In meiosis I, the process is similar to mitosis, with the pairing of homologous chromosomes during prophase I, their alignment at the metaphase plate during metaphase I, their separation and movement towards opposite poles during anaphase I, and the formation of two daughter cells during telophase I. However, the key difference occurs during an event called crossing over, which happens during prophase I. During crossing over, non-sister

chromatids of homologous chromosomes exchange genetic material, resulting in genetic recombination and an increase in genetic diversity. Meiosis II is similar to mitosis, but with the separation of sister chromatids instead of homologous chromosomes. This results in the formation of four haploid daughter cells, each containing a unique combination of genetic material (Wang, 2014; Strand & Boes, 2019). In summary, during both mitosis and meiosis, genetic information is passed from parental cells to daughter cells through the replication and division of chromosomes. However, meiosis involves additional processes such as crossing over and two rounds of division, leading to the formation of genetically diverse gametes.

2.17.6.1 Applications and implications

Understanding the relationship between cell division and genetics is crucial in explaining phenomena such as genetic disorders, genetic counselling, and genetic engineering. Cell division plays a significant role in the transmission of genetic information from one generation to the next, and any errors or abnormalities in this process can lead to genetic disorders (Alberts et al., 2014). Alberts, et al. (2014) explained genetic disorders as conditions that result from changes or mutations in genes. These mutations can occur during cell division, specifically during DNA replication or chromosome segregation. For example, in autosomal dominant disorders like Huntington's disease, a mutation in a single gene causes abnormal cell division and leads to the development of the disorder (Hart & Hart, 2009). To them, the connection between cell division and genetics is also relevant in genetic counselling.

Genetic counsellors assist individuals and families in understanding and managing the risk of inherited genetic conditions. The examination of the patterns of cell division, inheritance and genetic counsellors can assess the likelihood of a genetic disorder being passed on to future generations (Clayton et al., 2019). Additionally,

genetic engineering techniques rely on an understanding of cell division and genetics. Genetic engineering involves modifying an organism's genetic material to introduce desired traits or remove undesirable ones. Techniques like gene editing, such as CRISPR-Cas9, utilize cell division to introduce changes in an organism's DNA. By manipulating the process of cell division, scientists can edit genes and potentially cure genetic disorders or enhance desired traits (Hurle et al., 2013).

2.17.6.2 Genetic counselling

Understanding the relationship between cell division and genetics helps genetic counsellors provide accurate risk assessments and guidance to individuals and families. For instance, if a person carries a mutation in a gene associated with an autosomal dominant disorder, such as BRCA1 for hereditary breast and ovarian cancer, genetic counsellors can explain how the mutation affects cell division and the likelihood of passing it on to future generations (Sadava et al., 2011). To them, the information allows individuals to make informed decisions about their reproductive choices and potential preventive measures.

2.17.6.3 Genetic engineering

Cell division and genetics play a crucial role in genetic engineering techniques like gene therapy. In gene therapy, cells are modified to introduce functional genes or correct mutations. By understanding the processes of cell division and genetics, scientists can target specific cells or tissues for gene delivery, ensuring that the modified genetic material is properly incorporated into the dividing cells. This understanding helps improve the effectiveness and safety of gene therapy treatments (Sadava et al., 2011). For example, in the case of genetic disorders caused by a single gene mutation, such as cystic fibrosis, scientists can use gene editing tools like CRISPR-Cas9 to correct the mutation in affected cells. By means of precisely modifying the genetic material

during cell division, they can potentially provide a cure or alleviate symptoms of the disorder. The above examples demonstrate how understanding of the relationship between cell division and genetics in the fields of genetic counselling and genetic engineering can have practical applications in diagnosing, treating, and preventing genetic disorders (Sadava et al., 2011).

2.18 Empirical Review

In recent years, interactive multimedia instructional approach has gained popularity as a tool for enhancing learning experiences. This empirical review aims to examine the effectiveness of interactive multimedia instructional approach in enhancing the teaching and learning and its alignment with cognitive load theory in facilitating the learning of complex topics such as cell structure, cell division, and Mendelian genetics (MANUU, 2016; Abdulrahaman et al., 2020). The review synthesizes findings from a range of empirical studies conducted in educational settings. Several studies focused on the impact of interactive multimedia instructional approach on student engagement, knowledge acquisition, and conceptual understanding (Mikropoulos & Natsis, 2011; MANUU, 2016; Abdulrahaman et al., 2020). The integration of interactive multimedia instructional approach in educational settings has become increasingly prevalent due to its potential to enhance student engagement and facilitate active learning. This review investigates the empirical evidence supporting the use of interactive multimedia instructional approach specifically for teaching cells, cell division, and Mendelian genetics. A careful review of empirical studies on the use of interactive multimedia instructional approach in teaching the concepts cell, cell division and Mendelian genetics has unearthed a significant amount of information on the research topic.

2.19 Effect of Multimedia on Student Motivation and Engagement in Biology

Interactive multimedia instructional approach has consistently been shown to increase student engagement and integration into education systems, particularly in the field of science education. In recent years, it has been explored as a potential tool for enhancing the motivation and engagement of pre-service science teachers, especially in biology lessons. A study by Nilson and Goodson (2021) found that students using interactive multimedia instructional approaches were more actively involved in the learning process, as indicated by increased participation in class discussions and higher levels of motivation. Again, a study conducted by Garrison and Kanuka (2004) found that interactive multimedia instructional approaches can significantly improve the motivation and engagement of pre-service science teachers. The researchers found that the use of multimedia elements such as animations, simulations, and interactive quizzes increased the pre-service teachers' understanding of complex biological concepts, leading to increased motivation and engagement in the learning process. Similarly, another research conducted by Yang and Liu (2010) explored the impact of interactive multimedia instructional approach on pre-service science teachers' motivation and engagement in biology lessons. The results indicated that the use of interactive multimedia instructional approach led to increased motivation, improved learning outcomes, and a higher level of engagement among the participants. Again, a study by Hsu (2012) investigated the effect of interactive multimedia instructional approach on pre-service science teachers' self-efficacy, motivation, and engagement in biology lessons.

The findings revealed that the use of interactive multimedia instructional approach significantly improved the pre-service teachers' self-efficacy, motivation, and engagement in the learning process. The researcher concluded that interactive

multimedia instructional approach can be an effective tool in fostering motivation and engagement among pre-service science teachers. In a review by Ally (2007), it was noted that interactive multimedia instructional approach can offer a more engaging and immersive learning experience for pre-service science teachers. The reviewer suggested that the use of multimedia elements such as animations, simulations, and interactive quizzes can help to create a more dynamic and interactive learning environment, leading to increased motivation and engagement. Indeed, research has shown that interactive multimedia instructional approach can have a significant impact on pre-service science teachers' motivation and engagement in biology lessons. The use of multimedia elements such as animations, simulations, and interactive quizzes can lead to increased motivation, improved learning outcomes, and a higher level of engagement among pre-service science teachers (Ally & Ally, 2008). However, further research is needed to explore the long-term effects of interactive multimedia instructional approach on pre-service science teachers' motivation and engagement in biology lessons, as well as the potential challenges and limitations of this approach (Ally & Ally, 2008).

2.19.1 Knowledge acquisition

Multiple studies have demonstrated that interactive multimedia instructional approach positively impacts students' knowledge acquisition. In a randomized controlled trial conducted by Wang et al. (2022), students exposed to interactive multimedia instructional approaches showed significantly higher scores on post-assessment tests compared to those in traditional instruction groups.

2.19.2 Conceptual understanding

Interactive multimedia instructional approach has shown promise in promoting conceptual understanding of cells, cell division, and Mendelian genetics. Research by Chen and Lee (2018) revealed that students who utilized interactive multimedia

instructional approaches had a deeper understanding of cellular processes and Mendelian genetics concepts, as evidenced by their ability to apply acquired knowledge and skills in solving complex problems.

2.19.3 Limitations and challenges

In spite of the benefits of interactive multimedia instructional approach, several challenges exist. Studies have identified technical issues, such as software glitches and inadequate access to technology, as potential barriers to effective implementation. Moreover, some studies have highlighted the need for proper guidance and scaffolding to ensure optimal use of interactive multimedia instructional approaches. Again, Al-Ani (2013) conducted a study on blended learning approach using Moodle and Student's achievement at Sultan Qaboos University in Oman. The study attempts to identify factors behind the usage of a blended learning approach that could have an effect on students' achievement, motivation, collaboration and communication as perceived by students. It also aims to analyse obstacles faced by students in using Moodle in blended learning. A sample of 283-students from all colleges at Sultan Qaboos University was randomly selected. A questionnaire of 45 items was developed to collect data. The results revealed that using Moodle in blended learning has an average level of effectiveness related to students' motivation with a mean of 3.216 and mean of 3.164 for students' achievements, and mean of 3.199 is related to students' collaborations and communication. The results showed there is no statistically significant difference among student perceptions related to gender and college type. The results also revealed that the highest obstacles facing students related to frequent disturbance in computer devices with mean 3.090. Based on the result of the study, many recommendations have been developed.

2.20 The Long-term Benefits of Interactive multimedia instructional approach

Interactive multimedia instructional approaches have been found to have several long-term benefits for pre-service science teachers in retaining biology concepts. Some of these benefits include:

2.20.1 Improved long-term retention

Interactive multimedia instructional approach can lead to better long-term retention of biology concepts. A study by Mayer (2005) found that multimedia presentations that combined narration with on-screen text and graphics improved students' long-term recall of the material compared to presentations that used text alone.

2.20.2 Enhanced problem-solving skills

Interactive multimedia instructional approaches can foster problem-solving skills in pre-service science teachers. According to a study by Azevedo and Kali (2010), students who used interactive multimedia instructional approaches were better able to solve complex biology problems than those who used traditional textbooks.

2.20.3 Increased curiosity and interest

Interactive multimedia instructional approach can stimulate curiosity and interest in biology, leading to increased motivation and engagement. A study by Hong et al. (2016) found that pre-service science teachers who engaged with interactive multimedia instructional approach reported higher levels of interest and curiosity in biology than those who used traditional methods.

2.20.4 Facilitation of deeper learning

Interactive multimedia instructional approach can facilitate deeper learning by providing opportunities for active learning and critical thinking. A study by Clark and Mayer (2023) found that multimedia presentations that encouraged active learning and

critical thinking led to a deeper understanding of biology concepts compared to passive presentations.

2.20.5 Adaptability

Interactive multimedia instructional approaches can be easily adapted to meet the needs of individual learners. A study by Brame (2016) found that personalized multimedia learning environments improved students' understanding and retention of biology concepts. In conclusion, interactive multimedia instructional approaches have the potential to significantly improve the long-term retention of biology concepts for pre-service science teachers. By promoting active learning, critical thinking, and curiosity, these applications can lead to a more engaging and effective learning experience.

2.21 Rationale of the Study

Most science teachers often use only the lecture method to teach. As a result, the academic performance of basic and senior high school students especially in biology is on a continual decline in certain parts of the country. Because of this, there is the need to introduce an effective means of teaching learners with information or dissemination of abstract concepts to learners. According to Arthur-Baidoo et al. (2022) there has been the agitation for a shift from the traditional system of teaching learners with information to promote intellectual development. The reasons for advocating for a shift from the traditional method of teaching were to develop the thinking skills of learners. The implication of this is that, schools should have the teaching of concept formation at the core of their proceedings since in this modern technological sophisticated world, good thinking is the key to successful learning and the development of the intellectual and psychomotor skills of learners is the responsibility of teachers.

In order to improve students' understanding, practical, interactive multimedia instructional approach and demonstrative experiments, must be included in the teaching and learning strategies. Teachers must be aware of students' previous knowledge and misconceptions that are likely to destabilize their understanding of the subject matter, therefore, they have to employ appropriate instructional approaches that can either eradicate or curb misconceptions in the preparation and during the delivery of lessons by teachers. This is because learning occurs when students engage themselves in activities which involve demonstrations and discussions, as these exposes students' misconceptions and suggests appropriate ways to conceptualize knowledge in a simpler form (Aizikovitsh-Udi & Cheng, 2015; Arthur-Baidoo et al., 2022).

There is therefore, the need to equip pre-service science teachers with effective instructional approaches to overcome instructional misconceptions to result in meaningful learning. The rationale in this study was to use practical activities and interactive multimedia instructional approach to demystify some abstract concepts in biology such as cell structure, cell division and Mendelian genetics to be easier for students to learn. This conceptual change approach is applied and evaluated with respect to its effectiveness on teachers' pedagogical skills and academic performance of learners. The empirical evidence reviewed above suggests that interactive multimedia instructional approach positively impacted on student engagement, knowledge acquisition, and conceptual understanding in the context of cell structure, cell division, and Mendelian genetics. However, further research is needed to address challenges and explore additional ways to maximize the potential benefits of interactive multimedia instructional approach in teaching and learning these identified concepts in biology.

2.22 The Role of Multimedia in Biology Education

Multimedia approaches, which integrate text, images, audio, animation, and video, are increasingly being used in biology education to improve conceptual understanding. Mayer (2009) emphasizes that multimedia learning effectively uses both visual and auditory channels in the brain, enhancing comprehension and retention. Moreno and Mayer (2007) further found that well-designed multimedia approaches promote deeper learning than traditional instruction, especially in complex subjects like biology.

2.22.1 Types of effective multimedia approaches

Animations and Simulations

Animations are useful in visualizing dynamic biological processes such as mitosis, meiosis, and DNA replication. Akpan and Andre (2000) concluded that simulations helped students grasp abstract biology concepts better than conventional approaches. These approaches provide real-time feedback and interactive elements that support active learning.

Educational Videos

Educational videos, especially those used in flipped classroom models, have proven effective in improving student engagement and understanding. Kay (2012) found that students who accessed short instructional videos before class performed better and were more prepared for in-class activities.

Interactive Software and Mobile Apps

Programs such as BioMan Biology and Virtual Cell provide hands-on experiences through gamified learning. Rutten et al. (2012) observed that virtual labs helped develop students' inquiry skills and critical thinking in biology.

3D Models and Augmented Reality (AR)

The use of AR and 3D modelling tools allows students to explore microscopic and abstract biological structures like organelles and DNA in more tangible ways. Dunleavy and Dede (2014) showed that students using AR demonstrated improved spatial reasoning and were more engaged in learning activities.

2.22.2 Effective multimedia teaching strategies

Guided Discovery Learning, Flipped Classroom Approach and Scaffold Instruction

Rather than replacing teachers, multimedia approaches are most effective when used alongside guided instruction. De Jong and van Joolingen (1998) noted that students benefit more from simulations when given prompts and support, which helps bridge the gap between discovery and understanding. In flipped learning models, students watch educational content at home and engage in active learning during class. Bergmann and Sams (2012) demonstrated that this method increases classroom interaction and reinforces understanding through collaborative activities. Mayer and Moreno (2003) highlight the importance of scaffolding, such as using guiding questions or hints during multimedia learning to prevent cognitive overload and promote meaningful learning.

2.22.3 Challenges and considerations

Despite their advantages, the successful integration of multimedia depends on instructional design, teacher readiness, and technological infrastructure. Poorly designed materials may confuse learners, and in resource-limited settings like many Ghanaian Colleges of Education, access to devices and reliable internet remains a challenge (Anamuah-Mensah et al., 2019). Some of these challenges are:

Resource Availability, Teacher Training and Curriculum Alignment

The effectiveness of multimedia tools is contingent upon the availability of necessary technological resources, such as computers and internet access. In regions with limited resources, this can pose a significant barrier to implementation. Educators must be adequately trained to integrate multimedia tools into their teaching practices effectively. Without proper training, the potential benefits of these tools may not be fully realized. It's essential to ensure that multimedia approaches align with the curriculum and learning objectives. Misalignment can lead to confusion and hinder the learning process.

Infrastructure and Access, Pedagogical Readiness

A major challenge in many developing contexts is access to necessary hardware and stable internet. Without these, the implementation of multimedia tools is limited (Anamuah-Mensah et al., 2019). The effectiveness of multimedia tools depends on how well educators can integrate them into teaching. Many teachers lack sufficient training or familiarity with digital tools (Kay, 2012).

2.22.4 Benefits of interactive multimedia instructional approach in biology education

Enhanced Conceptual Understanding in Biology Concepts

Interactive multimedia instructional approach (IMIA) such as animations, virtual labs, and simulations enable students to observe dynamic biological processes that are otherwise invisible or abstract. For example, simulations of mitosis or the circulatory system can help students conceptualize the processes better than static textbook images (Mayer, 2009).

Increased Student Engagement

Multimedia content fosters active participation. Approaches like BioMan Biology or interactive simulations encourage students to engage with content playfully and meaningfully. Engagement leads to improved motivation and a positive attitude towards science learning (Moreno & Mayer, 2007).

Improved Academic Performance

Empirical studies have demonstrated improved academic performance when multimedia approaches are integrated into biology education. For instance, Adegoke (2011) found that students exposed to multimedia-assisted instruction performed significantly better in biology exams compared to those taught via traditional methods.

2.22.5 Effective instructional strategies for multimedia integration

Blended Learning: Combining traditional teaching with multimedia enhances learning outcomes by catering to various learning styles (Bergmann & Sams, 2012).

Guided Discovery and Scaffolding: Students should be guided while interacting with multimedia content to prevent misconceptions or cognitive overload (Mayer & Moreno, 2003).

Collaborative and Inquiry-Based Learning: Multimedia approaches foster inquiry-based activities. When students collaborate using simulations or digital labs, they develop higher-order thinking and problem-solving skills (De Jong & van Joolingen, 1998).

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter is composed of research perspective, research design and rationale for the research design. It further provides description of research settings, population, sample and sampling technique, instrumentation, validity and reliability of the instrument, data collection procedure and methods were employed to analyse the data collected.

3.1 Research Paradigm

The research paradigm that was used in this study is pragmatism. According to Collis and Hussey (2014), pragmatism as a research paradigm evaluates theories or beliefs in terms of their practical applications to real life situations thus explanations are aimed at understanding a complex reality and finds its philosophical foundation in the historical contributions of the philosophy of paradigms and, as such, holds plurality of methods. As a research paradigm, pragmatism is based on the scheme that researchers should use the philosophical and/or methodological approach that works best for the particular research problem that is being studied (Shan, 2022). Pragmatism is the most suitable methodology as compared to other research paradigm because the researchers can use the qualitative paradigm for one stage and the quantitative paradigm for another stage. Hence, the use of pragmatist approaches in the study.

3.2 Research Design

A research design is a plan or a blueprint that specifies how data relating to a given problem should be collected and analysed (Adusei, 2017). It consists of decisions about what, where, how much and what means to conduct a research study (Aboagye et al., 2020). They further stated that research design is needed because it aids the

smooth conduct of the various research operations, thereby making research as effective as possible and yielding the greatest amount of information with the least effort, time, and money. So, a research design is a strategy for collecting, analysing, interpreting and reporting research data (Chih-Pei & Chang, 2017). Once the topic and research problem have been established, the objectives have been sufficiently detailed, the concepts have been properly defined, and the researcher has accurately articulated the hypothesis, research should be based on some type of design (Akhtar, 2016). Therefore, a research design is a broad strategy for linking relevant empirical research to conceptual research questions. To put it another way, the study design specifies the steps to be taken on the designated day, the techniques to be utilized to collect and analyse research data, and the ways in which these factors work in performance to help answer the research questions.

The design that was used in this study was action research design and it's followed the convergent parallel mixed methods design (Creswell & Plano-Clark, 2011; Creswell, 2009; Bazeley, 2004). Thus, both quantitative and qualitative methods were used parallel to obtain complementary data on using interactive multimedia instructional approach to improve the academic performance of pre-service science teachers in teaching and learning of biology concepts such as cell structure, cell division and Mendelian genetics. It was also used to gather data on students' perceptions on the use of interactive multimedia in teaching and learning of biology and its effects on their academic performance. The quantitative and qualitative datasets were analysed separately, and the results were discussed along with the research questions.

A schematic diagram of the convergent parallel mixed methods design used in this study is presented in Figure 2.

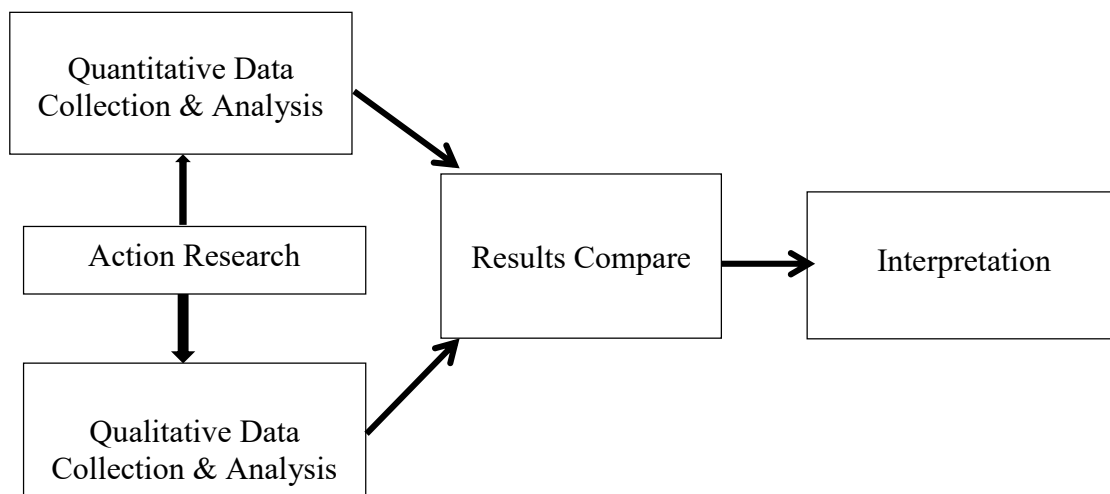


Figure 2:
Diagram of the convergent parallel mixed methods design

3.3 Rational for the Design

The rationale for using this design was that the study sought to improve pre-service science teachers' performance in selected biology concepts using interactive multimedia instructional approach (IMIA) as an intervention strategy. Action research was used for the study because it allowed the researcher and pre-service science teachers to actively engaged in the research process while simultaneously improving their performance in examinations (Cohen et al., 2013) and it's followed the convergent parallel mixed methods design (Creswell & Plano-Clark, 2011; Creswell, 2009; Bazeley, 2004). Thus, both quantitative and qualitative methods were used congruently to obtain complementary data on using interactive multimedia instructional approach to improve the academic performance of pre-service science teachers in teaching and learning of biology concepts such as cell structure, cell division and Mendelian genetics. It was also used to gather data about students' perceptions on the use of interactive multimedia instructional learning in biology and its effects on their academic performance. The iterative nature of action research allows for continuous improvement and refinement of strategies and interventions based on on-going feedback and

evaluation (Creswell & Creswell, 2017). Action research is typically conducted within a specific school or classroom context. This enables researchers to gain a deep understanding of the unique challenges, resources, and constraints present in that particular setting, leading to more contextually relevant and realistic findings.

3.4 Research Settings

The study was conducted in Science Education Department of Wiawso College of Education in the Wiawso Municipality in the Western North. The College is geographically located at latitude 6.1981° or $6^{\circ} 11' 53''$ north and longitude -2.49232° or $2^{\circ} 29' 32''$ west. The main Sefwi Wiawso town, which doubled as the capital of Wiawso Municipal and the region is one of the nine districts in Western North Region of Ghana (Fig.3). The Western North Region is one of the six new regions of Ghana created in 2019 (Ghana Immigration Service, 2019). The region is bounded by the Ivory Coast on the west, the Central region in the southeast, and the Ashanti, Ahafo, Bono East and Bono regions in the north. This Municipal is situated on a highland area and share common boundaries with Bibiani Anhwiaso Bekwai on the East; Bodi on the west; Juaboso on west north and Ankontombra on west south.

This Municipal is noted for its cocoa production and its commercial activities due to its strategic point in the map of Ghana; and can boast of at least three College of Education, four Nursing Training College and thirteen Senior High Schools, all public and one Private College of Education. The map below shows the study area or research setting. The Wiawso College of Education (abbreviated as WCoE aka WATICO) is one of the 46 public Colleges of Education in Ghana. The college offers sciences (mainly Chemistry, Biology, Physics and Integrated Science) as one of its academic programs. The medium of instruction is English Language and it has classrooms, lecture halls and a laboratory.

3.5 Population

Population of study for any research work has been variously defined by different scholars and their definitions pointed towards the same direction. According to Creswell and Creswell (2017) population of a study refers to a group of individuals or objects capable of providing the whole or part of the answers that satisfy the research questions of the study. Again, Rahi (2017) also conceptualised research population as all the people or objects that possess some characteristics that the researcher seeks to understand whiles Akinade and Owolabi (2009) defined population as “the total set of observations from which a sample is drawn”.

This means that population often connotes all members of the target of the study as defined by the aims and objectives of the study. Thus, population of a study deals with entire aggregates of people that the researcher was interested in obtaining relevant information from them for his/her study. The participants in this study were all pre-service science teachers from Wiawso College of Education, Sefwi Wiawso during the academic year 2022/2023. But for the purpose of this study, the target population for the research were the level 200 pre-service science teachers at Wiawso College of Education (Table1). The level 200 pre-service science teachers were grouped into science/mathematics and science/ICT students.

Table 1:

Participants in the study

School	Class	Males (%)	Females (%)	Total (%)
Wiawso CoE	L200 Science/Maths	41 (53.950)	06 (7.890)	47 (61.840)
	L200 Science/ICT	14 (18.420)	15 (19.740)	29 (38.160)
Total		55 (72.370)	21 (27.630)	76 (100.000)

Source: Field Data, 2024

The college has students' enrolment of 1,190 students of which male students numbered 621 and female students numbered 569. The college has a male principal, vice principal, 43 teaching staff (34 males & 9 females) and 58 auxiliary staff (35 males & 23 females) as the time of conducting this study. This College of Education was purposively chosen due to its closeness to the study centre. Besides the closeness, the college was also selected because of: - (a) willingness of the respondents (pre-service science teachers) to take part in the study; (b) almost all of these pre-service science teachers had difficulties learning these concepts, that is cell structure, cell division and Mendelian genetics; (c) availability of a reasonable number of second year pre-service science teachers in the science classes; and (d) the concepts being studied matches with the researchers' concepts under investigation.

3.6 Sample

A sample is a collection of certain components drawn from the entire population. From this sample, something may be learned and expressed about the entire population (Wilson & Smetana, 2011). Because all fourth-year pre-service science teachers at Wiawso College of Education are required to teach integrated science at a variety of basic schools for a semester. As a result, final-year pre-service science teachers were excluded since it was difficult to contact them. The sample consisted of 76 second-year pre-service science teachers for the study and since the population is fairly large, the researcher interviewed a small portion of it. In qualitative research, a smaller number of participants are often selected to allow for an in-depth exploration of participants' experiences and perspectives. From the population of 76 pre-service science teachers, 10 participants were conveniently selected for interviews because qualitative inquiry emphasizes richness of information rather than large sample sizes. According to Creswell and Poth, qualitative studies typically involve a small number

of participants to enable detailed data collection and analysis (Creswell & Poth, 2018). The ten participants who took part in the research were selected using Rapley (2014) maximum variety sampling techniques to constitute in a small focus group and interviewed in-depth.

Furthermore, interview sample sizes in qualitative research are often guided by the concept of data saturation, which occurs when additional interviews no longer yield new information. Guest et al. (2018) found that saturation in homogeneous groups is often reached within the first 6-12 interviews (Guest et al., 2006). Therefore, selecting 10 participants from the population of 76 was considered adequate to obtain rich and meaningful insights while ensuring manageability of the qualitative data.

3.7 Sampling Technique

The study used purposive sampling and convenience sampling techniques to sample pre-service science teachers in the second-year of Science Department in Wiawso College of Education. The college and the classes were purposively selected. The intact L200 two classes were made up of students who offered biology as an elective subject. According to Farrokhi & Mahmoudi-Hamidabad (2012), convenience sampling is a type of nonprobability sampling in which members of the target population who meet certain practical criteria, such as easy accessibility, geographic proximity, availability at a specific time, or willingness to participate, are included for the study's purposes.

Furthermore, according to Pruchno et al. (2008), convenience sampling refers to population study subjects that are readily available to the researcher. Convenience sampling was used because is inexpensive, simple, and the subjects are easily available. It is also vital to describe any participants who was omitted from the sample during the selection procedure or those who were overrepresented in the sample (Leiner, 2014).

The basic assumption behind convenience sampling is that the members of the target population are all the same. Battaglia and Battaglia (2016) went on to say that the study results received from a random sample, a local sample, a cooperative sample, or a sample taken in an inaccessible area of the population would all be the same. Furthermore, convenience sampling was employed in qualitative aspect of the study and purposive sampling was also employed in the quantitative study (Creswell & Creswell, 2017). As a result, the sample for this study was drawn from Wiawso College of Education second-year pre-service science teachers.

3.8 Instrumentation

The study used both quantitative and qualitative data gathering instruments namely interview, pre-test and post-test and, questionnaire. The interview constituted qualitative data gathering instrument whereas tests and questionnaire formed the quantitative part of the instruments. Again, written documents such as daily observational notes and audiotapes were made to augment information that were obtained from the main instruments. The combination of these approaches guaranteed triangulation of the collected data (Schuwirth, & van der Vleuten, 2012; Khald, 2017).

3.8.1 Description of the interview schedule items

A semi-structured interview items called the Pre-Service Science Teachers' Interview Schedule of the perception of pre-service science teachers on use of interactive multimedia instructional approach in teaching and learning of biology concepts was adopted and used to collect data from the respondents.

3.8.1.1 Description of IMIA interview schedules items

The Interactive Multimedia Instructional Approach Interview Schedule (IMIAIS) was approved and used to collect data from the pre-service science teachers after the implementation of interactive multimedia instructional approach intervention

activities. The interview schedule was made up of ten (10) questions (i.e., 1-10). These ten question items were formulated based on the research question 5 to find out the perceptions of the pre-service science teachers with respect to the interactive multimedia instructional approach instructional approach used in the teaching and learning of the concepts understudied. Sample of the interview schedule could be found in Appendix E2. The pre-service science teachers' responses were qualitatively analysed and transcribed verbatim.

3.8.2 Description of test items

Two sets of tests of similar standards called pre-intervention test and post-intervention test were constructed and approved based on the selected biology concepts and were used to collect data from the pre-service science teachers for the study. The pre-intervention test called "Pre-Service Science Teachers' Biology Diagnostic Test (TEST 1) was used before the implementation of Interactive Multimedia Instructional Approach intervention activities. On the hand, the post-intervention test called "Pre-Service Science Teachers' Biology Achievement Test (TEST 2) was used to assess the respondents' conceptual understanding of the selected biology concepts after the implementation of the Interactive Multimedia Instructional Approach (IMIA) intervention activities.

The pre-intervention test (TEST 1) consisted of preambles with general instructions and three (3) sections; Section A, B and C respectively. Each section is made up of thirty (30) multiple-choice objective question items grouped under the following; Section A- Cell Structure, Section B-Cell Division and section C-Mendelian Genetics, and the post-intervention test (TEST 2) also made up of preambles with general instructions and three (3) sections namely; Section A, B and C respectively. Each section is made up of 30 multiple-choice objective question items grouped under

the following; Section A- Cell Structure, Section B-Cell Division and section C- Mendelian Genetics. Additional eight essay type questions were added to the post-test to further evaluate the pre-service science teachers understanding of the three identified biology concepts under studying.

These questions were set based on selected biology concepts namely cell structure, cell division and Mendelian genetics of their Environmental Biology and Biology Around Us courses outlines (with Course Code: JBI 231 and JBI 232 respectively for colleges of education affiliated to UEW only). Again, some of questions were drawn from UEW mid-semester and end-of-semester past-questions (i.e., for the past eight years 2012 -2023) and the West African Examination Council (WAEC) Senior High School past question papers (i.e., for the past eight years 2015 - 2023). Although all the test items were standardized but they were still subjected to thorough evaluation. All the questions on the tests were evaluated by colleague CoE biology lecturers and my supervisors to ensure their appropriateness for measuring the academic content standards in accordance with College of Education biology curriculum. Each question item in the test had a stem followed by four (4) lettered options (a) to (d); with one correct answer and three plausible distracters. The duration for each test was 120 minutes. Each pre-service science teacher was required to select correct answer for one mark. Thus, the total highest score for each subject was 91 marks while the total lowest score for each of them was zero (0) mark. The eight essay type questions of the post-test were marked and scored.

Although the test items were standardized, they were still subjected to item analysis, and were categorised into six (6) cognitive ability levels reflecting principally the knowledge, comprehension, application, analysis, synthesis and evaluation. Determination of the difficulty and discrimination indices of the test items were

achieved through the pilot- testing of the test items which consequentially, helped improve the internal consistency of the items in the test instruments. Samples of the pre-intervention test and post-intervention test could be found in Appendix C1 and Appendix D1 respectively.

3.8.3 Description of questionnaire items

Four (4) different sets of questionnaires namely Pre-service science teachers' difficulties in learning cell structure, cell division, Mendelian genetics questionnaire (Appendix A), Pre-service science teachers' perceptions on the effectiveness of interactive multimedia instructional approach in teaching and learning of biology concepts questionnaire (Appendix E1), Pre-service science teachers' difficulties to use interactive multimedia instructional approach in classrooms in teaching and learning of biology concepts questionnaire (Appendix B), and Pre-service science teachers' motivation and engagement questionnaires (Appendix F) were adopted and was approved. These questionnaires were used to collect data from the respondents for the study. The nature and contents of these four different sets of questionnaires have been described briefly below as follows:

3.8.3.1 Description of pre-service science teachers' difficulties in learning cell structure, cell division and Mendelian genetics questionnaire items

(Appendix A)

The questionnaire called pre-service science teachers' difficulties in learning cell structure, cell division and Mendelian genetics questionnaire was approved and used to collect data from the 76 respondents before the implementation of the interactive multimedia instructional approach intervention activities. The questions were constructed by the researcher based on the information acquired through review of the related literature. The questions were formulated based on research questions 1

and it consisted of twelve (12) question items and was to assess respondents' possible causes of their conceptual difficulties in learning the selected biology concepts. The respondents were asked to indicate the intensity of their responses to each of the 12 question items (1-12) on a 5-point type Likert scale, strongest disagreement-(1), disagreement-(2), undecided-(3), agreement-(4) and strongly agreement-(5) of which these respondents were required to tick the appropriate box. Sample of this questionnaire could be found in Appendix A.

3.8.3.2 Pre-service science teachers' perceptions on the effectiveness of interactive multimedia instructional approach in teaching and learning of biology concepts questionnaire (Appendix B)

The questionnaire called pre-service science teachers' perceptions on the effectiveness of interactive multimedia instructional approach in teaching and learning of biology concepts questionnaire was approved and used to collect data from the seventy-six (76) respondents after the implementation of the interactive multimedia instructional approach intervention activities. The questions were constructed by the researcher based on the information acquired through review of the related literature. The questions were formulated based on research questions 5 and it consisted of 10 question items and was to assess respondents' perceptions of the effectiveness of interactive multimedia instructional approach in teaching and learning of biology concepts selected for the study (i.e., cell structure, cell division and Mendelian genetics). The respondents were asked to indicate the intensity of their responses to each of the 10 question items (13-22) on a 5-point type Likert scale, strongly disagreement-(1), disagreement-(2), undecided-(3), agreement-(4) and strongly agreement-(5) of which these respondents were required to tick the appropriate box. Sample of this questionnaire could be found in Appendix B.

3.8.3.3 Pre-service science teachers' difficulties to use interactive multimedia instructional approach in classrooms in teaching and learning of biology concepts questionnaire (Appendix B)

The questionnaire called pre-service science teachers' difficulties to use interactive multimedia instructional approach in classrooms in teaching and learning of biology concepts questionnaire was approved and used to collect data from the 76 respondents before the implementation of the interactive multimedia instructional approach intervention activities. The questions were constructed by the researcher based on the information acquired through review of the related literature. The items consist of two (2) main sections (A & B). Section A contains two (2) items that elicit information on the respondents' bio-data or demographic or background of the participants. The variables in part (A) covered respondent's sex and age. These data are in tune with the purpose of this research since the respondents' sex and age might have sufficient influence on their difficulties to use interactive multimedia instructional approach in teaching and learning of biology concepts selected for the study. The second section (B) consists of fifteen (15) items. The questions were formulated based on research questions 2 and it consisted of 15 question items and was to assess respondents' possible causes of their conceptual difficulties to use interactive multimedia instructional approach in teaching and learning the selected biology concepts (i.e., items 1-5 elicited information on respondents' attitudes towards the use of interactive multimedia instructional approach in classroom, 6-10 elicited information on respondents' perceived benefits of using multimedia instructional approach in biology lessons, and 11-15 elicited information on respondents' perceived difficulties in using interactive multimedia instructional approach in biology education). The respondents were asked to indicate the intensity of their responses to each of the 15

question items (1-15) on a 5-point type Likert scale, strongest disagreement-(5), disagreement-(4), undecided-(3), agreement-(2) and strongly agreement-(1) of which these respondents were required to tick the appropriate box. Sample of this questionnaire could be found in Appendix C.

3.8.3.4 Description of motivation and engagement questionnaire (Appendix F)

The questionnaire called Pre-Service Science Teachers' Motivation and Engagement Level Scale Questionnaire (PSSTMELSQ) was approved and was used to collect data from the seventy-six (76) respondents for the study. The question items in the PSSTMELSQ were formulated based on the research question 4 of this study. The PSSTMELSQ had two (2) Sections A and B. The Section A contained bio-data of the respondents such as code, sex and age, whereas Section B also contained 10 statements which conformed to the effect of IMIA on the respondents' motivation and engagement level towards the selected concepts in biology using interactive multimedia instructional approach. The questions were constructed by the researcher based on the information acquired through review of the related literature. The respondents were asked to indicate the intensity of their responses to each of the 10 question items on a 5-point type Likert scale (Strongly Agree -5 to Strongly Disagree -1). Statements that reflected high motivation and engagements level (e.g., "Interactive multimedia instructional approach motivates me to actively participate in biology instruction related to cell, cell division and Mendelian genetics activities based on IMIA") were scored as follows: -

Table 2:***Positively worded items in the Likert scale***

Response Intensity	Symbols	Score
Strongly Agree	SA	5
Agree	A	4
Undecided	UN	3
Disagree	D	2
Strongly Disagree	SD	1

On the other hand, statements that reflected the low motivation and engagement (e.g. “biology is difficult subject for me to study before the IMIA intervention activities”) were scored as follows: -

Table 3:***Negatively worded items in the Likert scale***

Response Intensity	Symbols	Score
Strongly Agree	SA	1
Agree	A	2
Undecided	UN	3
Disagree	D	4
Strongly Disagree	SD	5

3.9 Validity of the Instruments

Renz et al. (2018) conceptualised validity as unique principles that one uses to determine whether or not the research under question is of good quality or not. Moreover, Khald (2017) suggested that validity is crucial in any scientific study as it helps in achieving the accurate representation of findings by fusing multiple data collection methods to gather data from participants. In order to ensure both face and content validity of the three (3) instruments, the approved instruments namely; (a) interview schedules:- Pre-Service Science Teachers’ Interview Schedule on perception

on the effectiveness of interactive multimedia instructional approach in learning of biology concepts; (b) tests:- (pre-service science teachers' cell structure, cell division and Mendelian genetics diagnostic test (TEST 1) and pre-service science teachers' biology achievement test (TEST 2) and (c) questionnaire:- pre-service science teachers' difficulties in learning cell structure, cell division and Mendelian genetics questionnaire, pre-service science teachers' perceptions on the effectiveness of interactive multimedia instructional approach in teaching and learning of biology concepts, pre-service science teachers' difficulties to use interactive multimedia instructional approach in classrooms in the teaching and learning of biology concepts and pre-service science teachers' motivation and engagement level scale questionnaires were scrutinized by my course mates and my colleague biology lecturers.

These instruments were then presented to two senior biology educators in the Biology Education Department of Faculty of Science Education of the University of Education, UEW; with extensive knowledge and research experiences in designing instructional strategies and curriculum materials for their expert critique and advice on the content in order to ensure face validity of the instrument. The experts were asked to assess the instruments in terms of scope of coverage; content relevance, ambiguity and vagueness of expression. Corrections and suggestions arising from these experts were used to review the instruments. The inputs, suggestions and comments made by these experts lead to the improvement or betterment of the items in the instruments. The multiple data collection instruments used in this study (interviews, tests and questionnaires) and the multiple data collection techniques encouraged data trustworthiness through triangulation.

3.10 Pilot Testing

In order to determine the reliability of the instruments, the three (3) instruments that is interview schedule, tests and the questionnaires used for the study were pilot-tested at Komenda College of Education using twenty (20) students of the 2022/2023 second year pre-service science teachers pursuing biology courses as part of their science program. Komenda College of Education is situated in Komenda/Edina/Eguafo/Abrem Municipal Assembly of Central Region of Ghana. The college was selected because it has rural settings, programs and courses similar with the college under study. The pilot test enabled the researcher to restructure the test items to aid in eliciting the right responses.

3.11 Reliability of the Quantitative Instruments

The reliability coefficients of the tests were calculated using Cronbach's Alpha Reliability coefficient. Also, the questionnaires were performed using Cronbach alpha reliability coefficient. The Cronbach Alpha was used for the interview schedule and questionnaires because the items were not dichotomously scored. In a similar study, Emaikwu (2015) stated categorically that where two items are not dichotomously scored, the use of Cronbach Alpha becomes very appropriate, hence its usage for the interview schedule and the questionnaires. According to Borg, Gall and Gall (1996), the reliability coefficients values above 0.60 are considered reliable. Moreover, Nwobodo and Agusiobo (2017) also suggested that the coefficients of 0.78 and 0.98 indicate that the instruments are reliable. Therefore, reliability values ranging from 0.698 to 0.939 gave indications that these three (3) approved instruments were reliable and were used for the study.

3.12 Cronbach's Alpha Reliability Coefficient of the Study

To gauge the overall reliability test of the measurement scale, Cronbach's alpha measurement of internal consistency was used, where alpha estimated the proportion of the total variance that is not due to error, which represents the reliability of the scale. Based on Hair et al. (1998) criterion, the recommended minimum acceptable level of reliability "alpha" is 0.60.

Table 4:

Cronbach's alpha reliability coefficient of the study

No	Type of Instrument	Cronbach's Alpha
1	Tests	
	a). Pre-test (Test 1)	0.96
	b). Post-test (Test 2)	0.98
2	Questionnaire	
	a). Pre-service science teachers' Motivation and engagement	0.94
	b). Perception on the effect of interactive multimedia instructional approach	0.90
	c). Difficulties in using Interactive multimedia instructional approach	0.92
	d). Difficulties in cell structure, cell division & Mendelian genetics	0.88

Source: Field data, 2024

If the questionnaire is faulty, then the information that will be collected from respondents will be distorted. The questionnaire, which was attained through Cronbach's alpha reliability coefficient that ranges between 0.88 and 0.98 as presented in Table 4. That is, Pre-test with a Cronbach's alpha of 0.96, Post-test with a Cronbach's alpha of 0.98, pre-service science teachers' motivation and engagement with a Cronbach's alpha of 0.94, Difficulties in learning cell structure, cell division & Mendelian genetics with a cronbach's alpha of 0.88 and difficulties in using interactive

multimedia instructional approach with a Cronbach's alpha of 0.92, and with a Cronbach's alpha of 0.90 for perception of interactive multimedia instructional approach in the study. This indicates that the study is reliable and researcher stood on these findings to make recommendations about the future.

3.13 Dependability of the Qualitative Instrument

The dependability of the qualitative instrument signifies the ability of the validated instrument to elicit the data that bring out results which will enable the researcher to deduce findings and draw conclusions that are verifiable and reliable. To ensure the dependability of the findings and conclusions of this study, clear questions that reduced the biases and subjectivity of the researcher during the data collection process were used (Kusi, 2014). To further ensure the dependability of the data obtained via the semi-structured interviews, the researcher made a transcription of all the collected data and sent them back to their corresponding respondents for cross checking and rejection or confirmation of the ideas presented.

The respondents were made to read through the transcriptions and where necessary, they make the necessary corrections and further inputs. After this process, the researcher again will read through the transcriptions to the respondents in order to give them another chance to modify or reject the ideas presented. This was done because Zeldin et al. (2008) asserted that in order to get a dependable data from an interview schedule, the researcher should always ensure that the collected data will; (i) concurs with the wishes of the respondents (ii) the results of the collected data make sense and (iii) the collected data is consistent and dependable such that others intending to conduct the same study will obtain similar if not same results.

3.14 Credibility of the Qualitative Instrument

Credibility essentially requires of the researcher to link the findings of the research study to reality in order to demonstrate the truth of the research findings (Tracy, 2010; Sebele-Mpofu, 2021) asserted that primarily credibility is concerned with the features of truth and value. To ensure the credibility of the data gathered by the semi-structured interviews, there was a prolonged engagement with the research participants by the researcher to foster member check and triangulation. The researcher ensured prolonged engagement with the semi-structured interviewees by asking them various questions based on the variables of the study.

Additionally, the researcher encourages the semi-structured interviewees to give examples to support their claims. The researcher also asked follow up questions when there is the need for clarification of some of the issues raised. These were done to ensure that findings made represent plausible information drawn from the semi-structured interviewees' original data and that the collected data were a correct interpretation of the participants' original views. All the transcripts were sent to the semi-structured interviewees to enable them correct the interpretations and to challenge what they perceived to be wrong interpretations. After the necessary corrections, the researcher resent the data to the semi-structured interviewees for confirmation before the data is admitted as a finding. This was done to fulfil the underpinnings of member check as a factor of credibility (Dodgson, 2017; Zeldin et al., 2008). The collected data from the semi-structured interviewees (the pre-service science teachers) was then translated to gain a complete understanding of the issue under study (Guest et al., 2013).

3.15 Data Collection Procedure

For effective data collection, permission was sought from the authorities of the College, Head of Science Department and the biology lecturers in the Department. In addition, the consent of the seventy-six (76) pre-service science teachers used for the study was also sought. Upon series of engagements and meetings with the authorities, date and time were agreed upon to carry out the study. In all, eight (8) weeks was used for the entire study. Out of the eight (8) weeks, one (1) week was used for the pre-intervention phase activities; six (6) weeks was used for the intervention phase activities; whereas the last one week was used for the post-intervention activities phase. Data collection was done in three (3) phases namely; pre-intervention phase, intervention phase and post-intervention phase. This is illustrated in Figure 3.

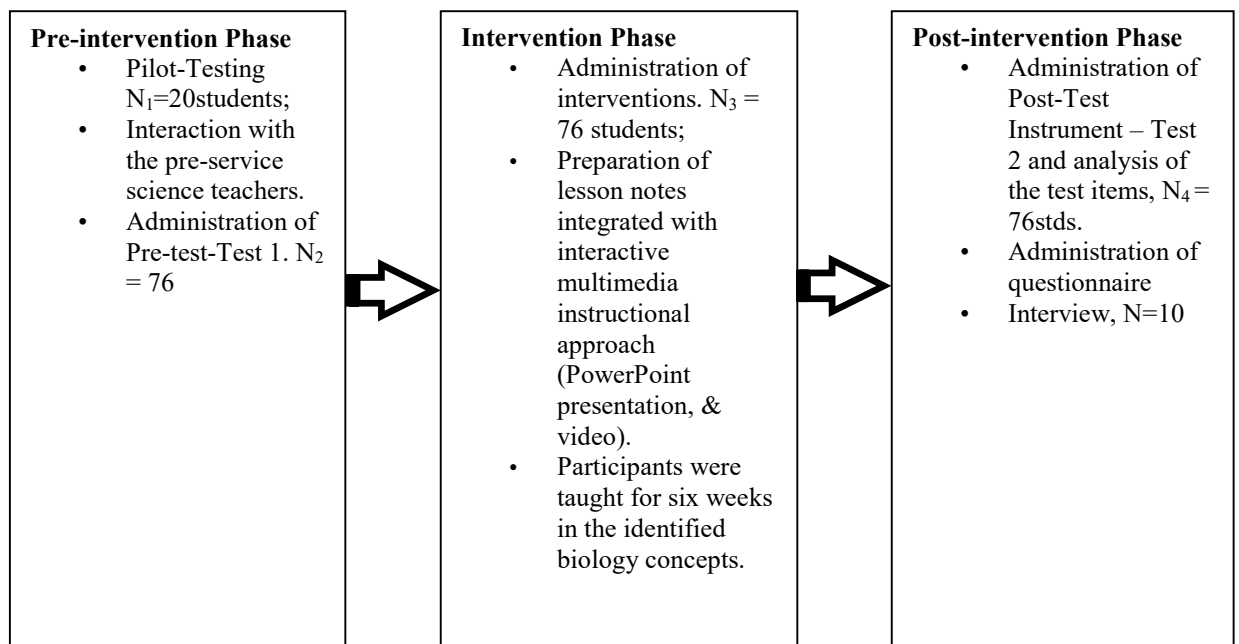


Figure 3:
The process of data collection

These three phases are described extensively below as follows: -

3.15.1 Pre-intervention phase (Week One: 21st Feb-25th 2024)

The main pre-intervention activities involved extensive discussions with respect to the purpose of the study; interaction with the pre-service science teachers, administration of pilot testing of the instruments and pre-intervention test. These three major activities under the pre-intervention phase have been described briefly below as follows: -

Day One Activities:

On the day one of the first week, the researcher went to Komenda College of Education to pilot the three instruments that was used in this study. The Head of Department was contacted and selected twenty (20) pre-service science teachers at Komenda CoE. Open and frank discussions with respect to the purpose of the research took place. Series of engagements in the form of discussions were also held with the participants. They were assured that there would be no risk involved in participating in the study and that they had the right to withdraw from the study if they wished. They were informed about the context of the study and how the results would be evaluated. The piloting went on successfully.

Day Two Activities:

On the second day of the first week, the researcher met the pre-service science teachers of Wiawso College of Education at the science laboratory in the morning for open and frank discussions with respect to the purpose of the study, a study timeline and benefit/significance of the study. Series of engagements in the form of discussions were also held with the participants at Wiawso CoE. They were assured that there would be no risk involved in participating in the study and that they had the right to withdraw from the study if they wished. They were informed about the context of the study and how the results would be evaluated. An informed consent form was given to the pre-service science teachers to read and fill them with their detailed information; after which the session was closed.

Day Three Activities:

In order to determine each pre-service science teacher's performance prior to the start of the Interactive Multimedia Instructional Approach intervention activities; a ninety (90) minutes pre-test on cell structure, cell division and Mendelian genetics diagnostic test (TEST 1) in Appendix C1 was conducted for all the participants at the college's lecture hall one (LH1). The test was done under strict but relaxed supervision. The pre-service science teachers were to answer the ninety (90) multiple-choice objective questions for 90 marks. After the ninety (90) minutes, the pre-test papers were collected, marked and scored using the marking scheme prepared by the researcher (Appendix C2). The pre-test was used to assess the pre-service science teachers' conceptual understanding of the selected biology concepts identified before the implementation of the IMIA intervention activities (Plate 1).



*Plate 1:
Participants writing the pre-test*

3.15.2 Intervention phase

The intervention phase dealt with the implementation of “Interactive Multimedia Instructional Approach” (IMIA) for three hours duration per week for six weeks period. The IMIA intervention activities started from the second (2nd) week to the seventh (7th) week (20th February to 28th April, 2024). In all, six IMIA lessons were taught for the six weeks period. Each week was used to teach one of the selected biology concepts based on Interactive Multimedia Instructional Approach as follows: -

Week Two Lesson: The Cell Structure and Classification of Cell Concepts (Plate 2).



Plate 2:

Participants dissecting a rabbit to observe the internal organs after studying cell structure.

Week Three Lesson: Plant and Animal Cell

Week Four Lesson: Membrane transport

Week Five Lesson: Cell Division-Cell Cycle (Mitosis and Meiosis Concepts)

Week Six Lesson: Mendelian Genetics-Definition of terms & Monohybrid Inheritance

Week Seven Lesson: Mendelian Genetics-Di-hybrid Inheritance

The IMIA intervention activities for each lesson consisted of IMIA-based lesson plan that is courseware, PowerPoint, video presentations. In all six (6) lesson plans, activity guides interactive multimedia instructional approaches were prepared altogether on the identified biology concepts and was taught for six weeks. For each of the six biology topics, six lesson plans, activity guides were prepared using interactive multimedia instructional approaches. During each lesson, the pre-service science teachers were taught each biology concepts using the interactive multimedia instructional approach in line with lesson's plan procedure prepared by the researcher. For each lesson, the pre-service science teachers were put into groups of eleven (11). Each member in group was given a role to play such as group leader, recorder, time keeper, etc and these roles were on rotational basis. The groups were made to prepare a short lesson on the topic taught using interactive multimedia instructional approach of their choice and present in the next lesson before the researcher takes them through the week activities. In each lesson presented by the researcher, pre-service science teachers were exposed to series of interactive multimedia instructional approach during the studies and some of these activities are shown in appendix H.

The pre-service science teachers in their respective groups actively participated in the Interactive Multimedia Instructional Approach lessons. The implementation of the interactive multimedia instructional approach intervention activities was done for six weeks.

Closure

After taken pre-service science teachers through the IMIA intervention activities; a lot of exercises in the form of quiz, project-work, assignments, and so forth

on the identified biology concepts were given to them in groups and individuals to solve. Almost all of them were able to solve almost all the questions given to them correctly.

3.15.3 Post intervention phase

After the interventional activities, post interventional activities were carried out. The main post-intervention activities involved conduction of post-test called TEST 2 (Appendix D1), administration of questionnaires namely Pre-service science teachers' difficulties in learning cell structure, cell division, Mendelian genetics questionnaire (Appendix A), Pre-service science teachers' difficulties to use interactive multimedia instructional approach in classrooms in teaching and learning of biology concepts questionnaire (Appendix B), Pre-service science teachers' motivation and engagement questionnaires (Appendix F) and conduction of interview session. These four major activities under the post-intervention stage have been described briefly below as follows: -

Day One Activities:

On the day one of the eight week, the participants were met and discussions were held with them about the IMIA study. After, the series of discussions, a ninety (90) minutes post-intervention test, TEST 2 in Appendix D was conducted for all the subjects at the college's LH2. The test was done under strict but relaxed supervision. The participants were to answer the ninety (90) multiple-choice objective questions for 90 marks. The post-test was used to assess the pre-service science teachers' conceptual understanding after the implementation of the IMIA intervention activities. After the 90 minutes, the papers were collected, marked, scored, recorded, analysed and compared with the pre-test scores to assess variations in their performance.

Day Two Activities:

On the second day of the eight (8) week, the pre-service science teachers were again met at the science laboratory in the morning. Upon series of engagements, Pre-service science teachers' difficulties in learning cell structure, cell division, Mendelian genetics questionnaire (Appendix A), Pre-service science teachers' difficulties to use interactive multimedia instructional approach in classrooms in teaching and learning of biology concepts questionnaire (Appendix B), Pre-service science teachers' motivation and engagement questionnaires (Appendix F) were distributed or given to them to fill in my presence. The supervision of the administration of questionnaires was done in relaxed. After the ninety (90) minutes, the questionnaires were collected from the participants; after which the session was closed.

Day Three Activities:

On the third day of the first week, the participants were met at the science laboratory in the afternoon. Upon series of engagements and discussions in a friendly manner, the IMIA Perception on the effectiveness of interactive multimedia instructional approach in learning some biology concepts Questionnaire in Appendix E1 was given to the pre-service science teachers to fill them in my presence. The supervision of the questionnaire administration was done in relaxed manner. After the 40 minutes, the questionnaires were collected from the participants; after which the session was closed.

Day Four Activities:

In order to assess pre-service science teacher's perceptions regarding the interactive multimedia instructional approach instructional approach used in the teaching and learning of the selected concepts in biology, a focus group interactive interview session was organised and conducted for some of the participants. This interactive interview session was

done using the interview Schedule in Appendix E2. This interactive interview session took place at the science laboratory and lasted for three hours. The interview session was audio-taped or recorded and transcribed verbatim; after which the participants were appreciated and the session was closed.

3.16 Data Analysis Procedure

Analysis Pertaining to the Research Questions of the Study

This section presents the results pertaining to the specific research questions of the study. With the help of the Statistical Package for Social Scientists (IBM SPSS) software version 27.0, descriptive and inferential statistical tools were used to analyse the data in order to answer the research questions of the study. Linear relationship between the predictor and the dependent variables was assumed. The responses from the questionnaire items were coded and analysed by the use of IBM SPSS. It is relatively user friendly and can do the majority of the data analysis required in quantitative analysis. On both test items, a t-test with equal variance was used to do statistical analysis (pre-test and post-test).

3.17 Ethical Considerations

This study adhered strictly to ethical standards laid down by the School of Graduate Studies of the University of Education, Winneba as well as the ethical standards in research suggested by Creswell and Creswell (2017). These include informing the respondents about the purpose of the study, voluntary participation and ensure their confidentiality. Ethical considerations in a study process should be reflected throughout each phase of the research process. Based on this, an introductory letter was obtained from the lead supervisor to enable me use the said college for my study (Appendix G).

Also, permission and approvals were sought from the Principal, Vice principal and the Head of Science Education Department of Wiawso College of Education. They had an

open and frank discussion with respect to the purpose of the study, a study timeline and benefit/significance of the study. Again, the pre-service science teachers who met inclusion criteria and selected were approached, informed of the study's purpose and significance of the study. Series of engagements in the form of discussions were held with the participants. They were assured that there would be no risk involved in participating in the study and that they had the right to withdraw from the study if they wished. They were informed about the context of the study and how the results would be evaluated. An informed consent form was given to the pre-service science teachers to read and fill them with their detailed information. Sample of the Informed Consent Form for the participants (pre-service science teachers) could be found in Appendix J.

The consents of these pre-service science teachers as interviewees were also sought before interviews were conducted. They were further informed that the interviews would be audiotaped or recorded. To avoid coercion, pre-service science teachers who took part in the study were informed of their right to decline to participate in and/or to withdraw from the interviews; and assured them that such a decision would not affect their scores in their end-of-semester examinations. This means that pre-service science teachers were free to choose whether or not to participate in the study (Taber, 2014); therefore, all the participants in the study participated voluntarily. Also, participants were assured of their confidentiality over the data that were collected and were informed that only the researcher and supervisor would have access to the data collected. Proper remedial actions including counselling and medical care were given to participants who were injured or traumatized. Also, pseudonyms and personal codes were assigned to participants in order to maintain their anonymity.

The participants were also assured that the completed instruments and consent forms would be kept under lock and key for five (5) years; such that they cannot be traced to any other person. The respondents were also made aware that the information they gave would

be treated with outmost confidentiality and that at no stage of the research processes would the information given be used except for the purpose of the final thesis. They were assured of the safeguards the storage of information (data). Information was stored on my computer and secured with password for protection. Finally, the researcher had no conflict of interest to declare; hence there was no bias; and the study was self-sponsored by the principal investigator.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter discusses the findings emanating from the data collected from the questionnaires, the pre-test and post-test, and the interview results of the students used as a case study. The discussion includes interpretation of findings in the light of previous findings and theory. The organization of the chapter is based on three major parts: It does include the background characteristics of the respondents, the second part looked at the descriptive statistics and the findings of the evaluation of the measurement model, that is, the descriptive analysis of the items used for measuring the main study dimensions, normality test, and the reliability test, while the third part was devoted to responses given by the respondents in accordance with the research questions.

4.1 Response Rate of the Study

A total of the 76 questionnaires distributed were deemed suitable for analysis. Hundred per cent (100%) of the respondents were valid, which is deemed adequate for a study of this kind (Coakes & Steed, 2003). According to Hair et al. 2010, the sample size needs to be at least ten times larger than the study's variables to be regarded as adequate for statistical analysis. Coakes and Steed (2003) said this should be more than 20 times or at the very least, it needs to be 5 times.

4.2 Background Characteristics of the Respondents

This section deals mainly with the distribution of the respondents by gender and age of the respondents. The results are presented in Table 5.

Table 5 displays the summary background characteristics of the respondents. The majority of the students, who participated in the pre-test and post-test examination,

were males representing 72.4% whilst 27.6% of them were females. With respect to their age distribution, 85% of them were in the age range of 21 to 25 years, and 14.50% of them were in the age range of 26 to 30 years. The findings revealed the true reflection of males' dominant in Ghanaian institutions and moreover, most of these students are in their youthful age.

Table 5:

Summary background characteristics of the respondents

Characteristics	Frequency (n=76)	Per cent (%)	Mean
Gender	Male	55	72.40
	Female	21	27.60
Age	21–25 years	65	85.50
	26– 30 years	11	14.50

Source: Field Data, 2024

4.3 Normality Test

Normality of the data was examined using both the Kolmogorov-Smirnov test (with Lilliefors correction) and the Shapiro-Wilk test as shown in Table 6. Results from the Kolmogorov-Smirnov test from Table 6 indicated that the pre-test ($D = 0.068$, $p = 0.20$) and post-test ($D = 0.09$, $p = 0.07$) scores were normally distributed. However, pre-service science teachers' engagement and all biology concept variables showed significant deviations from normality ($p < .05$). Again, the normality of the data was assessed using the Shapiro-Wilk test. The results indicated that the pre-test ($W = 0.98$, $p = .28$) and post-test ($W = 0.97$, $p = .07$) examination scores were normally distributed. However, pre-service science teachers' engagement and all biology concept scores showed significant deviations from normality ($p < .05$). Consequently, parametric statistical tests were applied to the pre- and post-test scores, while non-parametric tests were used for the engagement and biology concept variables (Test Statistic= W or D and).

Table 6:*Normality test of the study*

Questionnaire/Tests	Kolmogorov-Smirnov		Shapiro-Wilk	
	Sig.	Statistic	Sig.	Statistic
Pre-Test Examination	0.20	0.07	0.28	0.98
Post-Test Examination	0.07	0.09	0.07	0.97
Pre-service science teachers' engagement	0.00	0.25	0.00	0.78
Cell Structure	0.00	0.28	0.00	0.66
Cell Division	0.00	0.22	0.00	0.85
Mendelian Genetics	0.00	0.28	0.00	0.79
Biology Concepts	0.00	0.19	0.00	0.79

4.4 Presentation of Results Pertaining to the Research Questions of the Study

This section presents the results pertaining to the specific research questions of the study. This aspect of the study describes the response from the respondents. Since, the distribution is normal, the opinions of the participants are described using the mean and standard deviation coefficients. Since the items responses were numerically measured using a unilined scale, the mean scores were statistically estimated for simple interpretation. That is, mathematical approximation approaches to interpreting the mean scores based on Pallant (2020) recommendations were followed. Thus, all responses to all items of the study variables were made on a 5-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree.

The mean scores were used in concert with the standard deviations to determine the level of “Agree” of the variables. The mean scores of 2.49 and below meant the general “Disagree”; scores within the range of 2.50 to 2.99 meant “neutral”, and scores 3.000 and above meant a general “Agree”. The employees’ point of view is reflected in Tables 2 and Table 3. The nature of the scales used within this research is of a Likert type, where the respondent was asked to indicate their “Disagree” or “Agree” to a

statement or a series of statements. This is a quite frequent occurrence within social science studies, as explained by Saunders (2012). The typical scale, around which research is converging nowadays, is a 4-7 range Likert scale point ordinal scale for measuring phenomena. These make the respondent express the intensity of feelings towards the issue of interest. However, there is considerable debate over the interpretation of responses derived through these scales because whereas responses can be rated or ranked in an ordinal scale, the distance between responses is not measurable. That is, one cannot assume that the responses are equidistant even though the numbers usually assigned to them are unlike interval data where a score represents actual action.

The real issue therefore, is whether ordinal data, converted to numbers can be treated as interval data. That is, can means and standard deviations, and parametric statistics, which depend on data that are normally distributed, be used to analyse ordinal data? According to Sullivan and Artino (2013), when descriptive statistics are applied to responses on a Likert scale, their meanings- things like means and standard deviations-are not clearly defined. For example, what does the average of ‘likely’ and ‘nearly likely’ actually mean? Again, if responses fall at the high and low extremes, then the mean response may appear to reflect a neutral or middle response but that would not be an accurate descriptor of the data. Non-normal distributions of response data can equally lead to a mean score that is not useful as a measure of the data’s central tendency.

4.4.1 Research question 1

What are the pre-service science teachers’ challenges in learning cell structure, cell division and Mendelian genetics?

The research question one of the study was to find out the challenges the pre-service science teachers are faced in understanding concepts such as cell structure, cell

division, and Mendelian genetics. In Table 7a, most of the respondents agreed that they find it difficult or have challenges to understand the different parts of a cell and their functions, with a mean of 4.75 and a Std. Dev. of 0.82. They also agreed that it is difficult to visualize the three-dimensional structure of a cell, with a mean of 4.75 and a Std. Dev. of 0.82. Additional general agreement was that they find it difficult to make differentiation between plant and animal cell structures, with a mean of 4.07 and a standard deviation of 1.04, and also agreed that they could not easily memorize the functions of various cellular components, with a mean of 4.11 and a standard deviation of 1.14. Findings revealed that students' difficulties in learning cell structure include the understanding of different parts and their functions within a cell, visualization in three-dimensional structure, differentiation between plant and animal cell structures, and memorization of the functions of various cellular components.

Table 7a:

Views of the pre-service science teachers on challenges in learning cell structure

S/N	Statements	Mean	Std. Dev.
1	I find it difficult to understand the different parts of a cell and their functions	4.75	0.82
2	Visualizing the three-dimensional structure of a cell is challenging for me	4.75	0.82
3	I struggle to differentiate between plant and animal cell structures.	4.07	1.04
4	I find it difficult to memorize the functions of various cellular components and terms associated with it.	4.11	1.14
5	Overall	4.42	1.66

Source: Field Data, 2024

As established in Table 7b, most of the respondents agreed that they find it very challenging to understand the stages of mitosis and meiosis with the mean of 4.17 and standard deviation of 1.26. The pre-service science teachers agreed that they struggle

or find it difficult to differentiate between the processes of mitosis and meiosis with mean of 4.07 and standard deviation of 0.97. This finding agreed with the research conducted by Mehmet (2014), in the course of his study, he reported that cell division is one of the most difficult concepts in biology education for both the teaching and the learning processes.

Grasping cell division processes is another difficulty students may face during lessons. Students may find it difficult to understand the precise mechanisms involved in cell division, including spindle assembly, chromatid separation, and cytokinesis. These processes require a deep understanding of cell biology (Alberts, 2017). Furthermore, majority of the respondents agreed that the concept of chromosome separation during cell division is difficult for them (mean = 3.71; Std. Dev. = 1.31). Notwithstanding, most of the respondents agreed that they have trouble remembering the sequence of events in the cell cycle (mean = 3.85; Std. Dev. = 1.12) and also agreed that understanding the significance of cell division in growth and reproduction is challenging for them (mean = 4.48; Std. Dev. = 0.97). The findings from the study disclosed that most students have difficulties in learning cell division and these challenges are the ability to understand the stages of mitosis and meiosis and the concept of chromosome separation during cell division.

According to Alberts (2017), the understanding of the molecular processes involved in cell division, such as DNA replication and mitosis, can be challenging for students unless they have a solid understanding of genetics and molecular biology. Caruso and Raineri (2015) explained in a study that the step-by-step order and timing of events during cell division, including interphase, prophase, metaphase, anaphase, and telophase, may confuse students as they try to remember and differentiate these stages. Moreover, most student have trouble remembering the sequence of events in the

cell cycle and understanding the significance of cell division in growth and reproduction.

Table 7b:

Views of the pre-service science teachers on challenges in learning cell division

S/N	Statements	Mean	Std. Dev.
1	I find it difficult to understand the stages of mitosis and meiosis.	4.17	1.26
2	I struggle to differentiate between the processes of mitosis and meiosis.	4.07	0.97
3	The concept of chromosome separation during cell division is difficult for me	3.71	1.31
4	I have trouble remembering the sequence of events in the cell cycle.	3.85	1.12
5	Understanding the significance of cell division in growth and reproduction is challenging for me.	4.48	0.97
6	Overall	5.07	1.17

Source: Field Data, 2024

Table 7c displays the views of the respondents on students' challenges in learning Mendelian genetics. From the Table 7c most of the respondents agreed that they find it difficult to understand Mendel's laws of inheritance (mean = 4.52; Std. Dev. = 0.90) and agreed that the concept of dominant and recessive alleles confuses them (mean = 4.05; Std. Dev. = 1.35). Moreover, most of the respondents agreed that they have trouble solving genetic cross problems involving more than one characters (Dihybrid Inheritance) (mean = 4.31; Std. Dev. = 0.75). From the findings it can be deduced that majority of the students have difficulties in learning Mendelian genetics. That is, students find it difficult to understand Mendel's laws of inheritance, the concept of dominant and recessive alleles confuses students and most also have trouble solving

genetic cross problems involving more than one characters (Dihybrid Inheritance) when using Punnett square.

Table 7c:

Views of the pre-service science teachers on challenges in learning Mendelian genetics

S/N	Statements	Mean	Std. Dev.
1	I find it difficult to understand Mendel's laws of inheritance.	4.52	0.90
2	The concept of dominant and recessive alleles confuses me.	4.05	1.35
3	I have trouble solving genetic cross problems (Dihybrid Inheritance) using Punnett square.	4.31	0.75
4	Overall	4.29	1.00

Source: Field Data, 2024

Discussion of Findings

The findings related to research question one was positive, showing that pre-service science teachers participating in this study faced challenges in understanding concepts such as cell structure, cell division, and Mendelian genetics. Despite having previously studied these topics, all 76 participants initially demonstrated limited conceptual understanding. Prior to the intervention using interactive multimedia instructional approach, their performance was not optimal. It was noted that, although they had been taught these concepts before, many participants struggled with learning cell structure, particularly in understanding the various parts of a cell and their respective functions. As shown in Table 7a, most respondents reported finding it difficult to grasp these aspects, with a mean of 4.75 and a standard deviation of 0.82. Additionally, they agreed that visualizing the three-dimensional structure of cells posed a significant challenge, as reflected in the same mean and standard deviation.

The general consensus among participants was that they also found it challenging to differentiate between the structures of plant and animal cells, with a mean of 4.07 and a standard deviation of 1.04. Additionally, they agreed that memorizing the functions of various cellular components was difficult, with a mean of 4.11 and a standard deviation of 1.14. The findings indicate that pre-service science teachers' difficulties in learning about cell structure were related to understanding the different parts and their functions within a cell, visualizing the three-dimensional structure of cells, distinguishing between plant and animal cell structures, and memorizing the functions of cellular components. These results suggest that the pre-service science teachers who participated in this study found cell structure, cell division, and Mendelian genetics to be particularly challenging and difficult to learn. This aligns with the findings of Fernandez-Sanchez et al. (2015), who explained that cells are microscopic entities, and concepts related to their structure and division, such as the organization of organelles or the process of spindle formation, are often difficult to visualize and understand due to their abstract nature. Students may struggle with these topics if they lack a solid foundation in basic biology, especially in understanding cells (Hailikari et al., 2008). Fernandez-Sanchez et al. (2015) also noted that students often find it challenging to visualize the complex structures and organelles within a cell due to their small size and intricate details.

The difficulty of visualizing cell structures under a microscope or through diagrams can be a significant challenge for students and pre-service science teachers. These findings are consistent with the studies of Mehmet (2014), Tionpere and Tamaraudeinyefa (2022), Dina et al. (2012), and Musa (2010). Although these studies were not specifically designed to identify which areas of cell biology are most difficult to understand, they nonetheless highlighted some common challenges students face in

learning cell biology, such as identifying the parts of a cell and differentiating between the functions of animal and plant cells. Salleh et al. (2021) assessed the views of both teachers and students regarding difficult biology concepts and found that cell division, cell structure and organization, and chemical composition in cells were particularly challenging. These challenges align with the findings of Vijapurkar et al. (2014), who concluded that cell structure concepts are often difficult for pre-service science teachers to learn, as their understanding of fundamental concepts is typically insufficient. Additionally, the findings in Table 7a are in agreement with the work of Kavi Kishor et al. (2015) and Çeliker (2015), which highlighted the difficulty of understanding the complex terminology and functions of plant and animal cell components. The study confirmed that the conceptual understanding of prospective science teachers regarding plant and animal cells was not adequate. Terminologies like chromatin, centrioles, and kinetochore microtubules can be challenging to understand (Alberts, 2017). Niyigena and Nzabalirwa (2022) investigated the use of computer simulations as a teaching method for improving learners' performance in learning the concepts of plants and animal cells, they enumerated some problems students faced when learning plant and animal cells and are congruent with the findings in this study.

The cell is the fundamental unit of structure and function in all living organisms and serves as the foundation for all life forms (Suza & Lee, 2021). Despite its importance, learning about cell structure has consistently been shown to be a challenging concept for biology students to master. This aligns with the difficulties experienced by pre-service science teachers in understanding cell structure before the interventions in this study. Research by Salleh et al. (2021) and Fauzi and Mitalistiaini (2018) confirmed that high school students find concepts related to the cell particularly challenging. According to Pollard et al. (2022), cell biology encompasses a broad range

of sub-concepts, further affirming the challenges faced in learning about cell structure. These topics include the history of the cell, cell structure, the differentiation between plant and animal cells, and the process of cell division. While students often report difficulty with these concepts, it is statistically unlikely for them to struggle with every aspect of cell biology (Cimer, 2012). Therefore, it becomes crucial to identify the specific areas within the cell structure concept that students find most difficult, so that targeted attention can be given to those aspects. Unfortunately, there has been limited research focused on identifying which areas of cell biology are perceived as the most difficult to learn (Tionpere & Tamaraudeinyefa, 2022).

Again, as shown in Table 7b, most respondents reported difficulty in understanding the stages of mitosis and meiosis (mean = 4.17; Std. Dev. = 1.26). Additionally, they acknowledged struggling to differentiate between the processes of mitosis and meiosis (mean = 4.07; Std. Dev. = 0.97). These findings align with the research of Mehmet (2014), who identified cell division as one of the most challenging concepts in biology education, both for teaching and learning. Understanding cell division processes can be particularly difficult for students, especially the mechanisms involved in spindle assembly, chromatid separation, and cytokinesis, all of which require a deep understanding of cell biology (Alberts, 2017).

Furthermore, the majority of participants agreed that the concept of chromosome separation during cell division is difficult for them (mean = 3.71; Std. Dev. = 1.31). They also struggled to remember the sequence of events in the cell cycle (mean = 3.85 Std. Dev. = 1.12) and found understanding the significance of cell division in growth and reproduction challenging (mean = 4.48; Std. Dev. = 0.97). These findings indicate that many students face difficulties in learning cell division, particularly in

understanding the stages of mitosis and meiosis, as well as the concept of chromosome separation during cell division.

According to Alberts (2017), the understanding of the molecular processes involved in cell division, such as DNA replication and mitosis, can be challenging for students unless they have a solid understanding of genetics and molecular biology. Caruso and Raineri (2015) explained in a study that the step-by-step order and timing of events during cell division including interphase, prophase, metaphase, anaphase, and telophase, may confuse students as they try to remember and differentiate these stages. Moreover, many students struggle to remember the sequence of events in the cell cycle and have difficulty understanding the significance of cell division in growth and reproduction.

Table 7c also, displays the views of participants on pre-service science teachers' difficulties in learning Mendelian genetics. From the Table, most of the respondents agreed that they find it difficult to understand Mendel's laws of inheritance (mean = 4.52; Std. Dev. = 0.90) and agreed that the concept of dominant and recessive alleles confuses them (mean = 4.05; Std. Dev. = 1.35). Moreover, most of the respondents agreed that they have trouble solving genetic cross problems involving more than one characters (Dihybrid Inheritance) (mean = 4.31; Std. Dev. = 0.75). From the findings, it can be concluded that the majority of the students experience difficulties in learning Mendelian genetics. That is, students find it difficult to understand Mendel's laws of inheritance, the concept of dominant and recessive alleles confuses students and most also have trouble solving genetic cross problems involving more than one characters (Dihybrid Inheritance) when using Punnett square.

These findings agreed with Hart et al. (2009) and Mendel (2021) that patterns in dihybrid inheritance can be challenging to grasp, as they involve multiple alleles and

interactions between genes. The complexity of these patterns can lead to confusion and difficulty in applying the principles of Mendelian genetics to solve genetic problems and another difficulty students' encounter in learning Mendelian genetics is the lack of familiarity with statistical analysis in genetics. Mendelian genetics relies on probability and statistical analysis to predict and understand patterns of inheritance. Students may struggle with calculating probabilities and making predictions based on genetic crosses. They may find it challenging to understand concepts such as Punnett squares, pedigrees, and calculating the probability of specific genotypes or phenotypes. Several studies have investigated the difficulties students faced in learning Mendelian genetics. For example, a study by Marbach-Ad et al. (2008) examined students' misconceptions and difficulties in understanding genetics and they found that students often struggled with understanding the relationship between genotype and phenotype and had difficulty applying the principles of Mendelian genetics to solve problems.

Another study conducted by Dori and Hameiri (2003) confirmed that students often struggle to understand inheritance and that visual aids can significantly impact their learning. Their research showed that students commonly held misconceptions about dominance and had difficulty grasping how traits are inherited from parents. These results indicate that pre-service science teachers experience conceptual difficulties when learning about cell structure, cell division, and Mendelian genetics within their curriculum. This study further revealed several potential reasons for these difficulties. Notably, all 76 participating pre-service science teachers (100%) agreed that the biology syllabus was overly broad and dense, and that the lack of remedial support from college lecturers, largely due to their heavy workloads was a major contributing factor to these learning challenges. This suggests that both the complexity and breadth of the biology curriculum, as well as limited instructional support, are key

barriers to mastering these concepts. These findings support previous assertions by Cimer (2012), Hart et al. (2009), and Dori and Hameiri (2003), who also identified the abstract and extensive nature of biology content as major obstacles to student understanding. Similarly, Alberts (2017), Marbach-Ad et al. (2008), and Pollard et al. (2022) pointed to inadequate revisiting and in-depth instruction on foundational topics—such as the history and structure of the cell, plant and animal cell differences, and cell division processes—as additional causes of difficulty in learning these core biology concepts.

4.4.2 Research question 2

What is the effect of interactive multimedia instructional approach on the improvement of pre-service teachers' performance in the learning of cell structure, cell division and Mendelian genetics?

The research question two of the study was to find out how effective interactive multimedia instructional approach is in enhancing the performance of pre-service science teachers in the learning of the following biology concepts, namely, cell structure, cell division, and Mendelian genetics. To answer this research question, scores from the pre-test and post-test examination of the students were used. Independent sample t-test of the difference in average scores of both pre-test and post-test examination was done. The result is shown in the Tables 8 and 9.

Table 8 displays the pre and post-tests statistics. From the Table, the average score of the pre-service science teachers in pre-test examination was 36.62, whilst the average score of pre-service science teachers in the post-test examination was 71.89. This means that pre-service science teachers' performance in the post-test examination was much better than that of pre-test examination, which also signifies the effect of interactive multimedia instructional approach in enhancing pre-service science

teachers' performance in the learning of the following biology concepts: Cell Structure, Cell Division and Mendelian Genetics. The standard deviation value decrease from 10.23 (pre-test) to 7.18 (post-test), this suggests that post-test scores were more consistent and clustered more closely around the mean compared to pre-test score.

Table 8:

Group statistics

	Exams Type	N	Mean	Std. Deviation	Std. Error Mean
Exams Score	Pre-Test	76	36.61	10.23	1.17
	Post-Test	76	71.89	7.18	0.82

Source: Field Data, 2024

Table 9 discloses the independent samples t-test of the distribution of scores of pre-service science teachers. From the Table 9, the results showed that there was a statistically significant difference in examination scores between the pre-test and the post-test. The analysis indicated a mean difference of -35.27 (SE=1.43), and the 95% confidence interval range from -38.11 to 32.43. Since the $(0.00 < .50)$, the null hypothesis was rejected. This implies that there is sufficient evidence to conclude that a significant difference exists between the mean scores of pre-service science teachers on their examinations. Which means that the average pre-service science teacher score in post-test is different and significant than that of pre-test. This also signifies that pre-service science teachers' performance in post-test is better than that of pre-test examination. The extremely large effect size suggests that the interactive multimedia instructional approach used likely reduced extraneous cognitive load and enhanced germane cognitive processing. The finding indicates that well-designed interactive multimedia instructional approach significantly improved conceptual understanding and academic performance of the participants in the concepts of cell structure, cell division and Mendelian genetics.

Table 9:
Independent sample test

	t-test for Equality of Means						
	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Equal variances assumed	-24.59	75	.00	-35.27	1.43	-38.11	-32.43
Equal variances not assumed	-24.59	75	.00	-35.27	1.43	-38.11	-32.43

Source: Field Data, 2024

Discussion of Findings

The second research question of the study sought to find out the effect of interactive multimedia instructional approach in enhancing the academic performance of pre-service science teachers in learning specific biology concepts-namely, cell structure, cell division, and Mendelian genetics. To address this question, data were drawn from participants' pre-test and post-test scores. As shown in Table 8, the average score of pre-service science teachers in the pre-test was 36.62, whereas the post-test average increased significantly to 71.89. This improvement clearly indicates that the use of interactive multimedia instructional approach significantly enhanced the participants' understanding and performance in the targeted biology concepts. The study further revealed that the notable improvement in post-intervention test scores could be attributed to the use of interactive multimedia instructional approaches. These approaches appeared to help pre-service science teachers organize and internalize complex biology concepts in a more structured and meaningful way, leading to better

comprehension and retention. This outcome aligns with the findings of Thompson et al. (2014), who reported that students exposed to interactive multimedia instructional approach demonstrated higher post-assessment scores than those taught through traditional methods. Similarly, Chen and Lee (2018) found that students who engaged with interactive multimedia instructional approach showed a deeper understanding of cellular processes and Mendelian genetics, applying their knowledge more effectively to complex problems.

In addition, the statistical analysis indicated a significant difference between the pre-test and post-test mean scores, further confirming the positive impact of the multimedia intervention. These results support earlier research by Mayer (2005) and Azevedo and Kali (2010), which concluded that interactive multimedia instructional approaches significantly improve students' academic performance across various subjects, grade levels, and educational settings.

4.4.3 Research question 3

What are the difficulties, attitudes, and benefits of the pre-service science teachers to the use of interactive multimedia instructional approach in classrooms?

The third research question was supported by the rationale of establishing the difficulties, attitudes and benefits that pre-service science teachers have to integrate to the use of interactive multimedia instructional approach in their future classroom. The distribution was normal and, thus, the mean and standard deviation coefficients described the views of respondents. The mean scores were approximated mathematically for easy interpretation as the responses to the items were numerically measured by unilineal scale. In other words, in interpreting the mean scores, a mathematical approximation technique was used in this study; thus, Strongly Disagree falls within an interval range of 1.0-1.4, Disagree within 1.5 - 2.4, Neutral within 2.5 -

3.4, Agree within 3.5 - 4.4, and Strongly Agree within 4.5 - 5.0, based on Pallant's (2020) recommendation. All mean scores that were 3.0 were interpreted as neutral, less than 3.0 were interpreted as disagree while those that were more than 3.0 were interpreted as agree. The views of the pre-service science teachers are presented in Tables 10a, 10b and 10c.

The information in Table 10a revealed that several difficulties are perceived in using interactive multimedia instructional approach in biology education. Most respondents agreed that technical difficulties could hinder instruction, with a mean of 4.28 and standard deviation of 0.99, indicating some variation in responses. Finding appropriate multimedia approaches that align with the curriculum was perceived as more difficult, with a higher mean of 4.41 and standard deviation of 0.83, showing a broader range of opinions and some level of agreement. Limited access to technology and multimedia approaches was another common concern, with a mean of 4.21 and standard deviation of 0.83, suggesting overall agreement with relatively less variability. Respondents also agreed that a lack of training, lack of teacher competence and professional development opportunities for teachers is a challenge, reflected in a mean of 4.32 and standard deviation of 0.78, with minimal variation in responses. Finally, integrating multimedia approaches effectively was seen as requiring additional time and effort, with a mean of 3.88 and standard deviation of 1.30, indicating that most respondents recognized this challenge with moderate variability in their views.

Table 10a:***Views of pre-service science teachers' difficulties in using interactive multimedia instructional approach in biology education***

S/N	Statements	Mean	Std. Dev.
1	Technical difficulties in using interactive multimedia instructional approach can hinder instruction.	4.28	0.99
2	Finding appropriate interactive multimedia instructional approaches that align with curriculum can be difficult.	4.41	0.83
3	Limited access to technology and interactive multimedia instructional approach can restrict the use of the approaches.	4.21	0.83
4	Lack of training, lack of teachers' competency and professional development opportunities for teachers in using interactive multimedia instructional approach in science education.	4.32	0.78
5	Integrating interactive multimedia instructional approach effectively requires additional time and effort.	3.88	1.30
6	Overall	4.22	0.94

Source: Field Data, 2024

From Table 10b, it showed that there is strong evidence to support the claim that pre-service science teachers have positive attitude toward the use of the interactive multimedia instructional approach in biology education. The mean of 4.69 and standard deviation of 0.63 suggested that many respondents agreed that using interactive multimedia instructional approach improves teaching and learning in biology. In the same way, interactive multimedia instructional approaches are helpful in enhancing student's engagement in science lessons had a mean of 4.63 standard deviation of 0.56 indicating a strong agreement with the claim. The statement regarding interactive multimedia instructional approach provides opportunities for more interactive and hands-on learning experiences had a mean of 4.31 and standard deviation 0.906, reflecting agreement, but with some diversity in opinion. The mean of 4.48 and standard deviation of 0.68 for integrating interactive multimedia instructional approach in

science instruction can help students develop deeper understanding concepts, even though there were slightly varied responses. Finally, the students' approach to the use of interactive media effectively explaining complex scientific phenomena was positive and had a significant level of agreement, with a mean of 4.47 and standard deviation of 0.77, indicating that most respondents supported this statement with relatively low variation in their responses.

Table 10b:

Views of pre-service science teachers on attitude towards the use of interactive multimedia instructional approach in their classrooms' interactions

S/N	Statements	Mean	Std. Dev.
1	Using interactive multimedia instructional approach improves teaching and learning.	4.69	0.63
2	I believe interactive multimedia instructional approaches are helpful in enhancing student's engagement in science lessons.	4.63	0.56
3	Interactive multimedia instructional approach provides opportunities for more interactive and hands-on learning experiences.	4.31	0.90
4	Integrating interactive multimedia instructional approach in science instruction can help students develop deeper understanding concepts.	4.48	0.68
5	Interactive multimedia instructional approach enables me to explain complex scientific phenomena more effectively.	4.47	0.77
6	Overall	4.51	0.711

Source: Field Data, 2024

From Table 10c, it showed that there is strong evidence to support the claim that interactive multimedia instructional approaches are beneficial in various aspects of biology education. The mean of 4.69 and standard deviation of 0.91 suggested that many respondents agreed that multimedia approach was helpful in presenting abstract concepts in a concrete and visual manner. Similarly, the use of multimedia approaches

to improve students' engagement and motivation had a mean of 4.63 standard deviation of 0.81 indicating a strong agreement with the claim. The statement regarding accommodating different learning styles and abilities through multimedia approach had a mean of 4.36 and standard deviation 0.83, reflecting agreement, but with some diversity in opinion. The mean of 4.48 and standard deviation of 0.84 for using interactive multimedia instructional approach to facilitate exploration of real-life scientific situations showed general agreement, even though there were slightly varied responses. Finally, the effectiveness of interactive media in explaining complex scientific phenomena had a significant level of agreement, with a mean of 4.47 and standard deviation of 0.79, indicating that most respondents supported this statement with relatively low variation in their responses.

Table 10c:

Views of pre-service science teachers on benefits of interactive multimedia instructional approach in their classrooms' interactions

S/N	Statements	Mean	Std. Dev.
1	Using interactive multimedia instructional approach helps in presenting abstract concepts in a concrete and visual manner.	4.69	0.91
2	Interactive multimedia instructional approach improves students' engagement and motivation in science lessons.	4.63	0.81
3	Using interactive multimedia instructional approach helps in accommodating different learning styles and abilities.	4.36	0.83
4	Using interactive multimedia instructional approach facilitates the exploration of real-life scientific situation.	4.48	0.84
5	Interactive media enables me to explain complex scientific phenomena more effectively.	4.47	0.79
6	Overall	4.45	0.83

Source: Field Data, 2024

Discussion of Findings

The third research question aimed to identify the difficulties pre-service science teachers face in integrating and utilizing interactive multimedia instructional approaches in their future classrooms. The findings related to this question were encouraging. The responses provided by the pre-service teachers offered valuable insights that guided the researcher in selecting suitable multimedia approaches for the intervention. On the views of respondents on pre-service science teachers' perceived difficulties or challenges in using interactive multimedia instructional approaches in biology education as displayed in Table 10a. It is evidently clear that the pre-service science teachers have difficulty in using interactive multimedia instructional approach in teaching biology concepts. The information in Table 10a revealed that several challenges/difficulties/barriers are perceived by the pre-service science teachers in using interactive multimedia instructional approach in biology education. A majority of respondents acknowledged that technical difficulties could obstruct instruction, as reflected by a mean score of 4.28 and a standard deviation of 0.99, indicating moderate variability in their responses. This aligns with findings by Hassall and Lewis (2017), who asserted that without adequate technical support and comprehensive school-wide resources, teachers are unlikely to overcome the obstacles associated with ICT usage.

Similarly, Wang et al. (2014) emphasized that teacher training plays a crucial role in addressing barriers to effective classroom technology integration. Supporting this, Pelgrum (2001) identified a lack of technical support as one of the primary barriers reported by primary and secondary school teachers. Sicilia (2005) also highlighted technical issues, such as slow-loading websites, internet connectivity problems, printer failures, out-dated computers, and malfunctioning devices as significant impediments to effective technology use in the classroom.

Sicilia, (2005) also emphasized that technical obstacles could disrupt the smooth flow of classroom activities, a view that aligns with the experiences shared by the pre-service science teachers in this present study. This concern is echoed by Hüsing et al. (2006), who argued that having dedicated ICT support or maintenance contracts in schools enables teachers to focus on teaching without being burdened by hardware and software issues. Similarly, the Becta (2004) report noted that when technical support is lacking, maintenance may be infrequent, increasing the likelihood of system failures, further reinforcing the pre-service teachers' concerns about technological difficulties affecting effective use of interactive multimedia instructional approach in biology education. Moreover, Becta's (2004) survey revealed that many teachers are discouraged from using ICT due to fears of technical failures during lessons, a sentiment confirmed by the current findings.

Additionally, identifying suitable multimedia approaches that align with the curriculum emerged as a notable challenge, reflected in a higher mean score of 4.41 and a standard deviation of 0.83, indicating varied but generally high concern among respondents. Teachers must integrate multimedia instructional approaches into their lesson plans to create an engaging and interactive learning experience (Pryor & Bitter, 2008). For instance, using videos to explain complex concepts, interactive simulations to demonstrate biological processes, or audio clips to discuss the role of organisms in ecosystems can help students grasp the subject matter more effectively (Mayer, 2005). Again, teachers should strategically incorporate multimedia instructional approach into their lessons to enhance students' engagement and understanding. This may involve using animations to illustrate complex concepts, videos to demonstrate laboratory techniques, or interactive simulations for hands-on learning experiences (Francom, 2020). The role of a student in teaching and learning of biology using interactive

multimedia instructional approach is crucial, as it allows them to actively engage with the content, fostering a deeper understanding of the subject matter. Students can benefit from interactive multimedia instructional approach in various ways, such as improved motivation, enhanced retention of information, increased collaboration and performance.

Another frequently cited challenge was limited access to technology and multimedia approaches, with a mean response of 4.21 and a standard deviation of 0.83, reflecting general agreement among respondents with relatively low variability. A major barrier to integrating multimedia in biology instruction is the lack of adequate access to essential technologies such as computers, internet connectivity, and other digital tools. This scarcity can significantly restrict the availability of educational resources and impede the practical implementation of multimedia approaches in classrooms. Liu et al. (2009) highlighted that insufficient technological access poses a substantial obstacle to effectively using multimedia in biology teaching. Additionally, numerous studies have shown that limited access to technological resources, particularly at home is a multifaceted issue that discourages teachers from embracing new technologies in educational settings, including biology education. These studies also point to several contributing factors behind this lack of access, which are further explored in subsequent discussions.

Sicilia (2005) reported that many teachers found it challenging to consistently access computers, a sentiment echoed by participants in this study. Teachers cited issues such as needing to book computer laboratory in advance, often forgetting to do so, or being unable to reserve them for extended periods when multiple class sessions were required for project-based learning. This limited access was primarily due to the shared nature of ICT resources among teachers. Similarly, Becta highlighted that

inaccessibility to ICT tools is not solely a result of the absence of hardware or software in schools, but may also stem from factors such as disorganized resource management, out-dated or malfunctioning equipment, unsuitable software, or lack of individual access for teachers. These barriers, according to Becta, vary significantly across regions. Supporting this, Emor's (2016) European study concluded that restricted access remains the most significant obstacle to ICT integration in teaching. Teachers commonly reported a shortage of computers and inadequate digital materials as major challenges, reinforcing the findings of the current study.

Hüsing et al. (2006) highlighted that even in Europe; infrastructure-related ICT barriers persist, with one-third of schools lacking broadband internet access. Similarly, Pelgrum (2001) through a study involving educators from 26 countries and identify accessibility as a major challenge in implementing ICT in schools. Four of the top ten obstacles were related to access: limited numbers of computers, peripherals, software copies, and insufficient simultaneous internet connectivity. Toprakci (2006) reported similar barriers in Turkish schools, such as out-dated or slow ICT systems and a shortage of educational software. In Saudi Arabia, Al-Alwani (2005) found that lack of hardware and internet accesses were significant impediments to ICT integration. Albirini (2006) identified insufficient computer resources as one of the key barriers in Syrian classrooms. These studies all support the findings of this research, in which respondents also noted limited access to technology as a significant challenge to using interactive multimedia instructional approach in biology education.

Additionally, respondents pointed to the lack of training and professional development as major obstacles, a view reflected in the high mean score of 4.32 and a standard deviation of 0.78, indicating strong agreement. The most frequently cited barrier in the literature is insufficient training. Habibu (2012) also reported a lack of

training opportunities for teachers in ICT integration. Furthermore, the study's findings revealed that many pre-service science teachers lack the competence required to effectively incorporate ICT into teaching practices-an issue closely tied to teacher confidence. This emphasizes the need for better professional development and support structures to equip teachers with the necessary skills for successful ICT integration in biology education.

Several studies have identified a lack of confidence as a significant barrier preventing teachers from integrating ICT into their teaching practices. Dawes (2001) described this as a contextual factor that can act as a hindrance to the effective use of technology in education. This aligns with Becta's (2004) assertion that a lack of confidence is one of the key obstacles for teachers when adopting ICT in the classroom. Similarly, Regmi and Jones (2020) highlighted the lack of training as one of the top three barriers preventing teachers from using ICT effectively. Research conducted in Turkey also supported this view, where Özden (2007) found that insufficient in-service training programs for science teachers were a major issue in the implementation of new ICT technologies. Toprakci (2006) further concluded that the limited teacher training in ICT was a significant barrier to successful technology integration in Turkish schools.

This concern was also echoed by Becta (2004), who noted that teacher training in ICT is a complex issue. Becta emphasized that effective training must consider multiple components, such as adequate time for training, pedagogical skills, technical skills, and integrating ICT into initial teacher training programs. In a more recent study, Kulaksiz and Karaca (2023) identified similar barriers in science education, pointing out that a lack of digital literacy training, pedagogical and didactic skills on how to use ICT effectively in the classroom, and specialized training for science-specific technologies were obstacles to the integration of new technologies into teaching

practices. In Saudi Arabia, studies have also pointed to teacher training weaknesses as a major factor hindering the successful implementation of ICT in education.

According to Quamar (2020), a reliance on traditional teaching methods and a shortage of qualified teachers proficient in using ICT confidently were barriers to technology integration. Providing pedagogical training, rather than simply technical training on how to use ICT tools, is essential for improving teachers' confidence and competence in the classroom (Becta, 2004). Cox et al. (1999a) argued that training programs must focus on the pedagogical aspects of ICT use in teaching to truly convince educators of its value.

The research conducted by Cox et al. (1999a) revealed a significant gap between teachers' participation in professional development courses in ICT and their ability to effectively integrate ICT into their classrooms. Despite completing these courses, many teachers reported only being able to operate basic ICT equipment, such as running a computer or setting up a printer, without having the necessary pedagogical skills to use ICT in an educational context. The study highlighted that the professional development programs often focused solely on basic technical skills, neglecting the crucial pedagogical aspects of ICT integration in teaching.

In a similar vein, Balanskat et al. (2006) found that many teacher training programs fail to help teachers integrate ICT into their teaching practices and lesson preparations. The lack of focus on pedagogical practices in relation to ICT, coupled with an emphasis on developing basic ICT skills, hampers the effective use of technology in classrooms. This is in line with Becta's assertion that while pedagogical training is essential, teachers must still receive training in specific ICT skills to use technology effectively in the classroom. Schoepp (2005) also emphasized that teachers need specific training on how to integrate new technologies into their classrooms. He

argued that teachers must develop the necessary skills to use particular ICT tools effectively, which requires targeted training focused on the educational purposes of the technology rather than simply learning how to operate the tools.

Furthermore, Newhouse et al. (2002) contended that in addition to initial training, on-going professional development is essential to help teachers maintain their skills and knowledge about ICT integration. This continuous development ensures that teachers can keep pace with technological advancements and apply them effectively in the classroom. Osborne and Hennessy (2003) reinforced this view by stressing that training is fundamental when new tools and approaches to teaching are introduced. They argued that teachers need comprehensive training to effectively integrate new technologies into their teaching practices. However, Balanskat et al. (2006) pointed out that inadequate or inappropriate training programs leave teachers neither sufficiently prepared nor confident to fully integrate ICT into their teaching. This can create barriers to successful implementation of technology in the classroom. According to Newhouse et al. (2002), it is not enough for teachers to be merely computer literate; they also need to develop skills in integrating technology into their teaching and learning programs. Training should focus on both the technical aspects of using technology and its pedagogical application. Sicilia (2005) found that while teachers were eager to learn how to use new technologies, a lack of opportunities for professional development prevented them from fully integrating technology into their teaching, particularly in subjects like science.

The issue of professional development in ICT for teachers is multifaceted, as highlighted by several studies. Balanskat et al. (2006) pointed out that training courses are often not tailored to meet the specific learning needs of teachers, making them less effective in fostering meaningful ICT integration in classrooms. Additionally, these

training sessions are rarely updated, which means teachers may not receive training on the latest technologies and pedagogical approaches. As a result, even when teachers attend professional development programs, they may still face challenges in integrating technology into their teaching practices due to a lack of relevant or up-to-date training.

One critical aspect in overcoming these challenges is the role of pre-service science teachers' education. According to Albirini (2006), pre-service science teachers' education can provide an invaluable opportunity for teachers to experiment with ICT before they use it in actual classroom settings. This early exposure allows them to become familiar with the approaches and how to integrate them into their teaching practices, better preparing them for future classroom use. However, a lack of focus on ICT in initial teacher education can serve as a significant barrier. Becta (2004) found that the absence of ICT-focused training in pre-service science teachers programs makes it difficult for teachers to effectively utilize ICT resources during their teaching practice. If teachers are not trained to use these resources during their teacher education, they may find it challenging to incorporate them into their classrooms once they start teaching.

Moreover, integrating multimedia approaches in teaching is often perceived as requiring additional time and effort, which is another challenge identified in this study. With a mean score of 3.880 and a standard deviation of 1.300, it indicates that the majority of respondents recognized this challenge, albeit with moderate variability in their views. Teachers must dedicate extra time to learn how to use the technology, plan lessons that incorporate multimedia approaches, and troubleshoot potential issues. This added workload can discourage teachers from fully embracing multimedia approaches, especially if they already feel stretched in other areas of their teaching.

In line with this, many studies into the barriers to ICT integration have highlighted the role of teachers' attitudes toward change. According to Hashmi (2016), resistance to change is one of the most significant barriers to effective ICT integration in education. Gomes (2005) similarly found that science teachers' resistance to adopting new strategies and technologies was a substantial obstacle to the integration of ICT into biology education. Becta also recognized that resistance to change is an important factor preventing teachers from utilizing new technologies in their classrooms. Bingimlas (2009) argued that the integration of new technologies into educational settings requires significant change, and that different teachers handle this change in different ways. This resistance to change can manifest in various ways, including reluctance to embrace new teaching approaches or scepticism about the effectiveness of technology in enhancing student learning.

Habibu (2012) further affirmed this view in the context of Uganda, stating that teachers' beliefs and attitudes toward change significantly influence their teaching practices. Teachers who are resistant to change may be less likely to integrate new technologies effectively into their classrooms, thus hindering their students' access to the benefits that these technologies could offer. Table 10b presents the respondents' perspectives on the attitudes of pre-service science teachers regarding the integration and use of interactive multimedia instructional approaches in their future classrooms. The findings from this study revealed that the pre-service science teachers exhibited a positive attitude toward using interactive multimedia instructional approach activities in teaching and learning biology concepts such as cell structure, cell division, and Mendelian genetics.

According to the Table, a majority of the respondents strongly agreed that interactive multimedia instructional approach enhances the teaching and learning of science concepts (mean = 4.690; Std. Dev. = 0.613). Additionally, most participants strongly agreed that multimedia instructional approaches are effective in increasing student engagement during science lessons (mean = 4.630; Std. Dev. = 0.561). These results align with the study by Rusdewanti and Gafur (2014), which suggested that multimedia instructional approach plays a crucial role in making the learning process more engaging and motivating for students. Multimedia approaches help to visually present textual materials, sparking students' interest and fostering a positive attitude toward their use in teaching. By presenting complex biology concepts in an engaging and interactive way, multimedia can boost students' motivation.

The use of multimedia in education can enhance the learning experience by making it more enjoyable and stimulating, ultimately leading to increased motivation for learning biology concepts (Tzeng et al., 2022; Wu et al., 2018). Media in the learning process can spark students' enthusiasm, boost their motivation, and create a stimulating environment that positively affects their psychological engagement (Yudhie et al., 2021). These findings align with the studies by Shumack and Sheridan (2017) and Hough (2019), which highlighted that creative learning designs make the learning process more innovative, interesting, interactive, and effective. Such designs improve the quality of students' learning, enable teaching and learning to take place anywhere and anytime, and enhance students' attitudes and interest in learning. When asked about how multimedia approaches offer opportunities for interactive and hands-on learning, a significant number of respondents agreed with this statement (mean = 4.31; Std. Dev. = 0.56). This supports the findings of Borner (2019), who emphasized

that in learning activities focusing on process skills, the role of learning media is becoming increasingly crucial.

When multimedia technology is utilized in a well-designed and creative manner, it can significantly enhance students' learning, helping them understand the material better and improving the overall quality of their education. Susanto (2017) also highlighted that the quality of the teacher plays a crucial role in the learning process, as teachers are key components of educational success. Dema and Moeller (2012) further emphasized that interactive multimedia instructional approach motivates students to explore more information related to cultural backgrounds and real-life experiences, which can enhance their learning. In this study, most respondents agreed that integrating interactive multimedia instructional approach in biology instruction could foster a deeper understanding of concepts (mean = 4.48; Std. Dev. = 0.68). These findings are consistent with those of Vijapurkar et al. (2014), who explored students' difficulties in understanding complex biological concepts, particularly in visualizing three-dimensional (3-D) cells. Their research with grade 6 students in urban schools in India revealed that many students visualized biological cells as two-dimensional (2-D) structures, rather than as closed three-dimensional (3-D) functional units. They also found that students struggled to grasp the complex terminology and functions of plant and animal cell parts, which hindered their understanding of the concept (Kavi Kishor et al., 2015).

The vast amount of terminology associated with cell structure and cell division can be overwhelming for students. According to Çeliker (2015), understanding biology concepts and being able to explain them is essential for biology teachers. He argued that students' perceptions of biological concepts are influenced by the teachers who present these concepts. These studies reinforce the findings of this research, which

indicate that students often face challenges in learning biology concepts. Furthermore, a mean and standard deviation of 4.470 and 0.791 respectively indicated that interactive multimedia instructional approach enables biology teachers explain complex scientific phenomena more effectively as agreed by the respondents. Teachers must integrate multimedia approaches into their lesson plans to create an engaging and interactive learning experience (Pryor & Bitter, 2008). For instance, using videos to explain complex concepts, interactive simulations to demonstrate biological processes, or audio clips to discuss the role of organisms in ecosystems can help students grasp the subject matter more effectively (Mayer, 2005). Again, teachers should strategically incorporate multimedia approach into their lessons to enhance student engagement and understanding. This may involve using animations to illustrate complex concepts, videos to demonstrate lab techniques, or interactive simulations for hands-on learning experiences. The findings of this study also highlighted the perceived benefits of using interactive multimedia instructional approach in teaching and learning biology concepts, as reflected in Table 10c. The data strongly support the view that multimedia approaches are advantageous in various aspects of science education. For example, the mean of 4.690 and standard deviation of 0.917 suggest that many respondents believed multimedia approach is effective in presenting abstract concepts in a clear and visual way.

Previous research has also demonstrated the effectiveness of online learning compared to traditional classroom-based instruction (Unal, 2005), with a more recent analysis by Howell et al. (2009) showing that students who participated in online courses performed as well, if not better, than those in face-to-face classes. According to Howell et al. (2009), online learning offers unique benefits, including expanding

instructional options, facilitating teacher-student interactions, and promoting student collaboration through synchronous (real-time) and asynchronous (delayed) methods.

These findings align with Schoenfeld-Tacher et al. (2001), who studied the impact of online learning in an upper-level science course, Histology. Their research compared the performance of students in on-campus and online sections of the same course by assessing pre- and post-test results. The study revealed that although there were no initial differences in content knowledge, students in the online section significantly outperformed their on-campus counterparts by the end of the semester. This study suggested that interactions in an online course may exceed those in traditional classroom settings, with technology-supported practices enabling tutor-student interactions through emails, developing online communities of practice, engaging in active learning, and providing timely, constructive feedback—all of which support collaborative and cooperative learning. Similarly, the respondents in this study strongly agreed that multimedia approaches improve student engagement and motivation, as reflected by a mean of 4.630 and a standard deviation of 0.815. This suggests that multimedia approaches are seen as highly beneficial in fostering both student engagement and motivation in the learning process. The study by Rusdewanti and Gafur (2014) confirmed that multimedia approach is valuable in the learning process, making teaching more engaging for students and, as a result, enhancing their motivation to learn.

Multimedia approaches can help to increase student motivation by presenting complex biology concepts in an engaging, visual, and interactive manner. This can make the learning process more enjoyable and stimulating, which can lead to increased motivation to learn (He, Holton & Farkas, 2018). The statement regarding accommodating different learning styles and abilities through multimedia approach had

a mean of 4.360 and standard deviation of 0.832, reflecting agreement, but with some diversity in opinion. The mean of 4.480 standard deviation of 0.842 for using multimedia approach to facilitate exploration of real-life scientific situations showed general agreement, even though there were slightly varied responses. Finally, the effectiveness of interactive multimedia approach in explaining complex scientific phenomena had a significant level of agreement, with a mean of 4.470 and standard deviation of 0.791, indicating that most respondents supported this statement with relatively low variation in their responses.

4.4.4 Research question 4

What is the effect of interactive multimedia instructional approach on pre-service science teachers' motivation and engagement levels during biology instruction?

This section of the study displays the overall bivariate correlational analyses of all the constructs of the study. The various individual and composite constructs developed were tested in terms of their correlational relationships. The bivariate correlational analysis of the study variables is shown in Table 11. Pearson Correlation matrix is below the diagonal. However, as it considers a latent construct transformation from observed variables, the Pearson's correlation method was more appropriate for non-numerical or discrete variables. Linear regression analysis was undertaken to determine what effect of interactive multimedia instructional approach might have on pre-service science teachers' motivation and engagement in biology instructions.

Table 11 shows the relationship between interactive multimedia instructional approach, pre-service science teachers' motivation and engagement in biology instructions. From the Table, interactive multimedia instructional approach has a significant and strong positive relationship with pre-service science teacher' motivation

($r = 0.51$) and also interactive multimedia instructional approach has a strong positive and significant relationship with pre-service science teachers' engagement ($r = 0.72$).

Table 11:

Relationship between interactive multimedia instructional approach, pre-service science teachers' motivation and engagement in biology instructions

Variables	Interactive Multimedia Instructional Approach	
	Correlation Coefficient (r)	Sig.
Pre-service science teachers' motivation	0.51	0.00**
Pre-service science teachers' engagement	0.72	0.00**

Source: Field Data, 2024 ** $p < .01$, * $p < .05$

Considering the effect of using interactive multimedia instructional approach on the motivation of pre-service science teachers in biology instructions in Table 11. From the Table 11, the implication is that interactive multimedia instructional approach has a significant and positive effect on pre-service science teachers' motivation = 0.61, $p < .01$. As such, as the lecturer continue to use the interactive style of teaching, the motivation of the pre-service science teachers will be increased, hence increases the academic performance of the pre-service science teachers. However, what should be noted is that the independent factors account for 0.70 of the variation in the dependent variable, pre-service science teachers' motivation. It therefore means that 70 per cent of the volatility in pre-service science teachers' motivation can be forecast or predicted by interactive multimedia instructional approach. This means, regardless of the interactive multimedia instructional approach added into the model, other factors yet to be considered have a probability to add 30 per cent to the motivation of pre-service science teachers.

Table 12:

The effect of interactive multimedia instructional approach on pre-service science teachers' motivation in biology lesson

Variables	Unstandardized Coefficient		Standardized Coefficient	Sig.	Collinearity Statistics	
	B	Std. Error	Beta (β)		Tolerance	VIF
Interactive multimedia instructional approach	0.65	0.14	0.61	.00**	0.114	5.77
Constant			0.63			
R			0.79			
R Square			0.70			
Adjusted R Square			0.65			

Source: Field Data, 2024 *p < .05, **p < .01
Dependent Variable: Pre-service science teachers' motivation

Considering the effect of using interactive multimedia instructional approach on pre-service science teachers' involvement in biology instructions, it can be deduced from Table 13 that, the interactive engagement of pre-service science teachers in learning some biology concepts is significantly and positively influenced by the use of interactive multimedia instructional approach = 1.41, $p < .01$. The implication is that as the teachers continue to use the interactive style of teaching, the pre-service science teachers' engagement will be increased and as such increases the academic performance of pre-service science teachers. It is, however worth noting that the total contribution of independent factors to variation in the dependent variable, pre-service science teachers' engagement is 0.76 at an adjusted R^2 of 0.74. The implication here is that 76 per cent of the variance in pre-service science teachers' engagement is correctly predicted by interactive multimedia instructional approach. This means that, aside from the embedded interactive multimedia instructional approach in the model, other factors

as yet not considered contribute a probability of adding 24 per cent to pre-service science teachers' engagement.

Table 13:

The effect of interactive multimedia instructional approach on pre-service science teachers' engagement in biology lessons

Variables	Unstandardized Coefficient		Standardized Coefficient	Sig.	Collinearity Statistics	
	B	Std. Error	Beta (β)		Tolerance	VIF
Interactive multimedia instructional approach	1.61*	0.28	1.41	.00**	0.03	5.65
Constant			0.63			
R			0.85			
R Square			0.76			
Adjusted R Square			0.74			

Source: Field Data, 2024 * $p < .05$, ** $p < .01$
Dependent Variable: Pre-service science teachers' engagement

Discussion of Findings

The fourth research question aimed to assess the effect of interactive multimedia instructional approaches on pre-service science teachers' motivation and engagement in biology classes. The findings indicate that the use of interactive multimedia instructional approach interventions had a positive effect on the participants' motivation and engagement with the biology concepts identified. This suggests that the pre-service science teachers involved in the study were positively motivated and actively engaged when interactive multimedia instructional approaches were used in teaching and learning of biology concepts. From Table 11, interactive multimedia instructional approach has a significant and positive relationship with pre-service

science teacher' motivation ($r = 0.51$) and also interactive multimedia instructional approach has a positive and significant relationship with pre-service science teachers' engagements ($r = 0.72$). This finding is in agreement of Pryor and Bitter (2008) that teachers must integrate multimedia approaches into their lesson plans to create an engaging and interactive learning experience.

Again, the finding is consistent with Mayer (2005) which said that using videos to explain complex concepts, interactive simulations to demonstrate biological processes, or audio clips to discuss the role of organisms in ecosystems can help students grasp the subject matter more effectively. Ferreira et al. (2013) also indicated that teachers should strategically incorporate multimedia approach into their lessons to enhance student engagement and understanding. This may involve using animations to illustrate complex concepts, videos to demonstrate lab techniques, or interactive simulations for hands-on learning experiences.

The finding is also in agreement with Bonk and Zhong (2006) that multimedia approaches like as videos, simulations, and interactive games, can encourage students to actively participate in their learning, rather than passively consuming information and this active engagement can lead to improved understanding and retention of the concepts being learnt. Again, actively engaging with multimedia approaches are crucial to maximize the learning experience. Students take the initiative to explore various multimedia approaches, such as videos, interactive simulations, animations, and virtual labs, provided by their teachers or educational platforms (Satyaprakasha & Sudhanshu, 2014). They immerse themselves in these resources, asking questions, taking notes, and participating in interactive activities, to enhance their understanding of biology (Buckley, 2000). Multimedia approach can help to increase students' motivation by presenting complex biology concepts in an engaging, visual, and interactive manner.

This can make the learning process more enjoyable and stimulating, which can lead to increased motivation to learn (Tzeng et al., 2022; Wu et al., 2018).

4.4.5 Research question 5

What are the pre-service science teachers' perceptions on the effectiveness of interactive multimedia instructional approach in biology lessons?

In answering research question 5, all the 76 pre-service science teachers' responses to question items 13 to 22 in the part B of Perception Rating Questionnaire in Appendix G were analysed. The fifth research question was based on the rationale to determine the pre-service science teachers' perception of the effectiveness of interactive multimedia instructional approach in teaching and learning of biology concepts. Means and standard deviation coefficients were used to describe views of the respondents since the distribution was normal. All mean scores that were 3.0 were interpreted as neutral, less 3.0 were interpreted as disagree while those that were more than 3.0 were interpreted as agree. The views of the pre-service science teachers are presented in Table 14.

Table 14 shows the respondents' perception of the effectiveness of interactive multimedia instructional approach in teaching and learning of biology concepts as compared to traditional instructional approaches or methods with pre-service science teachers. From the Table, ninety-eight per cent (98%) of the respondents agreed that with the use of interactive multimedia instructional approach, the concept of biology is easier to understand (mean = 4.59; Std. Dev. = 0.65). Also, a majority agreed that with the interactive multimedia instructional approach, they retain biology concepts better compared to traditional methods (mean = 4.47; Std. Dev. = 0.64). Also, most of the respondents confirmed that through interactive multimedia instructional approach, they feel more inclined towards the subject matter of biology concepts that were learnt (cell

structure, cell division and Mendelian genetics) with a mean of 4.47 and standard deviation of 0.64.

In further detail, most of the respondents agreed with the fact that interactive multimedia instructional approach encourages them to go more in-depth into biology topics with a mean of 4.53 and standard deviation of 0.66. At the same time, the majority of the respondents opined that teaching and learning of biology concepts via interactive multimedia instructional approach is more enjoyable compared to traditional lectures with a mean of 4.49 and standard deviation of 0.73 and also agreed that the multimedia approaches allow them to visualize complex biology concepts more clearly (mean = 4.67; Std. Dev. = 0.73). Notwithstanding, majority of the respondents agreed that they find interactive multimedia instructional approach to be a motivating tool in teaching and learning of biology concepts (mean = 4.29; Std. Dev. = 0.93). Also, most of them agreed that they are able to work at their own pace when using interactive multimedia instructional approach for teaching and learning of biology (mean= 4.39; Std. Dev.=0.83) and they also agreed that through interactive multimedia instructional approach, problem-solving skills in biology are improved (mean= 4.59; Std. Dev.= 0.73). Lastly, the majority of the respondents agreed that through the feedback provided in the multimedia activities, they can understand the biology concepts of better (mean = 4.50 and Std. Dev. = 0.87).

Table 14:***Views of the pre-service science teachers on perception on the effect of interactive multimedia instructional approach in teaching and learning of biology concepts***

S/N	Statements	Mean	Std. Dev.
1	The use of interactive multimedia instructional approach makes biology concepts easier to understand	4.59	0.65
2	Interactive multimedia instructional approach helps me retain biology concepts better than traditional methods	4.47	0.64
3	I feel more engaged with biology content when using interactive multimedia instructional approach.	4.47	0.64
4	Interactive multimedia instructional approach encourages me to explore biology topics more deeply.	4.53	0.66
5	Teaching and learning of biology through interactive multimedia instructional approach is more enjoyable than traditional lectures.	4.49	0.73
6	The multimedia approach allows me to visualize complex biology concepts more clearly.	4.67	0.47
7	I find interactive multimedia instructional approach to be a motivating tool in teaching and learning of biology.	4.29	0.93
8	I am able to work at my own pace when using interactive multimedia instructional approach for teaching and learning of biology.	4.39	0.83
9	Interactive multimedia instructional approach improves my problem-solving skills in biology.	4.59	0.73
10	The feedback provided in multimedia instructional approach activities helps me to better understand biology concepts.	4.50	0.87
11	Overall	4.49	0.65

Source: Field Data, 2024

Additional data were collected or obtained through interviews. The sample consisted of seventy-six (76) second-year pre-service science teachers for the study and since the population is fairly large, the researcher interviewed a small portion of it. This is because convenience sample of ten (10) participants were selected from a population of seventy-six (76) pre-service science teachers to allow for in-depth exploration of their conceptual difficulties. Data collection ceased upon reaching saturation, where no

new themes emerged. The following excerpt from an interview exemplifies this notion (R and PSSTs stand for researcher and pre-service science teachers respectively). The interviewed responses from the ten (10) selected participants have been transcribed and presented verbatim under six thematic areas as follows:

Researcher: *What was your overall experience using interactive multimedia instructional approach for learning cell structure, cell division and Mendelian genetics?*

PSSTs: *“Please sir, hmmm, the lesson with interactive multimedia instructional approach were very interesting, engaging, good and I was able to make meaning of the abstract and complex concepts in cell structure, cell division and Mendelian genetics better than I used to be in the past lessons. The interactive multimedia instructional approach resources used provided us the opportunity to learn by engaging in active learning process. We want more of such lessons. In fact, we can like the videos and animations in the lessons because it was very enjoyable.”*

Researcher: *Did you find interactive multimedia instructional approach helpful in understanding complex and confusing concepts related to cell structure, cell division and Mendelian genetics?*

PSSTs: *“Please sir, yes. In our normal lectures we used to sit and listen to whiteboard explanation and talking from our science lecturers making us get confused to understand some concepts sometimes. In most situations, biology/science is taught using lecture method. This, therefore, affects our’ conceptual understanding of the concept as we learn by memorizing or by rote learning. But in these lessons with interactive multimedia instructional approach resources, we were actively involved in the teaching and learning processes making us have better conceptual understanding of the biology concepts taught than in our normal class and also motivates us in learning complex concepts in biology.”*

Researcher: *What was your favorite interactive multimedia instructional approach instructional approach used in learning about cell structure, cell division and Mendelian genetics?*

PSSTs: *“In general, they preferred the PowerPoints presentations with images, videos and animation box together.”*

Researcher: *From your experience, how could interactive multimedia instructional approach instructional approach be improved to better facilitate learning for students?*

PSSTs: *“Overall, the respondents’ views about the interactive multimedia instructional approach instructional approach were positive. They felt that the interactive multimedia instructional approach instructional approach (PowerPoint presentations-text, video, images, animations etc.) and the interactive multimedia instructional approach lessons instructions were very clear, more appropriate for their level and presented the concept under study in a simple and logical sequence, which made it easy for them to follow and understand the concepts being learnt and should not be one-day wonder or only when lecturers are doing research but be part of their teaching always.”*

Researcher: *From your experience with interactive multimedia instructional approach, how do you see these tools fitting into the overall biology curriculum?*

PSSTs: *” Hmm, from our experience, interactive multimedia instructional approach is very good, very helpful in using this method of instruction in teaching and learning of biology, it makes you actively involved in the discussion and activities related in cell structure, cell division and Mendelian genetics. If lecturers are well trained and equipped very well, it will help improve teaching and learning in biology classes and other subjects. I suggest other lecturers in the department should adopt this teaching learning method in their teaching as well.”*

Researcher: *Would you prefer more traditional methods of teaching or interactive multimedia tools in future biology classes about cell structure, cell division and Mendelian genetics?*

PSSTs: *“Okay sir mmmm. We like to prefer interactive multimedia instructional approach teaching approach than the traditional teaching approach. Because learning with interactive multimedia teaching approach comes with conducive learning environment. In fact, we would be very much happy if learning of*

biology and other science courses will continue this way until we complete school. Mmmm, we are in support of this unique instructional approach and we wanted it to be continued in this college especially in the teaching and learning of sciences even after this research project. We want other lecturers to use them in teaching us from now on.”

The responses and data presented in Table 14 indicate that the pre-service science teachers involved in the study held positive views toward the use of interactive multimedia instructional approach for teaching and learning specific biology topics, including cell structure, cell division, and Mendelian genetics. To assist pre-service science teachers in addressing the challenges associated with using interactive multimedia instructional approach for teaching biology concepts, a manual was introduced. This manual was specifically designed to support pre-service science teachers in understanding and effectively utilizing interactive multimedia instructional approach in teaching biology, with the aim of enhancing their instructional skills and boosting students' academic performance. The manual provides practical, step-by-step guidance on selecting using, evaluating it and ensuring lessons are engaging and effective. The researcher adapted and recommends effective multimedia instructional strategies in a form of manual for teaching and learning biology in Wiawso Colleges of Education. Combining traditional teaching with multimedia enhances learning outcomes by catering to various learning styles (Bergmann & Sams, 2012). Detail of the manual can be found in Appendix I.

Discussion of Findings

Research question five aimed to explore pre-service science teachers' perceptions of the effectiveness of interactive multimedia instructional approaches in teaching and learning biology concepts. The findings revealed that the participants held positive views about the use of interactive multimedia instructional approach for

learning selected biology concepts. According to Table 14, the majority of respondents agreed that learning biology concepts through interactive multimedia instructional approach made the material easier to understand (mean = 4.59; Std. Dev. = 0.65).

Additionally, most agreed that they were better able to retain the biology content learned through multimedia compared to traditional teaching methods (mean = 4.47; Std. Dev. = 0.64). Many respondents also indicated that the use of interactive multimedia instructional approach increased their interest in the subject matter, specifically in concepts such as cell structure, cell division, and Mendelian genetics. Furthermore, the majority of respondents agreed that interactive multimedia instructional approach encouraged them to explore biology concepts more deeply. Most participants also expressed that learning biology through multimedia was more enjoyable compared to traditional lecture-based methods. They agreed that the multimedia approach helped them to visualize complex biological concepts more clearly (mean = 4.67; Std. Dev. = 0.47). Additionally, a significant number found interactive multimedia instructional approach to be a motivating tool for both teaching and learning biology (mean = 4.29; Std. Dev. = 0.93). Respondents also noted that the multimedia format allowed them to learn at their own pace (mean = 4.39; Std. Dev. = 0.34) and believed it enhanced their problem-solving skills in biology (mean = 4.59; Std. Dev. = 0.73). Lastly, most participants agreed that the feedback provided through multimedia activities helped improve their understanding of biological concepts (mean = 4.50; Std. Dev. = 0.87).

This finding aligns with the results of Putra (2018), who observed that students taught using an interactive multimedia instructional approach reported a positive shift in their attitudes, identifying the method as a promising pedagogical strategy. Interactive multimedia instructional approach has consistently proven effective in

increasing student engagement, especially in biology education. In recent years, it has been explored as a valuable approach for enhancing the motivation and involvement of pre service science teachers, particularly in biology class. For instance, Smith and Johnson (2017) found that students using interactive multimedia instructional approach participated more actively in class discussions and demonstrated higher levels of motivation. Similarly, Garrison and Kanuka (2004) concluded that multimedia approaches such as animations, simulations, and interactive quizzes significantly improved student understanding of complex biological concepts, thus enhancing motivation and engagement. Yang and Liu (2010) also reported that interactive multimedia instructional approach positively impacted pre service science teachers' motivation, engagement, and learning outcomes in biology. These studies strongly support the present findings. Additionally, interviews conducted with a focus group of ten selected pre-service science teachers further confirmed these observations, providing qualitative insights into how multimedia enriched their learning experiences.

Almost all the selected pre-service science teachers expressed satisfaction with the interactive multimedia instructional approach used to learn cell structure, cell division, and Mendelian genetics in biology class. This could be attributed to the substantial academic gains they made following the intervention. Reflections from their interview responses highlighted several key opportunities that arose from using interactive multimedia instructional approach in teaching and learning biology concepts. One notable opportunity was the enhanced visualisation and conceptualisation of the abstract nature of the concepts being taught. This occurred through the formulation of hypotheses, observation of processes, and conceptual understanding, followed by discussions aimed at developing causal explanations.

The multimedia approaches were intentionally selected to serve as medium that encouraged active participation in the learning process. Furthermore, the intervention activities facilitated private dialogues with the teacher and peer interactions among the pre-service science teachers, enabling them to share perspectives and, importantly, uncover misconceptions. The approach promoted active learning by making pre-service science teachers responsible for their learning and encouraging self-assessment of their performance, attitudes, and progress through the use of carefully designed multimedia content. Many of the pre-service science teachers also noted that the multimedia approaches provided a valuable alternative learning approach beyond the classroom.

Interview reflections revealed that participants held positive opinions about the instructional approach. They described the multimedia materials as clear, level appropriate, and logically sequenced for presenting the identified biology concepts. They also agreed that the intervention activities helped engage them more actively in the learning process, improved their performance, stimulated interest, and fostered positive attitudes toward biology lessons. Some of the interviewees indicated that they were initially afraid to express their views in writing, fearing they might give incorrect answers. However, the interactive multimedia instructional approach helped them to visualise the concepts under study and gradually overcome their fears. This finding aligns with the result of Akinbadewa and Sofowora (2020), who reported that members of the experimental group in their study initially felt anxious about expressing their views both orally and in writing, but the multimedia-based approach lessons helped them to overcome these fears. The pre-service science teachers in this study also acknowledged and appreciated the conducive learning environment fostered by the interactive multimedia instructional approach.

The majority of them expressed a strong desire for this method of teaching to be sustained throughout their time in college. They explicitly stated their support for this unique instructional strategy and hoped it would continue to be used in the teaching and learning of other science courses, even beyond the duration of this project. This suggests that interactive multimedia instructional approach-based lessons contribute to a positive and supportive learning environment for pre-service science teachers participated in this study in some selected biology concepts. This finding is consistent with the results of Kassa et al. (2024), who found that students engaged in multimedia task-based instruction believed that multimedia learning strategies created a positive and active learning environment.

In conclusion, the feedback from pre-service science teachers who participated in this study demonstrated that they had a positive perception of the interactive multimedia instructional approaches used in teaching the identified biology concepts. This result supports findings from previous studies (e.g., Kassa et al., 2024; Akinbadewa and Sofowora, 2020; Williams et al., 2013), which similarly reported that students across various educational levels, including university, held positive views about the use of interactive multimedia instructional approaches in classroom.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS, AND SUGGESTIONS FOR FURTHER STUDIES

5.0 Overview

This chapter concludes the thesis by providing a summary of the study, key findings, conclusions, recommendations, and suggestions for future research. Additionally, it highlights the study's contributions to the field of science, its educational implications, and its overall contribution to knowledge.

5.1 Summary of the Study

The study aimed to evaluate the impact of interactive multimedia instructional approaches (IMIA) on the performance, motivation, and engagement of pre-service science teachers at Wiawso College of Education in selected biology concepts, such as cell structure, cell division, and Mendelian genetics. The specific objectives of the study were to:

1. Identify the students' challenges faced by pre-service science teachers in learning cell structure, cell division and Mendelian genetics.
2. Assess the effect of interactive multimedia instructional approach on pre-service science teachers' performance in the learning of the following biology concepts: cell structure, cell division and Mendelian genetics.
3. Assess the pre-service science teachers' difficulties, attitudes, and benefits to integrate the use of interactive multimedia instructional approach in their future classrooms.
4. Find out the effect of interactive multimedia instructional approach on pre-service science teachers' motivation and engagement in biology instructions.

5. Evaluate pre-service science teachers' perception on the effect of interactive multimedia instructional approach in teaching and learning of biology concepts.

An action research design was employed for this study. The total sample size consisted of 76 second-year pre-service science teachers from the 2023/2024 academic year, enrolled in systems, genetics, and cell division courses (as part of the Environmental Biology and Biology Around Us curriculum). Among the 76 pre-service teachers, 55 (72.37%) were male and 21 (27.63%) were female. The participants' ages ranged from 21 to 30 years, with an average age of 24. In line with Ghana's 1992 constitution, these participants were considered adults, and their responses were considered to reflect those of mature pre-service science teachers.

A purposive sampling technique, part of the non-probability sampling procedure, was used to select these 76 pre-service science teachers from an intact or whole class. The group was chosen because all members of the class were taking biology as an elective course. The decision to focus on second-year pre-service science teachers was based on two key factors:

1. The concepts of systems, genetics, and cell division were central to the level 200 biology curriculum, which these pre-service science teachers were studying at the time.
2. Almost all the participants in the class faced difficulties in learning concepts such as cell structure, cell division, and Mendelian genetics, which were selected for this research.

The entire class was involved in the study to ensure it fit within the regular teaching schedule without disrupting the college's academic calendar. The study utilized three primary instruments: tests, questionnaires, and interviews. Additionally, supplementary data were collected through written documents, including daily

observation notes, document analysis, and audio recordings, to enrich the information gathered from the main instruments. The data were analyzed using both quantitative and qualitative methods, with the Statistical Package for the Social Sciences (SPSS) software, version 27.0 for Windows, employed for statistical analysis.

5.2 Summary of Findings

1. The majority of respondents agreed that they found it difficult to understand the different parts of a cell and their functions, with a mean of 4.75 and a standard deviation of 0.82. They also reported difficulty in visualizing the three-dimensional structure of a cell, with the same mean and standard deviation.
2. Respondents generally agreed that they struggled to differentiate between plant and animal cell structures, with a mean of 4.07 and a standard deviation of 1.04. They also found it challenging to memorize the functions of various cellular components, with a mean of 4.11 and a standard deviation of 1.15.
3. The research found that the majority of respondents agreed that understanding the stages of mitosis and meiosis was difficult, with a mean of 4.170 and a standard deviation of 1.27. They also struggled to differentiate between the processes of mitosis and meiosis, with a mean of 4.07 and a standard deviation of 0.98.
4. Most respondents found it difficult to understand Mendel's laws of inheritance, with a mean of 4.52 and a standard deviation of 0.91. They also reported confusion over the concept of dominant and recessive alleles, with a mean of 4.05 and a standard deviation of 1.36. Additionally, many had trouble solving genetic cross problems involving more than one character (Dihybrid Inheritance), with a mean of 4.31 and a standard deviation of 0.75.
5. The study revealed that pre-service science teachers' academic performance in the selected biology concepts improved significantly after being exposed to interactive

multimedia instructional approach interventions, with the average score increasing from 36.62 in the pre-test to 71.89 in the post-test.

6. Most respondents agreed that technical difficulties could hinder instruction, with a mean of 4.28 and a standard deviation of 0.990, although some variation in responses was observed among the pre-service science teachers.
7. The research found that identifying appropriate interactive multimedia instructional approaches that align with the curriculum was considered particularly challenging, with a higher mean of 4.41 and a standard deviation of 0.84, indicating a broad range of opinions.
8. Limited access to technology and multimedia approaches emerged as another common concern, with a mean of 4.21 and a standard deviation of 0.83, reflecting general agreement.
9. The study revealed that challenges such as lack of training, insufficient teacher confidence/competence, and limited professional development opportunities were noted, with a mean of 4.32 and a standard deviation of 0.79.
10. The research found that a significant number of pre-service science teachers viewed the integration of multimedia instructional approach as an additional time and effort requirement, with a mean of 3.88 and a standard deviation of 1.30, showing moderate variability in responses.
11. The pre-service science teachers exhibited a positive attitude towards the use of interactive multimedia instructional approaches in teaching and learning the selected biology concepts.
12. Most pre-service science teachers agreed that interactive multimedia instructional approaches are beneficial in various aspects of biology education, with a mean of 4.69 and a standard deviation of 0.92, suggesting that interactive multimedia

instructional approach aids in presenting abstract concepts in a more concrete and visual manner.

13. The interactive multimedia instructional approach motivated and engaged the majority of the pre-service science teachers during the intervention activities, contributing to improved academic performance.
14. The interactive multimedia instructional approach had a significant positive effect on pre-service science teachers' engagement and motivation, leading to increased academic performance in the post-test.
15. The pre-service science teachers had very positive perceptions of the interactive multimedia instructional approach (IMIA). They believed that all lecturers should use IMIA, as it was effective, appropriate, engaging, enjoyable, and helped make abstract concepts more visible and understandable through a simple and, logical sequence of presentation.

5.3 Key Findings

The following key findings were made according to the five research questions:

1. Majority of respondents agreed that they found it difficult to understand the different parts of a cell and their functions, with a mean of 4.75 and a standard deviation of 0.82. They also reported difficulty in visualizing the three-dimensional structure of a cell. The respondents generally agreed that they struggled to differentiate between plant and animal cell structures, with a mean of 4.07 and a standard deviation of 1.04. They also found it challenging to memorize the functions of various cellular components, with a mean of 4.11 and a standard deviation of 1.15. Majority of respondents agreed that understanding the stages of mitosis and meiosis was difficult, with a mean of 4.170 and a standard deviation of 1.27. They also struggled to differentiate between the processes of mitosis and

meiosis, with a mean of 4.07 and a standard deviation of 0.98. Most respondents found it difficult to understand Mendel's laws of inheritance, with a mean of 4.52 and a standard deviation of 0.91. They also reported confusion over the concept of dominant and recessive alleles, with a mean of 4.05 and a standard deviation of 1.36. Additionally, many had trouble solving genetic cross problems involving more than one character (Dihybrid Inheritance), with a mean of 4.31 and a standard deviation of 0.75.

2. The study revealed that pre-service science teachers' academic performance in the selected biology concepts improved significantly after being exposed to interactive multimedia instructional approach interventions, with the average score increasing from 36.62 in the pre-test to 71.89 in the post-test.
3. Most respondents agreed that technical difficulties could hinder instruction, with a mean of 4.28 and a standard deviation of 0.990, although some variation in responses was observed among the pre-service science teachers. Again, the research revealed that identifying appropriate interactive multimedia instructional approaches that align with the curriculum was considered particularly challenging, with a higher mean of 4.41 and a standard deviation of 0.84, indicating a broad range of opinions. Limited access to technology and multimedia approaches emerged as another common concern, with a mean of 4.21 and a standard deviation of 0.83, reflecting general agreement. The study revealed that challenges such as lack of training, insufficient teacher confidence/competence, and limited professional development opportunities were noted, with a mean of 4.32 and a standard deviation of 0.79. Also, the research found that a significant number of pre-service science teachers viewed the integration of multimedia instructional approach as an additional time and effort requirement, with a mean of 3.88 and a

standard deviation of 1.30, showing moderate variability in responses. Again, the study found that pre-service science teachers exhibited a positive attitude towards the use of interactive multimedia instructional approaches in teaching and learning the selected biology concepts and also, the study showed that most pre-service science teachers agreed that interactive multimedia instructional approaches are beneficial in various aspects of biology education, with a mean of 4.69 and a standard deviation of 0.92, suggesting that interactive multimedia instructional approach aids in presenting abstract concepts in a more concrete and visual manner.

4. The interactive multimedia instructional approach motivated and engaged the majority of the pre-service science teachers during the intervention activities, contributing to improved academic performance. Again, interactive multimedia instructional approach had a significant positive effect on pre-service science teachers' engagement and motivation, leading to increased academic performance in the post-test.
5. The pre-service science teachers had very positive perceptions of the interactive multimedia instructional approach (IMIA). They believed that all lecturers should use IMIA, as it was effective, appropriate, engaging, enjoyable, and helped make abstract concepts more visible and understandable through a simple and, logical sequence presentation.

5.4 Conclusions

The results of the study indicated that pre-service science teachers exposed to the Interactive Multimedia Instructional Approach performed better in their post-test scores compared to their pre-test scores. This improvement in the academic performance was attributed to their exposure to IMIA. The study suggests that pre-service science teachers retained the selected biology concepts more effectively after

being taught using this approach. The statistical analysis showed a significant difference between the mean scores of the pre-test and post-test, demonstrating the positive impact of the IMIA on their academic performance. Furthermore, the study highlighted several challenges or barriers faced by the pre-service science teachers in using interactive multimedia instructional approach in biology/science education. Most participants agreed that technical difficulties could impede the instructional process, with a mean of 4.28 and a standard deviation of 0.99. The study revealed that the absence of proper technical support and adequate resources in the classroom could prevent teachers from overcoming obstacles to integrating ICT effectively into teaching.

The pre-service science teachers also indicated that integrating interactive multimedia instructional approach into biology instruction helped develop a deeper understanding of the selected biology concepts. The study strongly supported this claim, with a mean score of 4.69 and a standard deviation of 0.92, demonstrating that interactive multimedia instructional approaches are beneficial in various aspects of biology education. Additionally, the study revealed that pre-service science teachers who were taught the selected biology concepts such as cell structure, cell division, and Mendelian genetics, using interactive multimedia instructional approach showed more positive perceptions and attitudes towards these concepts. The finding emphasized that using interactive multimedia instructional approach to teach biology not only enhanced their understanding but also sparked greater interest and improved their overall academic performance. Furthermore, it contributed to the development of a more positive attitude towards the selected biology concepts. The present study reveals that almost all pre-service science teachers faced difficulties in studying cell structure, cell division, and Mendelian genetics in biology, despite having previously studied these

concepts. This suggests that the pre-service science teachers who participated in the study found cell structure, cell division, and Mendelian genetics to be difficult concepts to grasp. Moreover, the research found that most respondents found it difficult to understand the stages of mitosis and meiosis with a mean of 4.07 and a standard deviation of 0.98. Again, the participants reported that it was difficult to grasp the significance of cell division in growth and reproduction, with a mean of 4.48 and a standard deviation of 0.98.

The pre-service science teachers reported again that they found it difficult to understand Mendel's laws of inheritance, with a mean score of 4.52 and a standard deviation of 0.91. They also expressed confusion regarding the concepts of dominant and recessive alleles, as reflected in a mean of 4.05 and a standard deviation of 1.36. Additionally, a majority of respondents indicated challenges in solving genetic cross problems involving more than one character (dihybrid inheritance), with a mean of 4.31 and a standard deviation of 0.75. The participants noted specific difficulties in grasping concepts such as Punnett squares, genetic diagrams, and calculating the probabilities of certain genotypes or phenotypes. The findings further showed that most pre-service science teachers strongly agreed that interactive multimedia instructional approach enhanced the teaching and learning of the biology concepts, with a mean of 4.69 and a standard deviation of 0.61. They also strongly agreed that these approaches improve student engagement and motivation with a mean of 4.63 and a standard deviation of 0.56, and thus corresponded with the significant improvement of post-test performance of the pre-service science teachers.

5.5 Recommendations

Based on the findings and conclusions drawn from this research, the following recommendations were proposed:

1. Biology lecturers in Wiawso Colleges of Education should adopt and implement the interactive multimedia instructional approach to enhance pre-service science teachers' conceptual understanding, boost their academic performance, and foster positive attitudes toward abstract biology concepts.
2. It is recommended that Wiawso College of Education Biology Lecturers design active learning approaches and activities based on Interactive Multimedia Instructional Approach and integrate them with their usual classroom activities wherever necessary.
3. Regular training workshop should be organised to train the teachers/ students by the College.
4. It is suggested that the biology lecturers in Wiawso College of Education should guide and counsel their pre-service science teachers to develop positive attitudes towards abstract and difficult biology concepts such as cell structure, cell division and Mendelian genetics.
5. As the pre-service science teachers have difficulty in teaching and learning of biology concepts, it is recommended that college of education biology lecturers should adopt and the use of innovative instructional strategies such the Interactive Multimedia Instructional Approach so as to help college of education pre-service science teachers to learn abstract biology concepts such as cell structure, cell division and Mendelian genetics at the college level better.

6. Again, stakeholders in Wiawso College of Education are therefore recommended to equip the biology education unit and other science laboratories with the requisite resources in the form of instructional materials and reagents, software and computers, projectors, models, etc. to help in the teaching and learning of abstract biology concepts understudied to pre-service science teachers through the use of interactive multimedia instructional approach interventional activities and thereby demystify abstract concepts in biology at the colleges.
7. It was proposed that the Ministry of Education in collaboration with the National Commission of Teacher Education and other mentoring universities should organized in-service training on the use of Interactive Multimedia Instructional Approach for college of education biology lecturers to sharpen their pedagogical content knowledge in teaching abstract biology concepts so that college of education lecturers can in turn teach these concepts better to their pre-service science teachers.
8. Again, it is recommended that Wiawso College of Education Biology Lecturers should understand their pre-service science teachers' learning difficulties in abstract concepts in biology such as cell structure, cell division and Mendelian genetics and design appropriate instructional approach such as Interactive Multimedia Instructional Approach for them with relevant activities.
9. Again, the researcher recommended that instructors at the Wiawso College of Education use more innovative teaching methods such as Interactive Multimedia Instructional Approach with activities to empower the students to learn by using videos, images, stimulations, animations etc in order to

motivate and engage them.

10. Given that biology is often taught in abstract terms in many schools and colleges, it is recommended that biology lecturers in Wiawso Colleges of Education be encouraged to incorporate real-life examples, analogies, and interactive multimedia instructional approach to enhance the teaching of abstract biology concepts and support better conceptual understanding among students.
11. Curriculum developers and biology course experts should adopt and implement the instructional manual based on the interactive multimedia instructional approach as a method for teaching and learning biology.

5.6 Suggestions for Further Studies

The educational implications of the findings from this research highlight the need for further investigation into the use of the Interactive Multimedia Instructional Approach (IMIA) as a means of enhancing pre-service science teachers' performance and attitudes toward learning abstract and complex biology concepts in colleges of education. Based on this, the following suggestions are made for future research:

1. This study should be replicated with level 200 pre-service science teachers in Colleges of Education located in other regions of Ghana, using a larger sample size and different research design. This will allow for broader generalization of the findings regarding the effectiveness of the Interactive Multimedia Instructional Approach in improving academic performance in biology.
2. It is also suggested that similar research be conducted using an equal number of male and female pre-service science teachers across various college environments to examine any differences in performance and attitudes between genders when taught biology concepts using the Interactive Multimedia Instructional Approach.

5.7 Educational Implications of the Study

This study set out to examine the impact of the Interactive Multimedia Instructional Approach (IMIA) on the academic performance of pre-service science teachers at Wiawso College of Education, focusing on selected biology topics such as cell structure, cell division, and Mendelian genetics. Based on the findings and analysis, it can be concluded that IMIA is an effective instructional strategy that can be integrated into college-level science classrooms and laboratories to enhance both performance and attitudes toward learning biology. The research provided clear evidence that IMIA is suitable for all educational levels, including colleges of education, as it was observed that the pre-service science teachers became more engaged, motivated, and better able to grasp abstract biological concepts in a structured and enjoyable manner. In contrast, traditional teaching methods currently used in biology classrooms appear to be inadequate in helping students achieve a deep and visualized understanding of the subject matter.

Therefore, this research has developed and provided a practical manual to guide pre-service science teachers in selecting, designing, and using interactive multimedia instructional approach, as well as implementing the Interactive Multimedia Instructional Approach (IMIA) effectively in biology classrooms and laboratory settings. With this guidance, biology educators are expected to gain the competence and confidence to manage their classes more efficiently using this strategy. The integration of IMIA also carries significant implications for curriculum developers and In-Service Training coordinators, as there is a clear need to make the necessary resources and support available for lecturers to adopt and sustain the use of this approach. Given that interactive multimedia instructional approaches are not yet widely used in basic schools

and colleges of education in Ghana, science educators, particularly biology lecturers, require both support and access to relevant teaching materials aligned with the syllabus.

Furthermore, the findings of this study confirm that the application of IMIA significantly benefits students by making complex biology concepts, such as cell theory and structure, cell division, and Mendelian genetics, more accessible and easier to understand. As such, it is recommended that future curriculum planning prioritize the incorporation of IMIA. By doing so, biology educators can foster greater student interest, enhance academic performance, and cultivate more positive attitudes towards the study of biology.

5.8 Contributions to Knowledge

1. This research contributes to the body of knowledge by identifying the learning challenges faced by pre-service science teachers in Wiawso College of Education, particularly in understanding complex concepts like cell structure, cell division, and Mendelian genetics within their level 200 biology curriculum.
2. The study highlights that the Interactive Multimedia Instructional Approach (IMIA) enhances pre-service science teachers' performance in biology when compared to traditional teaching methods, proving its effectiveness in fostering better academic outcomes.
3. Additionally, the research found that while pre-service science teachers acknowledged the benefits of using interactive multimedia instructional approach, there were mixed opinions regarding its technical challenges and limited accessibility, both for teachers and students in the classroom.
4. These findings are novel and provide valuable contributions to the literature on biology education, particularly regarding the perceptions and academic performance of pre-service science teachers. The insights derived from this study

can guide future policies and practices aimed at improving academic performance in Wiawso Colleges of Education in Ghana.

5. A manual to guide pre-service science teachers on how to use Interactive Multimedia Instructional Approach have been produced and again, added to literature for academic use (Appendix I).

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APPENDIX A

WIAWSO COLLEGE OF EDUCATION

The students' difficulties in learning cell structure, cell division and Mendelian genetics

Instruction: -Dear Respondent, your responses provided in this questionnaire are specifically intended for academic purpose only. Kindly indicate your honest response to each item in the spaces provided. Your responses will be kept confidential. Thanks

The following statements are on the students' difficulties in learning cell structure, cell division and Mendelian genetics. Please tick the appropriate response as to extent to your agreement. Note that one (1) represents the strongest disagreement to the statements/items while five (5) represents the strongest agreement to the statements/items.

Statements/Items	1	2	3	4	5
Difficulties in Learning Cell Structure					
1. I find it difficult to understand the different parts of a cell and their functions.					
2. Visualizing the three-dimensional structure of a cell is challenging for me.					
3. I struggle to differentiate between plant and animal cell structures.					
4. I find it difficult to memorize the functions of various cellular components and terms associated with it.					
Difficulties in Learning Cell Division					
5. I find it difficult to understand the stages of mitosis and meiosis.					
6. I struggle to differentiate between the processes of mitosis and meiosis.					
7. The concept of chromosome separation during cell division is difficult for me.					
8. I have trouble remembering the sequence of events in the cell cycle.					
9. Understanding the significance of cell division in growth and reproduction is challenging for me.					
Difficulties in Learning Mendelian Genetics					

10. I find it difficult to understand Mendel's laws of inheritance.					
11. The concept of dominant and recessive alleles confuses me.					
12. I have trouble solving genetic cross problems (Dihybrid Inheritance) using Punnett square.					

APPENDIX B

WIAWSO COLLEGE OF EDUCATION

QUESTIONNAIRE FOR PRE-SERVICE SCIENCE TEACHERS

Dear Students,

I am conducting research on “**pre-service science teachers’ difficulties to use interactive multimedia instructional approach in classrooms in the teaching and learning of biology concepts**”. The researcher is into science education and this questionnaire form part of a research to help improve the teaching and learning of biology through the use of interactive multimedia instructional approach. It is hoped that the results of this research would be beneficial to biology students and teachers. Please, be assured that your opinions will be kept strictly confidential because this is entirely an academic exercise.

Students’ code.....

Section A: Respondents Bio-Data

1. Sex

Male []

Female []

2. Age

10-14years []

15-20years []

21-25years []

26-30years []

31+ years []

Section B:

Instruction: please tick in the appropriate box by indicating your extent of agreement or otherwise to the following on teaching with concept interactive multimedia instructional approach.

**1= strongly agree (SA) 2= agree(A) 3= undecided (UD) 4= disagree(D)
5=strongly disagree (SD)**

S/N	Attitudes towards the use of multimedia instructional approaches in classroom instruction	1	2	3	4	5
1	Using interactive multimedia instructional approach in science classrooms improves teaching and learning.					
2	I believe interactive multimedia instructional approaches are helpful in enhancing student engagement in science lessons.					
3	Interactive multimedia instructional approach provides opportunities for more interactive and hands-on learning experiences.					
4	Integrating interactive multimedia instructional approach in science instruction can help students develop a deeper understanding of concepts.					
5	Interactive multimedia instructional approach instructional enable me to explain complex scientific phenomena more effectively.					
	Perceived benefits of using multimedia approaches in science instruction					
6	Using interactive multimedia instructional approach in science classrooms helps in presenting abstract concepts in a concrete and visual manner.					
7	Interactive multimedia instructional approach improves students' engagement and motivation in science lessons.					

8	Interactive multimedia instructional approach assists in accommodating different learning styles and abilities.					
9	Using interactive multimedia instructional approach facilitates the exploration of real-life scientific situations.					
10	Interactive multimedia instructional approach enables me to create a dynamic and interactive learning environment.					
	Perceived difficulties in using interactive multimedia instructional approach in science education					
11	Technical difficulties in using interactive multimedia instructional approach can hinder instruction.					
12	Finding appropriate interactive multimedia instructional approach that align with the curriculum can be difficult.					
13	Limited access to technology and interactive multimedia instructional approaches resources can restrict the use of these tools.					
14	Lack of training and professional development opportunities for teachers in using interactive multimedia instructional approach in science instruction.					
15	Integrating interactive multimedia instructional approach effectively requires additional time and effort in lesson planning.					

APPENDIX C1

WIAWSO COLLEGE OF EDUCATION

PRE-TEST DATA COLLECTING INSTRUMENT - TEST 1

Name:

Gender: **Class:**

Name of school:

General Instructions: This test contains ninety-one (91) multiple-choice objective questions grouped in three (3) sections, namely Sections A (Cell structure), B (Cell division) and C (Mendelian genetics) and each section is made up of 30 multiple-choice questions. Please answer ALL the questions in ALL three (3) sections of the test.

Section A - Cell Structure

Multiple Choice Questions

Instructions: The following questions are followed by four (4) options lettered A to D. Find out the correct option and circle A, B, C or D to indicate your answer.

1. What is the basic unit of structure in all living organisms?
 - a) organ
 - b) tissue
 - c) cell
 - d) molecule
2. What is the outermost layer of a cell called?
 - a) cytoplasm
 - b) cell membrane
 - c) nucleus
 - d) mitochondria
3. What is the function of the cell membrane?
 - a) to protect the cell from its surroundings
 - b) to control the movement of substances into and out of the cell
 - c) to store genetic material
 - d) to produce energy for the cell

4. What is the term for the jelly-like substance that fills the cell?
 - a) cytoplasm
 - b) chloroplast
 - c) mitochondria
 - d) nucleus
5. Which organelle is responsible for producing energy for the cell?
 - a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus
6. Which organelle is responsible for protein synthesis?
 - a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus
7. Where is DNA located in a eukaryotic cell?
 - a) in the mitochondria
 - b) in the ribosome
 - c) in the cytoplasm
 - d) in the nucleus
8. Which organelle is responsible for packaging and distributing proteins within the cell?
 - a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus
9. Which organelle is responsible for breaking down and recycling cellular waste?
 - a) ribosome
 - b) mitochondria
 - c) lysosome
 - d) Golgi apparatus
10. Which of the following is NOT a type of cell?
 - a) eukaryotic
 - b) prokaryotic

- c) multicellular
 - d) unicellular
11. What is the main difference between prokaryotic and eukaryotic cells?
- a) eukaryotic cells have a nucleus, while prokaryotic cells do not
 - b) prokaryotic cells are larger than eukaryotic cells
 - c) eukaryotic cells are multicellular, while prokaryotic cells are unicellular
 - d) prokaryotic cells have mitochondria, while eukaryotic cells do not
12. What is the name of the structure within the nucleus that contains the cell's genetic material?
- a) chromatin
 - b) nucleolus
 - c) endoplasmic reticulum
 - d) Golgi apparatus
13. Which organelle is responsible for creating carbohydrates and lipids for the cell?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus
14. Which organelle is responsible for breaking down fatty acids and producing hydrogen peroxide?
- a) ribosome
 - b) mitochondria
 - c) peroxisome
 - d) Golgi apparatus
15. What is the name of the region in a prokaryotic cell where DNA is located?
- a) nucleus
 - b) mitochondria
 - c) cytoplasm
 - d) ribosome
16. Which organelle is responsible for detoxifying harmful substances within the cell?
- a) lysosome
 - b) peroxisome
 - c) Golgi apparatus

- d) mitochondria
17. Which organelle is responsible for maintaining cell shape and providing support?
- a) cell membrane
 - b) ribosome
 - c) cytoskeleton
 - d) Golgi apparatus
18. Which of the following is NOT a component of the cytoskeleton?
- a) microtubules
 - b) microfilaments
 - c) intermediate filaments
 - d) ribosomes
19. What is the name of the interconnected network of flattened sacs and tubules within the cell?
- a) endoplasmic reticulum
 - b) Golgi apparatus
 - c) lysosome
 - d) peroxisome
20. Which type of endoplasmic reticulum is responsible for protein synthesis?
- a) rough endoplasmic reticulum
 - b) smooth endoplasmic reticulum
 - c) both
 - d) neither
21. Which organelle is responsible for storing and transporting materials within the cell?
- a) ribosome
 - b) Golgi apparatus
 - c) endoplasmic reticulum
 - d) mitochondria
22. Which organelle is responsible for digestion and breaking down of cellular waste?
- a) ribosome
 - b) lysosome
 - c) mitochondria
 - d) Golgi apparatus

23. What is the term for the process by which a cell engulfs material from its surroundings?
- a) endocytosis
 - b) exocytosis
 - c) osmosis
 - d) diffusion
24. What is the term for the process by which a cell expels material to its surroundings?
- a) endocytosis
 - b) exocytosis
 - c) osmosis
 - d) diffusion
25. Which of the following is a type of passive transport?
- a) facilitated diffusion
 - b) active transport
 - c) endocytosis
 - d) exocytosis
26. What is the term for the movement of water across a semipermeable membrane?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) exocytosis
27. What is the term for the movement of substances from an area of high concentration to an area of low concentration?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion
28. What is the term for the movement of substances across a cell membrane that requires the input of energy?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion

29. Which type of transport is responsible for the movement of substances from an area of low concentration to an area of high concentration?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion
30. Which of the following is NOT a type of membrane protein?
- a) receptor protein
 - b) transport protein
 - c) enzyme protein
 - d) ribosomal protein
31. Which of the following is NOT a characteristic of a eukaryotic cell?
- a) Nucleus
 - b) Cell membrane
 - c) Cell wall
 - d) Ribosomes

Section B – Cell Division

32. What is the process by which a cell divides into two daughter cells?
- a) replication
 - b) translation
 - c) mitosis
 - d) meiosis
33. Which type of cell division produces two genetically identical daughter cells?
- a) mitosis
 - b) meiosis
 - c) cytokinesis
 - d) replication
34. Which of the following is not a stage of mitosis?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase

35. During which stage of mitosis do the chromosomes condense and become visible?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase
36. During which stage of mitosis do the chromosomes align on the equator of the cell?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase
37. During which stage of mitosis do the sister chromatids separate and move towards opposite poles of the cell?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase
38. During which stage of mitosis do the nuclear envelopes reform and the chromosomes decondense?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase
39. What is the process by which cells divide their cytoplasm and organelles to produce two daughter cells?
- a) mitosis
 - b) meiosis
 - c) cytokinesis
 - d) replication
40. In animal cells, which structure forms the contractile ring responsible for cytokinesis?
- a) microfilaments
 - b) microtubules
 - c) intermediate filaments

- d) centrosomes
41. In plant cells, which structure forms the cell plate responsible for cytokinesis?
- a) microfilaments
 - b) microtubules
 - c) intermediate filaments
 - d) Golgi apparatus
42. Which type of cell division produces four genetically different daughter cells?
- a) mitosis
 - b) meiosis
 - c) cytokinesis
 - d) replication
43. In which stage of meiosis does crossing-over occur?
- a) prophase I
 - b) metaphase I
 - c) anaphase I
 - d) telophase I
44. What is the term for the structure that holds two homologous chromosomes together during prophase I of meiosis?
- a) sister chromatids
 - b) centromere
 - c) spindle fiber
 - d) synaptonemal complex
45. During which stage of meiosis do the homologous chromosomes separate and move towards opposite poles of the cell?
- a) prophase I
 - b) metaphase I
 - c) anaphase I
 - d) telophase I
46. During which stage of meiosis do the sister chromatids separate and move towards opposite poles of the cell?
- a) prophase I
 - b) metaphase I
 - c) anaphase I
 - d) anaphase II

47. What is the process by which gametes are formed?
- a) mitosis
 - b) meiosis
 - c) cytokinesis
 - d) replication
48. Which type of cell undergoes meiosis to produce gametes?
- a) somatic cells
 - b) germ cells
 - c) stem cells
 - d) all cells undergo meiosis
49. What is the term for a diploid cell that undergoes meiosis to produce haploid cells?
- a) gamete
 - b) zygote
 - c) progenitor cell
 - d) none of the above
50. In humans, which type of cell undergoes meiosis to produce sperm?
- a) spermatogonia
 - b) spermatocytes
 - c) spermatids
 - d) spermatozoa
51. In humans, which type of cell undergoes meiosis to produce eggs?
- a) oogonia
 - b) oocytes
 - c) follicles
 - d) corpus luteum
52. What is the term for the failure of chromosomes to properly separate during cell division?
- a) nondisjunction
 - b) crossing-over
 - c) translocation
 - d) inversion
53. Which genetic disorder is caused by trisomy of chromosome 21?
- a) Down syndrome
 - b) Turner syndrome

- c) Klinefelter syndrome
 - d) Huntington's disease
54. Which genetic disorder is caused by the absence of an X chromosome?
- a) Down syndrome
 - b) Turner syndrome
 - c) Klinefelter syndrome
 - d) Huntington's disease
55. Which genetic disorder is caused by the presence of an extra X chromosome in males?
- a) Down syndrome
 - b) Turner syndrome
 - c) Klinefelter syndrome
 - d) Huntington's disease
56. What is the term for the programmed death of cells?
- a) apoptosis
 - b) necrosis
 - c) mitosis
 - d) cytokinesis
57. Which of the following is not a function of cell division?
- a) growth
 - b) repair
 - c) reproduction
 - d) energy production
58. Which type of cancer results from the uncontrolled growth of cells in the blood-forming tissues?
- a) leukemia
 - b) lymphoma
 - c) sarcoma
 - d) carcinoma
59. Which type of cancer results from the uncontrolled growth of cells in the lymphatic system?
- a) leukemia
 - b) lymphoma
 - c) sarcoma

- d) carcinoma
60. Which type of cancer results from the uncontrolled growth of cells in connective tissues?
- a) leukemia
 - b) lymphoma
 - c) sarcoma
 - d) carcinoma
61. Which type of cancer results from the uncontrolled growth of cells in epithelial tissues?
- a) leukemia
 - b) lymphoma
 - c) sarcoma
 - d) carcinoma

Section C - Mendelian Genetics

62. Who is known as the “father of genetics”?
- a) Charles Darwin
 - b) Gregor Mendel
 - c) James Watson
 - d) Francis Crick
63. Which of the following is NOT one of Mendel's laws of inheritance?
- a) Law of Dominance
 - b) Law of Segregation
 - c) Law of Independent Assortment
 - d) Law of Completeness
64. What is the term for an alternative version of a gene?
- a) genotype
 - b) phenotype
 - c) allele
 - d) chromosome
65. What is the term for the physical appearance of an organism?
- a) genotype
 - b) phenotype
 - c) allele

- d) chromosome
66. What is the term for an organism that has two identical alleles for a gene?
- a) homozygous
 - b) heterozygous
 - c) incomplete dominance
 - d) codominance
67. What is the term for an organism that has two different alleles for a gene?
- a) homozygous
 - b) heterozygous
 - c) incomplete dominance
 - d) codominance
68. What is the term for the physical expression of an allele in an organism's phenotype?
- a) dominant
 - b) recessive
 - c) incomplete dominance
 - d) codominance
69. What is the term for an inheritance pattern in which the heterozygous phenotype is distinct from the homozygous dominant phenotype?
- a) dominant inheritance
 - b) recessive inheritance
 - c) incomplete dominance
 - d) codominance
70. What is the term for an inheritance pattern in which both alleles are expressed equally in the phenotype?
- a) dominant inheritance
 - b) recessive inheritance
 - c) incomplete dominance
 - d) codominance
71. What is the term for a cross between two individuals with different genotypes for a single gene?
- a) monohybrid cross
 - b) dihybrid cross
 - c) trihybrid cross

- d) polygenic cross
72. What is the term for a cross between two individuals with different genotypes for two genes?
- a) monohybrid cross
 - b) dihybrid cross
 - c) trihybrid cross
 - d) polygenic cross
73. What is the term for a gene that masks the expression of another gene in the phenotype?
- a) recessive
 - b) dominant
 - c) codominant
 - d) incomplete dominant
74. What is the term for a gene that is only expressed when there are two copies of it present in the genotype?
- a) recessive
 - b) dominant
 - c) codominant
 - d) incomplete dominant
75. What does the Punnett square represent in genetics?
- a) the probability of offspring genotypes resulting from a particular cross
 - b) the probability of offspring phenotypes resulting from a particular cross
 - c) the actual genotypes of offspring resulting from a particular cross
 - d) the actual phenotypes of offspring resulting from a particular cross
76. Which of the following represents a homozygous dominant genotype?
- a) AA
 - b) Aa
 - c) aa
 - d) AB
77. Which of the following represents a homozygous recessive genotype?
- a) AA
 - b) Aa
 - c) aa
 - d) AB

78. Which of the following represents a heterozygous genotype?
- a) AA
 - b) Aa
 - c) aa
 - d) AB
79. What is the term for a trait that is controlled by multiple genes?
- a) polygenic trait
 - b) monogenic trait
 - c) dominant trait
 - d) recessive trait
80. In humans, which chromosome determines the sex of the individual?
- a) X chromosome
 - b) Y chromosome
 - c) Autosome
 - d) Mitochondrial chromosome
81. What is the term for a trait that is only expressed in one sex?
- a) sex-limited trait
 - b) sex-influenced trait
 - c) autosomal trait
 - d) sex-linked trait
82. What is the term for a trait that is influenced by the presence of male or female sex hormones?
- a) sex-limited trait
 - b) sex-influenced trait
 - c) autosomal trait
 - d) sex-linked trait
83. What is the term for a trait that is located on the X or Y chromosome?
- a) sex-limited trait
 - b) sex-influenced trait
 - c) autosomal trait
 - d) sex-linked trait
84. What is the term for the pattern of inheritance in which a gene on the X chromosome is passed from a mother to her son?
- a) sex-limited inheritance

- b) sex-influenced inheritance
 - c) autosomal inheritance
 - d) X-linked inheritance
85. What is the term for the pattern of inheritance in which a gene on the X chromosome is passed from a mother to her daughter?
- a) sex-limited inheritance
 - b) sex-influenced inheritance
 - c) autosomal inheritance
 - d) X-linked inheritance
86. What is the term for the pattern of inheritance in which a gene on an autosome (non-sex chromosome) is passed from parent to offspring?
- a) sex-limited inheritance
 - b) sex-influenced inheritance
 - c) autosomal inheritance
 - d) X-linked inheritance
87. In human blood type, which allele is dominant: A, B, or O?
- a) A
 - b) B
 - c) O
 - d) both A and B are dominant
88. What is the possible blood type of a person who is heterozygous for the A and B blood type alleles?
- a) A
 - b) B
 - c) AB
 - d) O
89. Which blood type is considered universal donor?
- a) A
 - b) B
 - c) AB
 - d) O
90. Which blood type is considered universal recipient?
- a) A
 - b) B

c) AB

d) O

91. Which of the following is NOT a possible genotype for an individual with AB blood type?

a) IA IB

b) IA i

c) IB i

d) ii

APPENDIX C2
WIAWSO COLLEGE OF EDUCATION
PRE-TEST DATA COLLECTING INSTRUMENT - TEST 1
MARKING SCHEME

Section A - Cell Structure

Multiple Choice Questions

Instructions: The following questions are followed by four (4) options lettered A to D. Find out the correct option and circle A, B, C or D to indicate your answer.

1. What is the basic unit of structure in all living organisms?
 - a) organ
 - b) tissue
 - c) cell
 - d) molecule

Answer: C

2. What is the outermost layer of a cell called?
 - a) cytoplasm
 - b) cell membrane
 - c) nucleus
 - d) mitochondria

Answer: B

3. What is the function of the cell membrane?
 - a) to protect the cell from its surroundings
 - b) to control the movement of substances into and out of the cell
 - c) to store genetic material
 - d) to produce energy for the cell

Answer: B

4. What is the term for the jelly-like substance that fills the cell?
 - a) cytoplasm
 - b) chloroplast
 - c) mitochondria
 - d) nucleus

Answer: A

5. Which organelle is responsible for producing energy for the cell?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: B

6. Which organelle is responsible for protein synthesis?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: A

7. Where is DNA located in a eukaryotic cell?
- a) in the mitochondria
 - b) in the ribosome
 - c) in the cytoplasm
 - d) in the nucleus

Answer: D

8. Which organelle is responsible for packaging and distributing proteins within the cell?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: D

9. Which organelle is responsible for breaking down and recycling cellular waste?
- a) ribosome
 - b) mitochondria
 - c) lysosome
 - d) Golgi apparatus

Answer: C

10. Which of the following is NOT a type of cell?

- a) eukaryotic
- b) prokaryotic
- c) multicellular
- d) unicellular

Answer: C

11. What is the main difference between prokaryotic and eukaryotic cells?
- a) eukaryotic cells have a nucleus, while prokaryotic cells do not
 - b) prokaryotic cells are larger than eukaryotic cells
 - c) eukaryotic cells are multicellular, while prokaryotic cells are unicellular
 - d) prokaryotic cells have mitochondria, while eukaryotic cells do not

Answer: A

12. What is the name of the structure within the nucleus that contains the cell's genetic material?
- a) chromatin
 - b) nucleolus
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: A

13. Which organelle is responsible for creating carbohydrates and lipids for the cell?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: C

14. Which organelle is responsible for breaking down fatty acids and producing hydrogen peroxide?
- a) ribosome
 - b) mitochondria
 - c) peroxisome
 - d) Golgi apparatus

Answer: C

15. What is the name of the region in a prokaryotic cell where DNA is located?
- a) nucleus
 - b) mitochondria

- c) cytoplasm
- d) ribosome

Answer: C

16. Which organelle is responsible for detoxifying harmful substances within the cell?
- a) lysosome
 - b) peroxisome
 - c) Golgi apparatus
 - d) mitochondria

Answer: B

17. Which organelle is responsible for maintaining cell shape and providing support?
- a) cell membrane
 - b) ribosome
 - c) cytoskeleton
 - d) Golgi apparatus

Answer: C

18. Which of the following is NOT a component of the cytoskeleton?
- a) microtubules
 - b) microfilaments
 - c) intermediate filaments
 - d) ribosomes

Answer: D

19. What is the name of the interconnected network of flattened sacs and tubules within the cell?
- a) endoplasmic reticulum
 - b) Golgi apparatus
 - c) lysosome
 - d) peroxisome

Answer: A

20. Which type of endoplasmic reticulum is responsible for protein synthesis?
- a) rough endoplasmic reticulum
 - b) smooth endoplasmic reticulum
 - c) both
 - d) neither

Answer: A

21. Which organelle is responsible for storing and transporting materials within the cell?
- a) ribosome
 - b) Golgi apparatus
 - c) endoplasmic reticulum
 - d) mitochondria

Answer: B

22. Which organelle is responsible for digestion and breaking down of cellular waste?
- a) ribosome
 - b) lysosome
 - c) mitochondria
 - d) Golgi apparatus

Answer: B

23. What is the term for the process by which a cell engulfs material from its surroundings?
- a) endocytosis
 - b) exocytosis
 - c) osmosis
 - d) diffusion

Answer: A

24. What is the term for the process by which a cell expels material to its surroundings?
- a) endocytosis
 - b) exocytosis
 - c) osmosis
 - d) diffusion

Answer: B

25. Which of the following is a type of passive transport?
- a) facilitated diffusion
 - b) active transport
 - c) endocytosis
 - d) exocytosis

Answer: A

26. What is the term for the movement of water across a semipermeable membrane?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) exocytosis

Answer: B

27. What is the term for the movement of substances from an area of high concentration to an area of low concentration?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion

Answer: D

28. What is the term for the movement of substances across a cell membrane that requires the input of energy?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion

Answer: C

29. Which type of transport is responsible for the movement of substances from an area of low concentration to an area of high concentration?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion

Answer: C

30. Which of the following is NOT a type of membrane protein?
- a) receptor protein
 - b) transport protein
 - c) enzyme protein
 - d) ribosomal protein

Answer: D

31. Which of the following is NOT a characteristic of a eukaryotic cell?

- a) Nucleus
- b) Cell membrane
- c) Cell wall
- d) Ribosomes

Answer: C

Section B – Cell Division

32. What is the process by which a cell divides into two daughter cells?

- a) replication
- b) translation
- c) mitosis
- d) meiosis

Answer: C

33. Which type of cell division produces two genetically identical daughter cells?

- a) mitosis
- b) meiosis
- c) cytokinesis
- d) replication

Answer: A

34. Which of the following is not a stage of mitosis?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: D

35. During which stage of mitosis do the chromosomes condense and become visible?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: A

36. During which stage of mitosis do the chromosomes align on the equator of the cell?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: B

37. During which stage of mitosis do the sister chromatids separate and move towards opposite poles of the cell?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: C

38. During which stage of mitosis do the nuclear envelopes reform and the chromosomes decondense?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: D

39. What is the process by which cells divide their cytoplasm and organelles to produce two daughter cells?

- a) mitosis
- b) meiosis
- c) cytokinesis
- d) replication

Answer: C

40. In animal cells, which structure forms the contractile ring responsible for cytokinesis?

- a) microfilaments
- b) microtubules
- c) intermediate filaments
- d) centrosomes

Answer: A

41. In plant cells, which structure forms the cell plate responsible for cytokinesis?

- a) microfilaments
- b) microtubules
- c) intermediate filaments
- d) Golgi apparatus

Answer: D

42. Which type of cell division produces four genetically different daughter cells?

- a) mitosis
- b) meiosis
- c) cytokinesis
- d) replication

Answer: B

43. In which stage of meiosis does crossing-over occur?

- a) prophase I
- b) metaphase I
- c) anaphase I
- d) telophase I

Answer: A

44. What is the term for the structure that holds two homologous chromosomes together during prophase I of meiosis?

- a) sister chromatids
- b) centromere
- c) spindle fiber
- d) synaptonemal complex

Answer: D

45. During which stage of meiosis do the homologous chromosomes separate and move towards opposite poles of the cell?

- a) prophase I
- b) metaphase I
- c) anaphase I
- d) telophase I

Answer: C

46. During which stage of meiosis do the sister chromatids separate and move towards opposite poles of the cell?

- a) prophase I
- b) metaphase I
- c) anaphase I
- d) anaphase II

Answer: D

47. What is the process by which gametes are formed?

- a) mitosis
- b) meiosis
- c) cytokinesis
- d) replication

Answer: B

48. Which type of cell undergoes meiosis to produce gametes?

- a) somatic cells
- b) germ cells
- c) stem cells
- d) all cells undergo meiosis

Answer: B

49. What is the term for a diploid cell that undergoes meiosis to produce haploid cells?

- a) gamete
- b) zygote
- c) progenitor cell
- d) none of the above

Answer: C

50. In humans, which type of cell undergoes meiosis to produce sperm?

- a) spermatogonia
- b) spermatocytes
- c) spermatids
- d) spermatozoa

Answer: B

51. In humans, which type of cell undergoes meiosis to produce eggs?

- a) oogonia
- b) oocytes
- c) follicles
- d) corpus luteum

Answer: B

52. What is the term for the failure of chromosomes to properly separate during cell division?

- a) nondisjunction
- b) crossing-over
- c) translocation
- d) inversion

Answer: A

53. Which genetic disorder is caused by trisomy of chromosome 21?

- a) Down syndrome
- b) Turner syndrome
- c) Klinefelter syndrome
- d) Huntington's disease

Answer: A

54. Which genetic disorder is caused by the absence of an X chromosome?

- a) Down syndrome
- b) Turner syndrome
- c) Klinefelter syndrome
- d) Huntington's disease

Answer: B

55. Which genetic disorder is caused by the presence of an extra X chromosome in males?

- a) Down syndrome
- b) Turner syndrome
- c) Klinefelter syndrome
- d) Huntington's disease

Answer: C

56. What is the term for the programmed death of cells?

- a) apoptosis

- b) necrosis
- c) mitosis
- d) cytokinesis

Answer: A

57. Which of the following is not a function of cell division?

- a) growth
- b) repair
- c) reproduction
- d) energy production

Answer: D

58. Which type of cancer results from the uncontrolled growth of cells in the blood-forming tissues?

- a) leukemia
- b) lymphoma
- c) sarcoma
- d) carcinoma

Answer: A

59. Which type of cancer results from the uncontrolled growth of cells in the lymphatic system?

- a) leukemia
- b) lymphoma
- c) sarcoma
- d) carcinoma

Answer: B

60. Which type of cancer results from the uncontrolled growth of cells in connective tissues?

- a) leukemia
- b) lymphoma
- c) sarcoma
- d) carcinoma

Answer: C

61. Which type of cancer results from the uncontrolled growth of cells in epithelial tissues?

- a) leukemia

- b) lymphoma
- c) sarcoma
- d) carcinoma

Answer: D

Section C - Mendelian Genetics

62. Who is known as the “father of genetics”?

- a) Charles Darwin
- b) Gregor Mendel
- c) James Watson
- d) Francis Crick

Answer: B

63. Which of the following is NOT one of Mendel's laws of inheritance?

- a) Law of Dominance
- b) Law of Segregation
- c) Law of Independent Assortment
- d) Law of Completeness

Answer: D

64. What is the term for an alternative version of a gene?

- a) genotype
- b) phenotype
- c) allele
- d) chromosome

Answer: C

65. What is the term for the physical appearance of an organism?

- a) genotype
- b) phenotype
- c) allele
- d) chromosome

Answer: B

66. What is the term for an organism that has two identical alleles for a gene?

- a) homozygous
- b) heterozygous
- c) incomplete dominance

d) codominance

Answer: A

67. What is the term for an organism that has two different alleles for a gene?

- a) homozygous
- b) heterozygous
- c) incomplete dominance
- d) codominance

Answer: B

68. What is the term for the physical expression of an allele in an organism's phenotype?

- a) dominant
- b) recessive
- c) incomplete dominance
- d) codominance

Answer: A

69. What is the term for an inheritance pattern in which the heterozygous phenotype is distinct from the homozygous dominant phenotype?

- a) dominant inheritance
- b) recessive inheritance
- c) incomplete dominance
- d) codominance

Answer: C

70. What is the term for an inheritance pattern in which both alleles are expressed equally in the phenotype?

- a) dominant inheritance
- b) recessive inheritance
- c) incomplete dominance
- d) codominance

Answer: D

71. What is the term for a cross between two individuals with different genotypes for a single gene?

- a) monohybrid cross
- b) dihybrid cross
- c) trihybrid cross
- d) polygenic cross

Answer: A

72. What is the term for a cross between two individuals with different genotypes for two genes?

- a) monohybrid cross
- b) dihybrid cross
- c) trihybrid cross
- d) polygenic cross

Answer: B

73. What is the term for a gene that masks the expression of another gene in the phenotype?

- a) recessive
- b) dominant
- c) codominant
- d) incomplete dominant

Answer: B

74. What is the term for a gene that is only expressed when there are two copies of it present in the genotype?

- a) recessive
- b) dominant
- c) codominant
- d) incomplete dominant

Answer: A

75. What does the Punnett square represent in genetics?

- a) the probability of offspring genotypes resulting from a particular cross
- b) the probability of offspring phenotypes resulting from a particular cross
- c) the actual genotypes of offspring resulting from a particular cross
- d) the actual phenotypes of offspring resulting from a particular cross

Answer: A

76. Which of the following represents a homozygous dominant genotype?

- a) AA
- b) Aa
- c) aa
- d) AB

Answer: A

77. Which of the following represents a homozygous recessive genotype?

- a) AA
- b) Aa
- c) aa
- d) AB

Answer: C

78. Which of the following represents a heterozygous genotype?

- a) AA
- b) Aa
- c) aa
- d) AB

Answer: B

79. What is the term for a trait that is controlled by multiple genes?

- a) polygenic trait
- b) monogenic trait
- c) dominant trait
- d) recessive trait

Answer: A

80. In humans, which chromosome determines the sex of the individual?

- a) X chromosome
- b) Y chromosome
- c) Autosome
- d) Mitochondrial chromosome

Answer: B

81. What is the term for a trait that is only expressed in one sex?

- a) sex-limited trait
- b) sex-influenced trait
- c) autosomal trait
- d) sex-linked trait

Answer: A

82. What is the term for a trait that is influenced by the presence of male or female sex hormones?

- a) sex-limited trait
- b) sex-influenced trait

- c) autosomal trait
- d) sex-linked trait

Answer: B

83. What is the term for a trait that is located on the X or Y chromosome?

- a) sex-limited trait
- b) sex-influenced trait
- c) autosomal trait
- d) sex-linked trait

Answer: D

84. What is the term for the pattern of inheritance in which a gene on the X chromosome is passed from a mother to her son?

- a) sex-limited inheritance
- b) sex-influenced inheritance
- c) autosomal inheritance
- d) X-linked inheritance

Answer: D

85. What is the term for the pattern of inheritance in which a gene on the X chromosome is passed from a mother to her daughter?

- a) sex-limited inheritance
- b) sex-influenced inheritance
- c) autosomal inheritance
- d) X-linked inheritance

Answer: D

86. What is the term for the pattern of inheritance in which a gene on an autosome (non-sex chromosome) is passed from parent to offspring?

- a) sex-limited inheritance
- b) sex-influenced inheritance
- c) autosomal inheritance
- d) X-linked inheritance

Answer: C

87. In human blood type, which allele is dominant: A, B, or O?

- a) A
- b) B
- c) O

d) both A and B are dominant

Answer: D

88. What is the possible blood type of a person who is heterozygous for the A and B blood type alleles?

- a) A
- b) B
- c) AB
- d) O

Answer: C

89. Which blood type is considered universal donor?

- a) A
- b) B
- c) AB
- d) O

Answer: D

90. Which blood type is considered universal recipient?

- a) A
- b) B
- c) AB
- d) O

Answer: C

91. Which of the following is NOT a possible genotype for an individual with AB blood type?

- a) $I^A I^B$
- b) $I^A i$
- c) $I^B i$
- d) ii

Answer: D

APPENDIX D1

WIAWSO COLLEGE OF EDUCATION

POST-TEST DATA COLLECTING INSTRUMENT - TEST 2

PSST'S Code:

Gender: **Class:**

Name of school:

General Instructions: This test contains ninety-one (91) multiple-choice questions and eight essay type questions grouped in three (3) sections, namely Sections A (Cell structure), B (Cell division) and C (Mendelian genetics) and each section is made up of 30 multiple-choice questions. Please answer ALL the questions in ALL three (3) sections of the test.

Section A - Cell Structure

Multiple Choice Questions

Instructions: The following questions are followed by four (4) options lettered A to D. Find out the correct option and circle A, B, C or D to indicate your answer.

1. What is the basic unit of structure in all living organisms?
 - a) organ
 - b) tissue
 - c) cell
 - d) molecule
2. What is the outermost layer of a cell called?
 - a) cytoplasm
 - b) cell membrane
 - c) nucleus
 - d) mitochondria
3. What is the function of the cell membrane?
 - a) to protect the cell from its surroundings
 - b) to control the movement of substances into and out of the cell
 - c) to store genetic material
 - d) to produce energy for the cell

4. What is the term for the jelly-like substance that fills the cell?
 - a) cytoplasm
 - b) chloroplast
 - c) mitochondria
 - d) nucleus
5. Which organelle is responsible for producing energy for the cell?
 - a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus
6. Which organelle is responsible for protein synthesis?
 - a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus
7. Where is DNA located in a eukaryotic cell?
 - a) in the mitochondria
 - b) in the ribosome
 - c) in the cytoplasm
 - d) in the nucleus
8. Which organelle is responsible for packaging and distributing proteins within the cell?
 - a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus
9. Which organelle is responsible for breaking down and recycling cellular waste?
 - a) ribosome
 - b) mitochondria
 - c) lysosome
 - d) Golgi apparatus
10. Which of the following is NOT a type of cell?
 - a) eukaryotic
 - b) prokaryotic

- c) multicellular
 - d) unicellular
11. What is the main difference between prokaryotic and eukaryotic cells?
- a) eukaryotic cells have a nucleus, while prokaryotic cells do not
 - b) prokaryotic cells are larger than eukaryotic cells
 - c) eukaryotic cells are multicellular, while prokaryotic cells are unicellular
 - d) prokaryotic cells have mitochondria, while eukaryotic cells do not
12. What is the name of the structure within the nucleus that contains the cell's genetic material?
- a) chromatin
 - b) nucleolus
 - c) endoplasmic reticulum
 - d) Golgi apparatus
13. Which organelle is responsible for creating carbohydrates and lipids for the cell?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus
14. Which organelle is responsible for breaking down fatty acids and producing hydrogen peroxide?
- a) ribosome
 - b) mitochondria
 - c) peroxisome
 - d) Golgi apparatus
15. What is the name of the region in a prokaryotic cell where DNA is located?
- a) nucleus
 - b) mitochondria
 - c) cytoplasm
 - d) ribosome
16. Which organelle is responsible for detoxifying harmful substances within the cell?
- a) lysosome
 - b) peroxisome
 - c) Golgi apparatus

- d) mitochondria
17. Which organelle is responsible for maintaining cell shape and providing support?
- a) cell membrane
 - b) ribosome
 - c) cytoskeleton
 - d) Golgi apparatus
18. Which of the following is NOT a component of the cytoskeleton?
- a) microtubules
 - b) microfilaments
 - c) intermediate filaments
 - d) ribosomes
19. What is the name of the interconnected network of flattened sacs and tubules within the cell?
- a) endoplasmic reticulum
 - b) Golgi apparatus
 - c) lysosome
 - d) peroxisome
20. Which type of endoplasmic reticulum is responsible for protein synthesis?
- a) rough endoplasmic reticulum
 - b) smooth endoplasmic reticulum
 - c) both
 - d) neither
21. Which organelle is responsible for storing and transporting materials within the cell?
- a) ribosome
 - b) Golgi apparatus
 - c) endoplasmic reticulum
 - d) mitochondria
22. Which organelle is responsible for digestion and breaking down of cellular waste?
- a) ribosome
 - b) lysosome
 - c) mitochondria
 - d) Golgi apparatus

23. What is the term for the process by which a cell engulfs material from its surroundings?
- a) endocytosis
 - b) exocytosis
 - c) osmosis
 - d) diffusion
24. What is the term for the process by which a cell expels material to its surroundings?
- a) endocytosis
 - b) exocytosis
 - c) osmosis
 - d) diffusion
25. Which of the following is a type of passive transport?
- a) facilitated diffusion
 - b) active transport
 - c) endocytosis
 - d) exocytosis
26. What is the term for the movement of water across a semipermeable membrane?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) exocytosis
27. What is the term for the movement of substances from an area of high concentration to an area of low concentration?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion
28. What is the term for the movement of substances across a cell membrane that requires the input of energy?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion

29. Which type of transport is responsible for the movement of substances from an area of low concentration to an area of high concentration?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion
30. Which of the following is NOT a type of membrane protein?
- a) receptor protein
 - b) transport protein
 - c) enzyme protein
 - d) ribosomal protein
31. Which of the following is NOT a characteristic of a eukaryotic cell?
- a) Nucleus
 - b) Cell membrane
 - c) Cell wall
 - d) Ribosomes

Section B – Cell Division

32. What is the process by which a cell divides into two daughter cells?
- a) replication
 - b) translation
 - c) mitosis
 - d) meiosis
33. Which type of cell division produces two genetically identical daughter cells?
- a) mitosis
 - b) meiosis
 - c) cytokinesis
 - d) replication
34. Which of the following is not a stage of mitosis?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase

35. During which stage of mitosis do the chromosomes condense and become visible?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase
36. During which stage of mitosis do the chromosomes align on the equator of the cell?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase
37. During which stage of mitosis do the sister chromatids separate and move towards opposite poles of the cell?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase
38. During which stage of mitosis do the nuclear envelopes reform and the chromosomes decondense?
- a) prophase
 - b) metaphase
 - c) anaphase
 - d) telophase
39. What is the process by which cells divide their cytoplasm and organelles to produce two daughter cells?
- a) mitosis
 - b) meiosis
 - c) cytokinesis
 - d) replication
40. In animal cells, which structure forms the contractile ring responsible for cytokinesis?
- a) microfilaments
 - b) microtubules
 - c) intermediate filaments
 - d) centrosomes

41. In plant cells, which structure forms the cell plate responsible for cytokinesis?
- a) microfilaments
 - b) microtubules
 - c) intermediate filaments
 - d) Golgi apparatus
42. Which type of cell division produces four genetically different daughter cells?
- a) mitosis
 - b) meiosis
 - c) cytokinesis
 - d) replication
43. In which stage of meiosis does crossing-over occur?
- a) prophase I
 - b) metaphase I
 - c) anaphase I
 - d) telophase
44. What is the term for the structure that holds two homologous chromosomes together during prophase I of meiosis?
- a) sister chromatids
 - b) centromere
 - c) spindle fiber
 - d) synaptonemal complex
45. During which stage of meiosis do the homologous chromosomes separate and move towards opposite poles of the cell?
- a) prophase I
 - b) metaphase I
 - c) anaphase I
 - d) telophase I
46. During which stage of meiosis do the sister chromatids separate and move towards opposite poles of the cell?
- a) prophase I
 - b) metaphase I
 - c) anaphase I
 - d) anaphase II

47. What is the process by which gametes are formed?
- a) mitosis
 - b) meiosis
 - c) cytokinesis
 - d) replication
48. Which type of cell undergoes meiosis to produce gametes?
- a) somatic cells
 - b) germ cells
 - c) stem cells
 - d) all cells undergo meiosis
49. What is the term for a diploid cell that undergoes meiosis to produce haploid cells?
- a) gamete
 - b) zygote
 - c) progenitor cell
 - d) none of the above
50. In humans, which type of cell undergoes meiosis to produce sperm?
- a) spermatogonia
 - b) spermatocytes
 - c) spermatids
 - d) spermatozoa
51. In humans, which type of cell undergoes meiosis to produce eggs?
- a) oogonia
 - b) oocytes
 - c) follicles
 - d) corpus luteum
52. What is the term for the failure of chromosomes to properly separate during cell division?
- a) nondisjunction
 - b) crossing-over
 - c) translocation
 - d) inversion
53. Which genetic disorder is caused by trisomy of chromosome 21?
- a) Down syndrome
 - b) Turner syndrome

- c) Klinefelter syndrome
 - d) Huntington's disease
54. Which genetic disorder is caused by the absence of an X chromosome?
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 - b) Turner syndrome
 - c) Klinefelter syndrome
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55. Which genetic disorder is caused by the presence of an extra X chromosome in males?
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 - b) Turner syndrome
 - c) Klinefelter syndrome
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56. What is the term for the programmed death of cells?
- a) apoptosis
 - b) necrosis
 - c) mitosis
 - d) cytokinesis
57. Which of the following is not a function of cell division?
- a) growth
 - b) repair
 - c) reproduction
 - d) energy production
58. Which type of cancer results from the uncontrolled growth of cells in the blood-forming tissues?
- a) leukemia
 - b) lymphoma
 - c) sarcoma
 - d) carcinoma
59. Which type of cancer results from the uncontrolled growth of cells in the lymphatic system?
- a) leukemia
 - b) lymphoma
 - c) sarcoma

d) carcinoma

60. Which type of cancer results from the uncontrolled growth of cells in connective tissues?

- a) leukemia
- b) lymphoma
- c) sarcoma
- d) carcinoma

61. Which type of cancer results from the uncontrolled growth of cells in epithelial tissues?

- a) leukemia
- b) lymphoma
- c) sarcoma
- d) carcinoma

Section C - Mendelian Genetics

62. Who is known as the “father of genetics”?

- a) Charles Darwin
- b) Gregor Mendel
- c) James Watson
- d) Francis Crick

63. Which of the following is NOT one of Mendel's laws of inheritance?

- a) Law of Dominance
- b) Law of Segregation
- c) Law of Independent Assortment
- d) Law of Completeness

64. What is the term for an alternative version of a gene?

- a) genotype
- b) phenotype
- c) allele
- d) chromosome

65. What is the term for the physical appearance of an organism?

- a) genotype
- b) phenotype
- c) allele

- d) chromosome
66. What is the term for an organism that has two identical alleles for a gene?
- a) homozygous
 - b) heterozygous
 - c) incomplete dominance
 - d) codominance
67. What is the term for an organism that has two different alleles for a gene?
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 - b) heterozygous
 - c) incomplete dominance
 - d) codominance
68. What is the term for the physical expression of an allele in an organism's phenotype?
- a) dominant
 - b) recessive
 - c) incomplete dominance
 - d) codominance
69. What is the term for an inheritance pattern in which the heterozygous phenotype is distinct from the homozygous dominant phenotype?
- a) dominant inheritance
 - b) recessive inheritance
 - c) incomplete dominance
 - d) codominance
70. What is the term for an inheritance pattern in which both alleles are expressed equally in the phenotype?
- a) dominant inheritance
 - b) recessive inheritance
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 - d) codominance
71. What is the term for a cross between two individuals with different genotypes for a single gene?
- a) monohybrid cross
 - b) dihybrid cross
 - c) trihybrid cross
 - d) polygenic cross

72. What is the term for a cross between two individuals with different genotypes for two genes?

- a) monohybrid cross
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73. What is the term for a gene that masks the expression of another gene in the phenotype?

- a) recessive
- b) dominant
- c) codominant
- d) incomplete dominant

74. What is the term for a gene that is only expressed when there are two copies of it present in the genotype?

- a) recessive
- b) dominant
- c) codominant
- d) incomplete dominant

75. What does the Punnett square represent in genetics?

- a) the probability of offspring genotypes resulting from a particular cross
- b) the probability of offspring phenotypes resulting from a particular cross
- c) the actual genotypes of offspring resulting from a particular cross
- d) the actual phenotypes of offspring resulting from a particular cross

76. Which of the following represents a homozygous dominant genotype?

- a) AA
- b) Aa
- c) aa
- d) AB

77. Which of the following represents a homozygous recessive genotype?

- a) AA
- b) Aa
- c) aa
- d) AB

78. Which of the following represents a heterozygous genotype?
- a) AA
 - b) Aa
 - c) aa
 - d) AB
79. What is the term for a trait that is controlled by multiple genes?
- a) polygenic trait
 - b) monogenic trait
 - c) dominant trait
 - d) recessive trait
80. In humans, which chromosome determines the sex of the individual?
- a) X chromosome
 - b) Y chromosome
 - c) Autosome
 - d) Mitochondrial chromosome
81. What is the term for a trait that is only expressed in one sex?
- a) sex-limited trait
 - b) sex-influenced trait
 - c) autosomal trait
 - d) sex-linked trait
82. What is the term for a trait that is influenced by the presence of male or female sex hormones?
- a) sex-limited trait
 - b) sex-influenced trait
 - c) autosomal trait
 - d) sex-linked trait
83. What is the term for a trait that is located on the X or Y chromosome?
- a) sex-limited trait
 - b) sex-influenced trait
 - c) autosomal trait
 - d) sex-linked trait

84. What is the term for the pattern of inheritance in which a gene on the X chromosome is passed from a mother to her son?

- a) sex-limited inheritance
- b) sex-influenced inheritance
- c) autosomal inheritance
- d) X-linked inheritance

85. What is the term for the pattern of inheritance in which a gene on the X chromosome is passed from a mother to her daughter?

- a) sex-limited inheritance
- b) sex-influenced inheritance
- c) autosomal inheritance
- d) X-linked inheritance

86. What is the term for the pattern of inheritance in which a gene on an autosome (non-sex chromosome) is passed from parent to offspring?

- a) sex-limited inheritance
- b) sex-influenced inheritance
- c) autosomal inheritance
- d) X-linked inheritance

87. In human blood type, which allele is dominant: A, B, or O?

- a) A
- b) B
- c) O
- d) both A and B are dominant

88. What is the possible blood type of a person who is heterozygous for the A and B blood type alleles?

- a) A
- b) B
- c) AB
- d) O

89. Which blood type is considered universal donor?

- a) A
- b) B
- c) AB
- d) O

90. Which blood type is considered universal recipient?

- a) A
- b) B
- c) AB
- d) O

Essay type

1. Short answer question: Describe the process of cytokinesis in animal cells.

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2. A cell has 10 chromosomes. During mitosis, how many chromosomes will each daughter cell have?

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3. Explain the difference between homozygous and heterozygous genotypes.

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4. If a parent has the genotype Aa and the other parent has the genotype aa, what is the probability of their offspring having the genotype Aa?

5. Compare and contrast mitosis and meiosis.

6. A cell has 24 chromosomes. During meiosis, how many chromosomes will each daughter cell have?

7. Explain the concept of dominance in Mendelian genetics.

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8. If a parent has the genotype BB and the other parent has the genotype bb, what is the probability of their offspring having the genotype Bb?

APPENDIX D2

WIAWSO COLLEGE OF EDUCATION

POST-TEST DATA COLLECTING INSTRUMENT - TEST 2

MARKING SCHEME

Section a - Cell Structure

Multiple Choice Questions

Instructions: The following questions are followed by four (4) options lettered A to D.

Find out the correct option and circle A, B, C or D to indicate your answer.

1. What is the basic unit of structure in all living organisms?

- a) organ
- b) tissue
- c) cell
- d) molecule

Answer: C

2. What is the outermost layer of a cell called?

- a) cytoplasm
- b) cell membrane
- c) nucleus
- d) mitochondria

Answer: B

3. What is the function of the cell membrane?

- a) to protect the cell from its surroundings
- b) to control the movement of substances into and out of the cell
- c) to store genetic material
- d) to produce energy for the cell

Answer: B

4. What is the term for the jelly-like substance that fills the cell?

- a) cytoplasm
- b) chloroplast
- c) mitochondria
- d) nucleus

Answer: A

5. Which organelle is responsible for producing energy for the cell?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: B

6. Which organelle is responsible for protein synthesis?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: A

7. Where is DNA located in a eukaryotic cell?
- a) in the mitochondria
 - b) in the ribosome
 - c) in the cytoplasm
 - d) in the nucleus

Answer: D

8. Which organelle is responsible for packaging and distributing proteins within the cell?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: D

9. Which organelle is responsible for breaking down and recycling cellular waste?
- a) ribosome
 - b) mitochondria
 - c) lysosome
 - d) Golgi apparatus

Answer: C

10. Which of the following is NOT a type of cell?
- a) eukaryotic

- b) prokaryotic
- c) multicellular
- d) unicellular

Answer: C

11. What is the main difference between prokaryotic and eukaryotic cells?
- a) eukaryotic cells have a nucleus, while prokaryotic cells do not
 - b) prokaryotic cells are larger than eukaryotic cells
 - c) eukaryotic cells are multicellular, while prokaryotic cells are unicellular
 - d) prokaryotic cells have mitochondria, while eukaryotic cells do not

Answer: A

12. What is the name of the structure within the nucleus that contains the cell's genetic material?
- a) chromatin
 - b) nucleolus
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: A

13. Which organelle is responsible for creating carbohydrates and lipids for the cell?
- a) ribosome
 - b) mitochondria
 - c) endoplasmic reticulum
 - d) Golgi apparatus

Answer: C

14. Which organelle is responsible for breaking down fatty acids and producing hydrogen peroxide?
- a) ribosome
 - b) mitochondria
 - c) peroxisome
 - d) Golgi apparatus

Answer: C

15. What is the name of the region in a prokaryotic cell where DNA is located?
- a) nucleus
 - b) mitochondria
 - c) cytoplasm

d) ribosome

Answer: C

16. Which organelle is responsible for detoxifying harmful substances within the cell?

- a) lysosome
- b) peroxisome
- c) Golgi apparatus
- d) mitochondria

Answer: B

17. Which organelle is responsible for maintaining cell shape and providing support?

- a) cell membrane
- b) ribosome
- c) cytoskeleton
- d) Golgi apparatus

Answer: C

18. Which of the following is NOT a component of the cytoskeleton?

- a) microtubules
- b) microfilaments
- c) intermediate filaments
- d) ribosomes

Answer: D

19. What is the name of the interconnected network of flattened sacs and tubules within the cell?

- a) endoplasmic reticulum
- b) Golgi apparatus
- c) lysosome
- d) peroxisome

Answer: A

20. Which type of endoplasmic reticulum is responsible for protein synthesis?

- a) rough endoplasmic reticulum
- b) smooth endoplasmic reticulum
- c) both
- d) neither

Answer: A

21. Which organelle is responsible for storing and transporting materials within the cell?

- a) ribosome
- b) Golgi apparatus
- c) endoplasmic reticulum
- d) mitochondria

Answer: B

22. Which organelle is responsible for digestion and breaking down of cellular waste?

- a) ribosome
- b) lysosome
- c) mitochondria
- d) Golgi apparatus

Answer: B

23. What is the term for the process by which a cell engulfs material from its surroundings?

- a) endocytosis
- b) exocytosis
- c) osmosis
- d) diffusion

Answer: A

24. What is the term for the process by which a cell expels material to its surroundings?

- a) endocytosis
- b) exocytosis
- c) osmosis
- d) diffusion

Answer: B

25. Which of the following is a type of passive transport?

- a) facilitated diffusion
- b) active transport
- c) endocytosis
- d) exocytosis

Answer: A

26. What is the term for the movement of water across a semipermeable membrane?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) exocytosis

Answer: B

27. What is the term for the movement of substances from an area of high concentration to an area of low concentration?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion

Answer: D

28. What is the term for the movement of substances across a cell membrane that requires the input of energy?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion

Answer: C

29. Which type of transport is responsible for the movement of substances from an area of low concentration to an area of high concentration?
- a) facilitated diffusion
 - b) osmosis
 - c) active transport
 - d) diffusion

Answer: C

30. Which of the following is NOT a type of membrane protein?
- a) receptor protein
 - b) transport protein
 - c) enzyme protein
 - d) ribosomal protein

Answer: D

31. Which of the following is NOT a characteristic of a eukaryotic cell?

- a) Nucleus
- b) Cell membrane
- c) Cell wall
- d) Ribosomes

Answer: C

Section B – Cell Division

32. What is the process by which a cell divides into two daughter cells?

- a) replication
- b) translation
- c) mitosis
- d) meiosis

Answer: C

33. Which type of cell division produces two genetically identical daughter cells?

- a) mitosis
- b) meiosis
- c) cytokinesis
- d) replication

Answer: A

34. Which of the following is not a stage of mitosis?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: D

35. During which stage of mitosis do the chromosomes condense and become visible?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: A

36. During which stage of mitosis do the chromosomes align on the equator of the cell?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: B

37. During which stage of mitosis do the sister chromatids separate and move towards opposite poles of the cell?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: C

38. During which stage of mitosis do the nuclear envelopes reform and the chromosomes decondense?

- a) prophase
- b) metaphase
- c) anaphase
- d) telophase

Answer: D

39. What is the process by which cells divide their cytoplasm and organelles to produce two daughter cells?

- a) mitosis
- b) meiosis
- c) cytokinesis
- d) replication

Answer: C

40. In animal cells, which structure forms the contractile ring responsible for cytokinesis?

- a) microfilaments
- b) microtubules
- c) intermediate filaments
- d) centrosomes

Answer: A

41. In plant cells, which structure forms the cell plate responsible for cytokinesis?

- a) microfilaments
- b) microtubules
- c) intermediate filaments
- d) Golgi apparatus

Answer: D

42. Which type of cell division produces four genetically different daughter cells?

- a) mitosis
- b) meiosis
- c) cytokinesis
- d) replication

Answer: B

43. In which stage of meiosis does crossing-over occur?

- a) prophase I
- b) metaphase I
- c) anaphase I
- d) telophase I

Answer: A

44. What is the term for the structure that holds two homologous chromosomes together during prophase I of meiosis?

- a) sister chromatids
- b) centromere
- c) spindle fiber
- d) synaptonemal complex

Answer: D

45. During which stage of meiosis do the homologous chromosomes separate and move towards opposite poles of the cell?

- a) prophase I
- b) metaphase I
- c) anaphase I
- d) telophase I

Answer: C

46. During which stage of meiosis do the sister chromatids separate and move towards opposite poles of the cell?

- a) prophase I
- b) metaphase I
- c) anaphase I
- d) anaphase II

Answer: D

47. What is the process by which gametes are formed?

- a) mitosis
- b) meiosis
- c) cytokinesis
- d) replication

Answer: B

48. Which type of cell undergoes meiosis to produce gametes?

- a) somatic cells
- b) germ cells
- c) stem cells
- d) all cells undergo meiosis

Answer: B

49. What is the term for a diploid cell that undergoes meiosis to produce haploid cells?

- a) gamete
- b) zygote
- c) progenitor cell
- d) none of the above

Answer: C

50. In humans, which type of cell undergoes meiosis to produce sperm?

- a) spermatogonia
- b) spermatocytes
- c) spermatids
- d) spermatozoa

Answer: B

51. In humans, which type of cell undergoes meiosis to produce eggs?

- a) oogonia
- b) oocytes

- c) follicles
- d) corpus luteum

Answer: B

52. What is the term for the failure of chromosomes to properly separate during cell division?

- a) nondisjunction
- b) crossing-over
- c) translocation
- d) inversion

Answer: A

53. Which genetic disorder is caused by trisomy of chromosome 21?

- a) Down syndrome
- b) Turner syndrome
- c) Klinefelter syndrome
- d) Huntington's disease

Answer: A

54. Which genetic disorder is caused by the absence of an X chromosome?

- a) Down syndrome
- b) Turner syndrome
- c) Klinefelter syndrome
- d) Huntington's disease

Answer: B

55. Which genetic disorder is caused by the presence of an extra X chromosome in males?

- a) Down syndrome
- b) Turner syndrome
- c) Klinefelter syndrome
- d) Huntington's disease

Answer: C

56. What is the term for the programmed death of cells?

- a) apoptosis
- b) necrosis
- c) mitosis
- d) cytokinesis

Answer: A

57. Which of the following is not a function of cell division?

- a) growth
- b) repair
- c) reproduction
- d) energy production

Answer: D

58. Which type of cancer results from the uncontrolled growth of cells in the blood-forming tissues?

- a) leukemia
- b) lymphoma
- c) sarcoma
- d) carcinoma

Answer: A

59. Which type of cancer results from the uncontrolled growth of cells in the lymphatic system?

- a) leukemia
- b) lymphoma
- c) sarcoma
- d) carcinoma

Answer: B

60. Which type of cancer results from the uncontrolled growth of cells in connective tissues?

- a) leukemia
- b) lymphoma
- c) sarcoma
- d) carcinoma

Answer: C

61. Which type of cancer results from the uncontrolled growth of cells in epithelial tissues?

- a) leukemia
- b) lymphoma
- c) sarcoma
- d) carcinoma

Answer: D

Section C - Mendelian Genetics

62. Who is known as the “father of genetics”?

- a) Charles Darwin
- b) Gregor Mendel
- c) James Watson
- d) Francis Crick

Answer: B

63. Which of the following is NOT one of Mendel's laws of inheritance?

- a) Law of Dominance
- b) Law of Segregation
- c) Law of Independent Assortment
- d) Law of Completeness

Answer: D

64. What is the term for an alternative version of a gene?

- a) genotype
- b) phenotype
- c) allele
- d) chromosome

Answer: C

65. What is the term for the physical appearance of an organism?

- a) genotype
- b) phenotype
- c) allele
- d) chromosome

Answer: B

66. What is the term for an organism that has two identical alleles for a gene?

- a) homozygous
- b) heterozygous
- c) incomplete dominance
- d) codominance

Answer: A

67. What is the term for an organism that has two different alleles for a gene?

- a) homozygous
- b) heterozygous
- c) incomplete dominance
- d) codominance

Answer: B

68. What is the term for the physical expression of an allele in an organism's phenotype?

- a) dominant
- b) recessive
- c) incomplete dominance
- d) codominance

Answer: A

69. What is the term for an inheritance pattern in which the heterozygous phenotype is distinct from the homozygous dominant phenotype?

- a) dominant inheritance
- b) recessive inheritance
- c) incomplete dominance
- d) codominance

Answer: C

70. What is the term for an inheritance pattern in which both alleles are expressed equally in the phenotype?

- a) dominant inheritance
- b) recessive inheritance
- c) incomplete dominance
- d) codominance

Answer: D

71. What is the term for a cross between two individuals with different genotypes for a single gene?

- a) monohybrid cross
- b) dihybrid cross
- c) trihybrid cross
- d) polygenic cross

Answer: A

72. What is the term for a cross between two individuals with different genotypes for two genes?

- a) monohybrid cross
- b) dihybrid cross
- c) trihybrid cross
- d) polygenic cross

Answer: B

73. What is the term for a gene that masks the expression of another gene in the phenotype?

- a) recessive
- b) dominant
- c) codominant
- d) incomplete dominant

Answer: B

74. What is the term for a gene that is only expressed when there are two copies of it present in the genotype?

- a) recessive
- b) dominant
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Answer: A

75. What does the Punnett square represent in genetics?

- a) the probability of offspring genotypes resulting from a particular cross
- b) the probability of offspring phenotypes resulting from a particular cross
- c) the actual genotypes of offspring resulting from a particular cross
- d) the actual phenotypes of offspring resulting from a particular cross

Answer: A

76. Which of the following represents a homozygous dominant genotype?

- a) AA
- b) Aa
- c) aa
- d) AB

Answer: A

77. Which of the following represents a homozygous recessive genotype?

- a) AA
- b) Aa
- c) aa
- d) AB

Answer: C

78. Which of the following represents a heterozygous genotype?

- a) AA
- b) Aa
- c) aa
- d) AB

Answer: B

79. What is the term for a trait that is controlled by multiple genes?

- a) polygenic trait
- b) monogenic trait
- c) dominant trait
- d) recessive trait

Answer: A

80. In humans, which chromosome determines the sex of the individual?

- a) X chromosome
- b) Y chromosome
- c) Autosome
- d) Mitochondrial chromosome

Answer: B

81. What is the term for a trait that is only expressed in one sex?

- a) sex-limited trait
- b) sex-influenced trait
- c) autosomal trait
- d) sex-linked trait

Answer: A

82. What is the term for a trait that is influenced by the presence of male or female sex hormones?

- a) sex-limited trait
- b) sex-influenced trait

- c) autosomal trait
- d) sex-linked trait

Answer: B

83. What is the term for a trait that is located on the X or Y chromosome?

- a) sex-limited trait
- b) sex-influenced trait
- c) autosomal trait
- d) sex-linked trait

Answer: D

84. What is the term for the pattern of inheritance in which a gene on the X chromosome is passed from a mother to her son?

- a) sex-limited inheritance
- b) sex-influenced inheritance
- c) autosomal inheritance
- d) X-linked inheritance

Answer: D

85. What is the term for the pattern of inheritance in which a gene on the X chromosome is passed from a mother to her daughter?

- a) sex-limited inheritance
- b) sex-influenced inheritance
- c) autosomal inheritance
- d) X-linked inheritance

Answer: D

86. What is the term for the pattern of inheritance in which a gene on an autosome (non-sex chromosome) is passed from parent to offspring?

- a) sex-limited inheritance
- b) sex-influenced inheritance
- c) autosomal inheritance
- d) X-linked inheritance

Answer: C

87. In human blood type, which allele is dominant: A, B, or O?

- a) A
- b) B
- c) O

d) both A and B are dominant

Answer: D

88. What is the possible blood type of a person who is heterozygous for the A and B blood type alleles?

- a) A
- b) B
- c) AB
- d) O

Answer: C

89. Which blood type is considered universal donor?

- a) A
- b) B
- c) AB
- d) O

Answer: D

90. Which blood type is considered universal recipient?

- a) A
- b) B
- c) AB
- d) O

Answer: C

91. Which of the following is NOT a possible genotype for an individual with AB blood type?

- a) $I^A I^B$
- b) $I^A i$
- c) $I^B i$
- d) ii

Answer: D

92. What is the purpose of meiosis?

- a) Production of identical cells
- b) Growth and repair of tissues
- c) Production of gametes
- d) Maintenance of homeostasis

Answer: C

93. During which phase of the cell cycle does DNA replication occur?

- a) G1 phase
- b) S phase
- c) G2 phase
- d) M phase

Answer: B

94. What is the phenotypic ratio of a monohybrid cross involving two heterozygous individuals?

- a) 1:1
- b) 3:1
- c) 9:3:3:1
- d) 4:0

Answer: B

Easy type

1. Describe the process of cytokinesis in animal cells.

Answer: *cytokinesis in animal cells is the final step of the cell cycle, following mitosis, where the cytoplasm divides to form two genetically identical daughter cells.*

2. A cell has 10 chromosomes. During mitosis, how many chromosomes will each daughter cell have?

Answer: *10 chromosomes each*

3. Explain the difference between homozygous and heterozygous genotypes.

Answer:

Homozygous Genotype

- *An organism having two identical alleles for a specific gene.*
- *Example:*
 - *Homozygous dominant: AA*
 - *Homozygous recessive: aa*
- *Both alleles either promote or suppress a trait the same way.*
- *Trait is usually clearly expressed, either dominantly or recessively.*

Heterozygous Genotype

- *An organism having two different alleles for a specific gene.*
- *Example: Aa (one dominant, one recessive allele)*
- *The dominant allele usually masks the effect of the recessive one.*

- The trait expressed is usually the **dominant** one, but the organism is a **carrier** of the recessive allele.

4. If a parent has the genotype Aa and the other parent has the genotype aa, what is the probability of their offspring having the genotype Aa?

Answer: Using Punnet Square

	<i>a</i>	<i>a</i>
<i>A</i>	<i>Aa</i>	<i>Aa</i>
<i>a</i>	<i>aa</i>	<i>aa</i>

Probability of offspring being Aa:

- **2 out of 4, or 50%**

Answer: 50% chance that an offspring will have the genotype Aa

5. Compare and contrast mitosis and meiosis.

Answer

mitosis

2n

clone

Same genetic information in parent cell and daughter cell

Give me another one just like the other one

meiosis

1n

Daughter cells different from parent cell and from each other

Daughter cells have ½ the number of chromosomes as somatic cell.

Shuffling the genes

6. A cell has 24 chromosomes. During meiosis, how many chromosomes will each daughter cell have?

Answer: 12 chromosomes. That is half the number of chromosomes of the parent.

7. Explain the concept of dominance in Mendelian genetics.

*Answer: In **Mendelian genetics**, the concept of **dominance** refers to how certain alleles can mask the expression of others when they are paired together in a heterozygous individual.*

8. If a parent has the genotype BB and the other parent has the genotype bb, what is the probability of their offspring having the genotype Bb?

	<i>b</i>	<i>b</i>
<i>B</i>	<i>Bb</i>	<i>Bb</i>
<i>B</i>	<i>Bb</i>	<i>Bb</i>

Probability of offspring being Bb:

- *4 out of 4, or 100%*

Answer: 100% chance that an offspring will have the genotype Bb.

APPENDIX E1**WIAWSO COLLEGE OF EDUCATION****THE PRE-SERVICE SCIENCE TEACHERS' PERCEPTION ON THE EFFECTIVENESS OF INTERACTIVE MULTIMEDIA INSTRUCTIONAL APPROACH IN LEARNING BIOLOGY CONCEPTS.**

The following statements are on the pre-service science teachers' perception on the effectiveness of interactive multimedia instructional approach in learning biology concepts. Please tick the appropriate response as to extent to your agreement. Note that one (1) represents the strongest disagreement to the statements/items while five (5) represents the strongest agreement to the statements/items.

Statements/Items	1	2	3	4	5
13. The use of interactive multimedia instructional approach makes biology concepts easier to understand.					
14. Interactive multimedia instructional approach helps me retain biology concepts better than traditional methods.					
15. I feel more engaged with biology content when using interactive multimedia instructional approach.					
16. Interactive multimedia instructional approach encourages me to explore biology topics more deeply.					
17. Learning biology through interactive multimedia instructional approach is more enjoyable than traditional lectures.					
18. The multimedia approach allows me to visualize complex biology concepts more clearly.					
19. I find interactive multimedia instructional approach to be a motivating tool in learning biology.					
20. I am able to work at my own pace when using interactive multimedia instructional approach for learning biology.					
21. Interactive multimedia instructional approach improves my problem-solving skills in biology.					
22. The feedback provided in multimedia activities helps me to better understand biology concepts.					

APPENDIX E2

WIAWSO COLLEGE OF EDUCATION PRE-SERVICE SCIENCE TEACHERS' INTERVIEW SCHEDULE (PSSTIS)

Section A: Respondents Bio-Data

1. Code: -..... Sex Male [] Female []
2. Age..... Date: -

Section B: - Items in the Post-Interview Schedule

1. What was your overall experience using interactive multimedia instructional approach for learning about cells, cell division, and Mendelian genetics?
2. Did you find interactive multimedia instructional approach helpful in understanding complex concepts related to cells, cell division, and Mendelian genetics?
3. What was your favorite interactive multimedia instructional approach used in learning about cells, cell division, and Mendelian genetics?
4. How did interactive multimedia instructional approach enhance the learning experience in comparison to traditional teaching methods?
5. Did interactive multimedia instructional approach help you remember content better?
6. What were your experiences with interactive multimedia instructional approach that were not helpful or engaging and how can they be improved to better suit student learning?
7. Did interactive multimedia instructional approach motivate you to learn more about cells, cell division, and Mendelian genetics? Why or why not?
8. From your experience, how could interactive multimedia instructional approach be improved to better facilitate learning for students?
9. Would you prefer more traditional methods of learning or interactive multimedia instructional approach in future biology classes about cells, cell division, and Mendelian genetics?

10. From your experience with interactive multimedia instructional approach, how do you see these tools fitting into the overall biology curriculum?

APPENDIX F1

WIAWSO COLLEGE OF EDUCATION DESCRIPTION OF MOTIVATION AND ENGAGEMENT IN USING INTERACTIVE MULTIMEDIA INSTRUCTIONAL APPROACH QUESTIONNAIRE ITEMS (PSSTMEIMQ)

Dear Students,

Thank you for participating in this study. I am conducting research on “Using interactive multimedia instructional approach to improve the academic performance of pre-service science teachers **in learning of some biology concepts**”. The researcher is into science education and the purpose of this questionnaire is to assess your motivation and engagement levels during biology instruction, specifically in the context of cell, cell division, and Mendelian genetics using interactive multimedia instructional approach. Please answer the following questions honestly and to the best of your ability. Your responses will remain anonymous and will be used for research purposes only. This questionnaire form part of a research to help improve the teaching and learning of biology through the use of interactive multimedia instructional approach. It is hoped that the results of this research would be beneficial to biology students and teachers.

Section A: Bio-Data

1. Student' code
2. Sex:
 - a) Male
 - b) Female
3. Age:
 - a) 18-25
 - b) 26-35
 - c) 36-45

Section B: Motivation and Engagement Levels in Biology Instruction

Please rate the following statements based on your level of agreement using a 5-point Likert scale (SA = **strongly agree**, A=**agree**, UN=**undecided**, D=**disagree**, SD = **strongly disagree**).

S/N	The use of interactive multimedia instructional approach	1	2	3	4	5
1	How often does your teacher use interactive multimedia instructional approach (e.g., videos, simulations, or animations) during science lessons?					
2	How effective do you think the use of interactive multimedia instructional approach is in helping you understand complex science concepts?					
3	Do you believe that interactive multimedia instructional approach improve the overall learning experience in your science class					
4	How satisfied are you with the frequency of interactive multimedia instructional approach use in your science lessons					
5	To what extent does interactive multimedia instructional approach make learning science more enjoyable for you?					
	Motivation towards the use of multimedia approach in classroom instruction					
6	To what extent do you feel motivated to learn science concepts when interactive multimedia instructional approaches are used in the classroom					
7	Do you find that interactive multimedia instructional approach helps increase your interest in science topics compared to traditional teaching methods					
8	How often do you feel a sense of accomplishment when using interactive multimedia instructional approach during science lessons					
9	Does the use of interactive multimedia instructional approach encourage you to explore science concepts outside of the classroom					

10	How motivated are you to complete assignments or projects that incorporate interactive multimedia instructional approach					
	Engagement towards the use of multimedia approaches in classroom instruction					
11	How engaged are you during science lessons that utilize interactive multimedia instructional approach					
12	Do you find yourself participating more in class discussions when interactive multimedia instructional approach is used					
13	How often do you actively participate in activities or experiments involving interactive multimedia instructional approach in science lessons					
14	To what extent do interactive multimedia instructional approach help you focus on the science lesson content					
15	Do you feel more connected to the learning material when interactive multimedia instructional approach is incorporated into the lesson?					

APPENDIX F2

WIAWSO COLLEGE OF EDUCATION DESCRIPTION OF MOTIVATION AND ENGAGEMENT LEVEL SCALE QUESTIONNAIRE ITEMS (PSSTMELSQ)

Dear Students,

Thank you for participating in this study. I am conducting research on “Using interactive multimedia instructional approach to improve the academic performance of pre-service science teachers **in learning of some biology concepts**”. The researcher is into science education and the purpose of this questionnaire is to assess your motivation and engagement levels during biology instruction, specifically in the context of cell, cell division, and Mendelian genetics using interactive multimedia instructional approach. Please answer the following questions honestly and to the best of your ability. Your responses will remain anonymous and will be used for research purposes only. This questionnaire form part of a research to help improve the teaching and learning of biology through the use of interactive multimedia instructional approach. It is hoped that the results of this research would be beneficial to biology students and teachers.

Section A: Bio-Data

1. Student' code
2. Sex:
 - a) Male []
 - b) Female []
3. Age:
 - a) 18-25 []
 - b) 26-35 []
 - c) 36-45 []

Section B: Motivation and Engagement Levels in Biology Instruction

Please rate the following statements based on your level of agreement using a 5-point Likert scale (SA = **strongly agree**, A=**agree**, UN=**undecided**, D=**disagree**, SD = **strongly disagree**).

S/N	Question	SA	A	UN	D	SD
1	The use of interactive multimedia instructional approach in biology instruction enhances my interest in the topic of cell, cell division, and Mendelian genetics.					
2	Interactive multimedia instructional approach helps me understand complex biological concepts related to cell, cell division, and Mendelian genetics					
3	The use of interactive multimedia instructional approach in biology instruction makes learning about cell, cell division, and Mendelian genetics more enjoyable for me					
4	Interactive multimedia instructional approach motivates me to actively participate in biology instruction related to cell, cell division, and Mendelian genetics					
5	I feel more engaged in the learning process when interactive multimedia instructional approach is incorporated into biology instruction					
6	Interactive multimedia instructional approach helps me visualize and comprehend the processes involved in cell, cell division, and Mendelian genetics					
7	The use of interactive multimedia instructional approach in biology instruction increases my confidence in understanding cell, cell division, and Mendelian genetics					
8	Interactive multimedia instructional approach stimulates my curiosity and desire to explore further					

	in the field of biology, specifically in cell, cell division, and Mendelian genetics					
9	I find interactive multimedia instructional approach to be a valuable tool for reinforcing my knowledge of cell, cell division, and Mendelian genetics					
10	The use of interactive multimedia instructional approach in biology instruction makes me more actively involved in discussions and activities related to cell, cell division, and Mendelian genetics					

APPENDIX F3

WIAWSO COLLEGE OF EDUCATION

PRE-SERVICE SCIENCE TEACHERS' PERCEPTION OF THE EFFECTIVENESS OF INTERACTIVE MULTIMEDIA INSTRUCTIONAL APPROACH INSTRUCTIONAL APPROACH IN LEARNING BIOLOGY CONCEPTS

Dear Students,

I am conducting research on “pre-service science teachers’ perception of the effectiveness of interactive multimedia instructional approach in learning some biology concepts”. The researcher is into science education and this questionnaire form part of a research to help improve the teaching and learning of biology through the use of interactive multimedia instructional approach. It is hoped that the results of this research would be beneficial to biology students and teachers. Please, be assured that your opinions will be kept strictly confidential because this is entirely an academic exercise.

Section A: Respondents Bio-Data

1. Students’ code.....

2. Sex

Male []

Female []

3. Age

10-14years []

15-20years []

21-25years []

26-30years []

31+ years []

Section B:

Instruction: please tick in the appropriate box by indicating your extent of agreement or otherwise to the following on teaching with concept Interactive multimedia instructional approach.

SA= strongly agree A= agree UN= undecided D= disagree

SD=strongly disagree

S/N	Question	SA	A	UN	D	SD
1	Interactive multimedia instructional approach makes biology lesson interesting					
2	Interactive multimedia instructional approach makes teaching and learning of cell, cell division and Mendelian genetics concept					
3	Interactive multimedia instructional approach helps me to reconcile inconsistency in Mendelian genetics					
4	Interactive multimedia instructional approach is very effective tool that help me to improve my conceptual understanding of the cell, cell division and Mendelian genetics concepts taught.					
5	Interactive multimedia instructional approach brings out the meaning of abstracts concepts better					
6	Interactive multimedia instructional approach provides aid for expanding what has been learned					
7	Interactive multimedia instructional approach promotes gender friendliness among learners					
8	The interactive multimedia instructional approach helps to get rid of misconceptions on					

	cell division and Mendelian genetics concepts taught in class					
9	Interactive multimedia instructional approach provides me better understanding of complex issues in biology class					
10	The interactive multimedia instructional approach is an effective approach in reducing boredom in classroom and in engaging pre-service science teachers in active learning process in biology class					
11	Interactive multimedia instructional approach gives more permanent and meaningful understanding since students are actively involved in performing hands-on activities					
12	Interactive multimedia instructional approach enhances group work, corporative learning and healthy discussions among pre-service teachers					
13	Interactive multimedia instructional approach helps to improve performance and to develop positive attitudes towards cell, cell division and Mendelian genetics concepts					
14	Using interactive multimedia instructional approach is not time-consuming.					
15	Interactive multimedia instructional approach can be used for other courses or subjects.					

APPENDIX G

INTRODUCTORY LETTER



Our Ref: ISED/PG/VOL.1/90

14th August, 2024

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

LETTER OF INTRODUCTION

I am writing to introduce **Mr. Francis Arthur-Baidoo**, with index number **9231610013**, a PhD Science Education student at the University of Education, Winneba.

As part of the program requirement, **Mr. Francis Arthur-Baidoo** is researching “**The Effects of Interactive Multimedia in Teaching Pre-Service Science Teachers in Some Biology Concepts**” He needs to gather information to analyze the said research topic.

I would be grateful if he would be given the needed assistance to carry out this exercise.

Thank you.

Yours faithfully,

DR. CHARLES K. KOOMSON

Ag. Head of Department



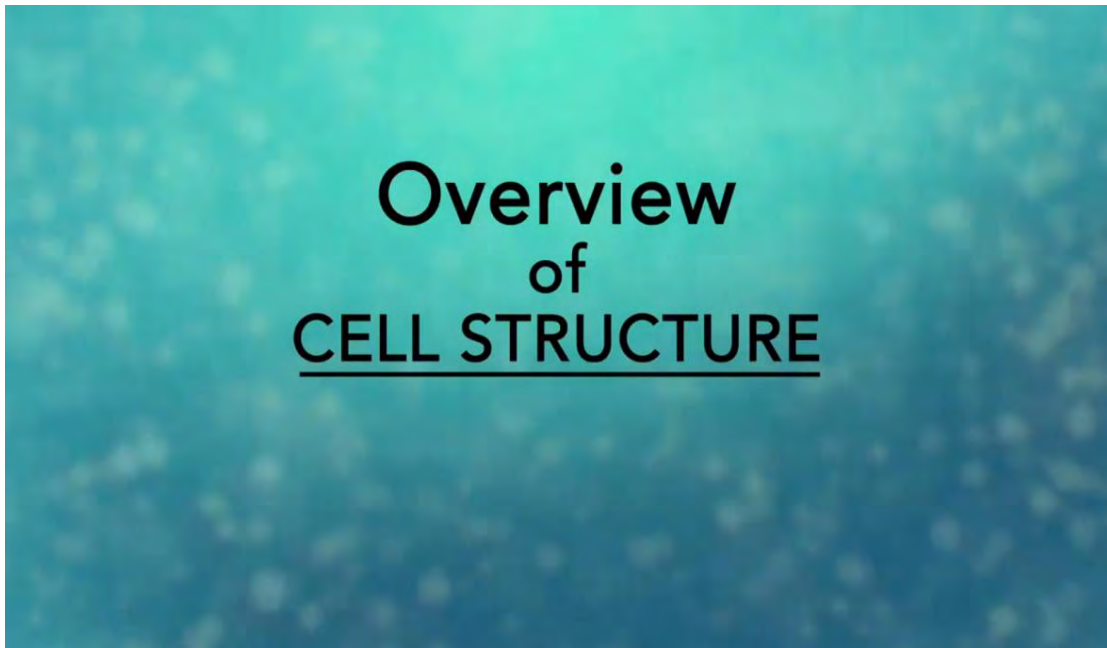
APPENDIX H

INTERACTIVE MULTIMEDIA INSTRUCTIONAL APPROACH LESSONS

Week: Two and Three

Lesson: One

Topic: The Cell Structure and Classification



Source : https://youtu.be/XKZhcYetvsc?si=XSlanIm70Hlt_Cis

The screenshot shows a PowerPoint slide with the following content:

- OpenStax logo in the top right corner.
- Section title: **CONCEPTS OF BIOLOGY**
- Chapter title: **Chapter 3 CELL STRUCTURE AND FUNCTION**
- Subtitle: **PowerPoint Image Slideshow**
- Image of a book cover titled 'Concepts Biology'.
- Learning Objectives:
 - 1. Explain the structure and function of cells.
 - 2. Describe the structure and function of plant and animal cells.
 - 3. Explain the structure and function of microorganisms.
- Footer: This work is licensed under [cc by 4.0 license](https://creativecommons.org/licenses/by/4.0/). Credit: OpenStax, modified by M. F. Sega & J. Wedincamp for ALG 16 grant through addition of ppt slides with texts made using OpenStax textbook information.

The left sidebar shows the presentation outline with the following items:

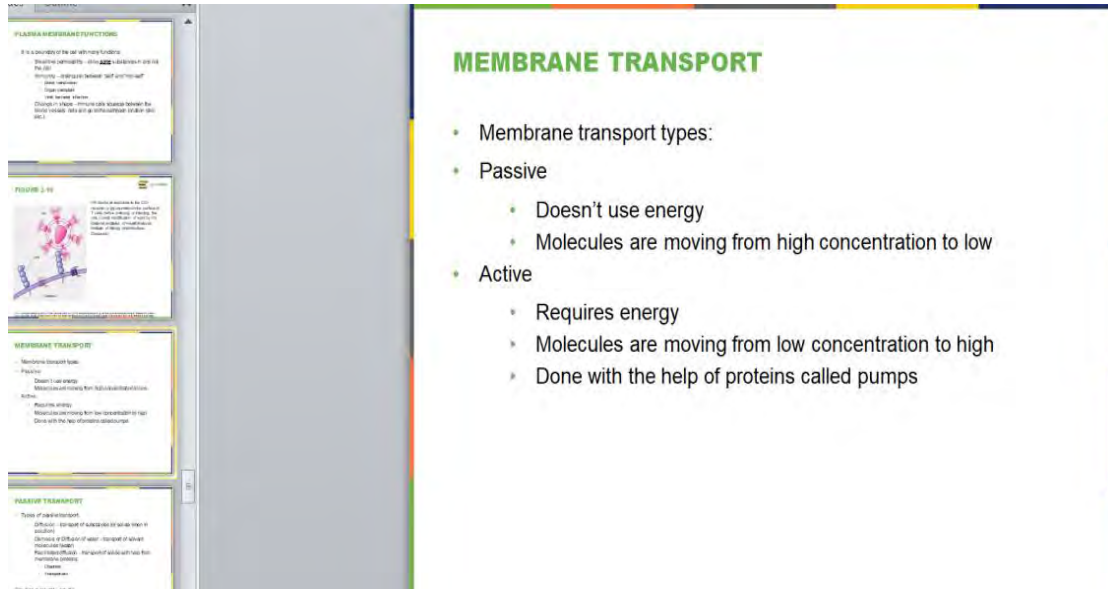
- CONCEPTS OF BIOLOGY
- CHAPTER 3 CELL STRUCTURE AND FUNCTION
- FIGURE 3.1 - CELLS
- MICROSCOPY TO STUDY CELLS
- FIGURE 3.2 - LIGHT VS. ELECTRON MICROSCOPY

APPENDIX H continue

Week: Four

Lesson: Two

Topic: Membrane Transport



The image shows a presentation slide titled "MEMBRANE TRANSPORT" in green text. To the left, a smaller window displays a document with text and a diagram. The main slide contains a bulleted list of membrane transport types:

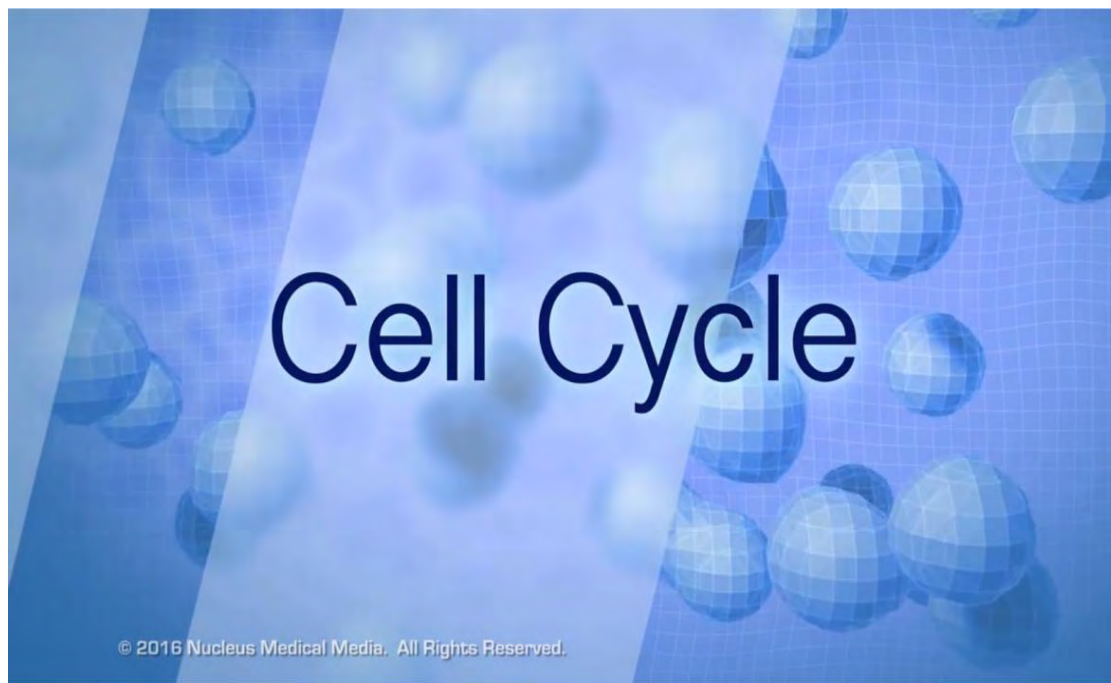
- Membrane transport types:
- Passive
 - Doesn't use energy
 - Molecules are moving from high concentration to low
- Active
 - Requires energy
 - Molecules are moving from low concentration to high
 - Done with the help of proteins called pumps

APPENDIX H continued

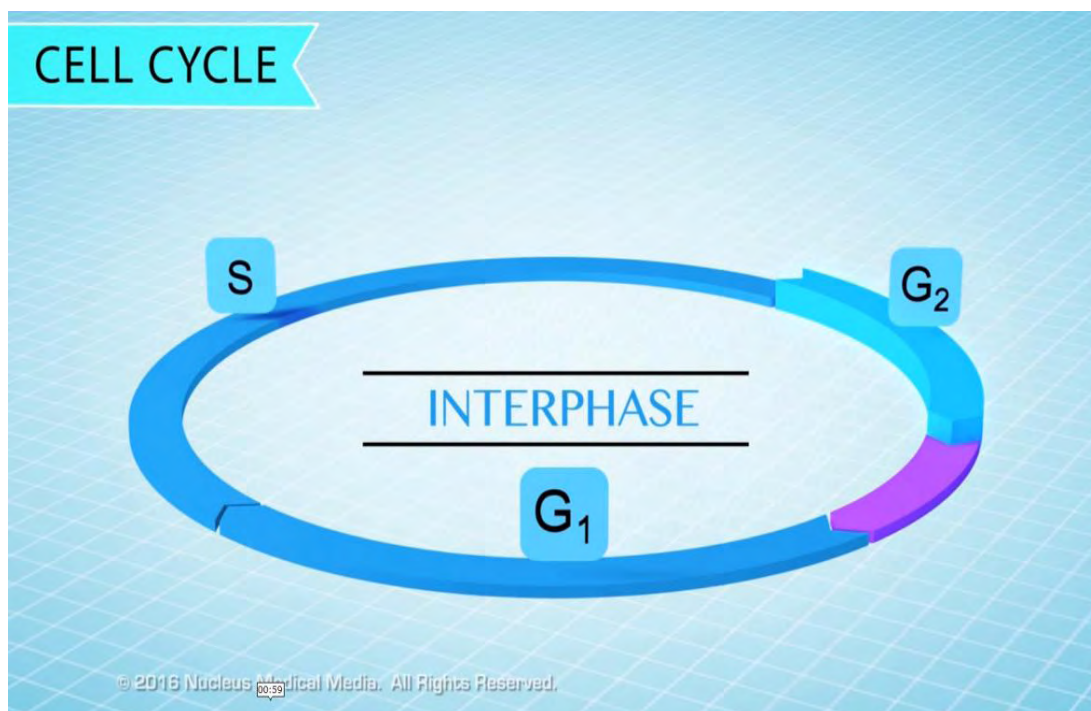
Week: Five

Lesson: Three

Topic: Cell Division



Source: <https://youtu.be/URUJD5NEXC8?si=ECbzEWAtQqiiOgoI>



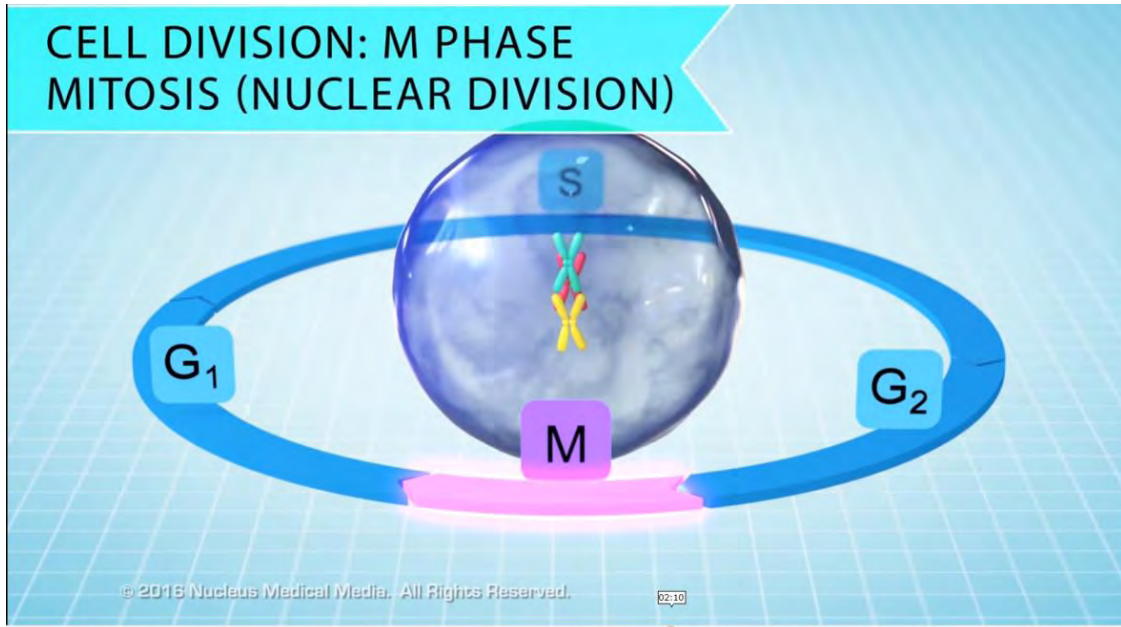
Source: <https://youtu.be/URUJD5NEXC8?si=ECbzEWAtQqiiOgoI>

APPENDIX H continued

Week: Five

Lesson: Four

Topic: Cell Division Continuation



Source: <https://youtu.be/GH1A76-h3c?si=ETxQXpyrpVieKK1i>

MEIOSIS

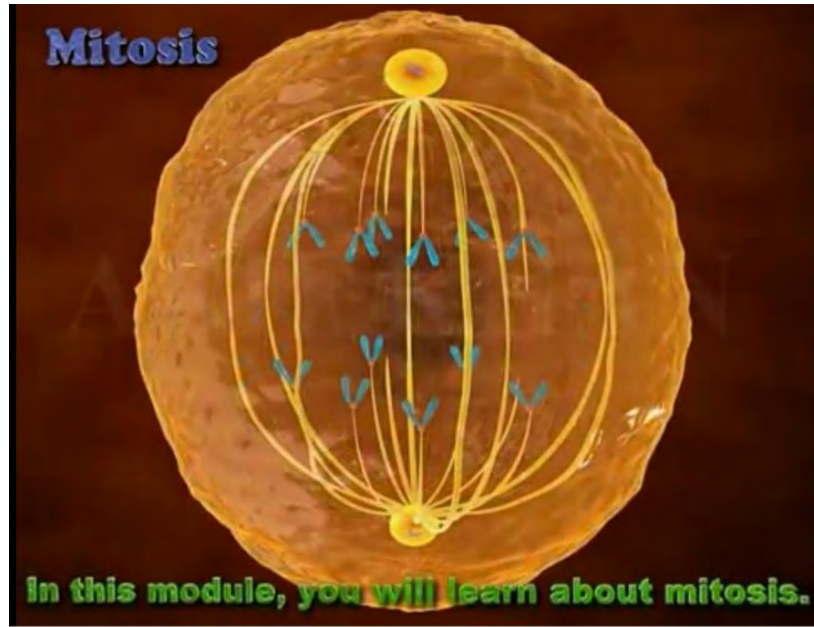
Source : <https://youtu.be/GH1A76-h3c?si=ETxQXpyrpVieKK1i>

APPENDIX H continue

Week: Five

Lesson: Four

Topic: Cell Division Continuation



Source: <https://youtu.be/GH1A76-h3c?si=ETxQXpyrpVieKK1i>

APPENDIX H continued

Week: Six

Lesson: Five

Topic: Mendelian Genetics Continuation

DIHYBRID CROSS

Homozygous plants
(For characters: Height and Flower colour)

TTPP → Tall and Purple flowered

tpp

Source: <https://youtu.be/NR3779ef9yQ?si=ndpjLebvAzghyggL>

DIHYBRID CROSS

Punnett square

F₂ Generation :

		♀			
	X	TP	Tp	tP	tp
♂	TP	TTPP	TTPp	TtPP	TtPp
	Tp	TTPp	TTpp	TtPp	Ttpp
	tP	TtPP	TtPp	ttPP	ttPp
	tp	TtPp	Ttpp	ttPp	ttpp

Source : <https://youtu.be/NR3779ef9yQ?si=ndpjLebvAzghyggL>


APPENDIX H continued

Week: Seven

Lesson: Six


Topic: Mendelian Genetics Continuation

- Introduction to Genetics and heredity
- Gregor Mendel – a brief bio
- Genetic terminology (glossary)
- Monohybrid crosses
- Patterns of inheritance
- Dihybrid crosses
- Test cross
- Beyond Mendelian Genetics – incomplete dominance



MENDELIAN GENETICS


- Introduction to Genetics and heredity
- Gregor Mendel – a brief bio
- Genetic terminology (glossary)
- Monohybrid crosses
- Patterns of inheritance
- Dihybrid crosses
- Test cross
- Beyond Mendelian Genetics – incomplete dominance



2
29

Introduction to Genetics

- **GENETICS** – branch of biology that deals with heredity and variation of organisms.
- **Chromosomes** carry the hereditary information (genes)
 - Arrangement of nucleotides in DNA
 - DNA → RNA → Protein




3
29

- Chromosomes (and genes) occur in pairs

Homologous Chromosome

- New combinations of genes occur at sexual reproduction
 - Fertilization from two parents



Click to add notes

APPENDIX I

INTERACTIVE MULTIMEDIA INSTRUCTIONAL APPROACH MANUAL

1. Introduction

1.1 Benefits for Pre-Service Science Teachers

1. **Deeper Subject Understanding:**

Interactive Multimedia Instructional Approaches simplify abstract concepts, such as cell biology or Mendelian genetics and ecosystems, making them easier to teach and learn.

2. **Enhanced Student Engagement:**

Interactive multimedia approaches maintain students' interest, helping pre-service teachers manage the classroom better.

3. **Skill Development:**

Builds proficiency in using technology, which is essential for modern classrooms.

4. **Inclusive Learning:**

Interactive Multimedia Instructional Approach caters to diverse learning styles such as visual, auditory, and kinaesthetic-ensuring no student is left behind.

2. Selecting Multimedia Approaches

2.1 Criteria for Effective Approaches

When selecting approaches, consider:

- **Alignment with Learning Objectives:** Ensure the approaches complements the biology curriculum.
- **Ease of Use:** Approaches should be intuitive for both the teacher and the students.
- **Engagement Features:** Look for approaches that allow students interaction, such as simulations or gamified quizzes and animations that can attract their attention.
- **Cost and Accessibility:** opts for free or affordable platforms that work across devices.
- **Scientific Accuracy:** Content should be sourced from credible educational providers or platforms.

3. Implementation in Teaching Biology

3.1 Planning and Preparation

1. **Choose Topics:** Identify which parts of the syllabus can benefit most from multimedia approach (e.g., cell biology, ecosystems, genetics).
2. **Set Goals:** Define clear learning objectives for the lesson.
3. **Prepare Resources:** Gather multimedia instructional content and test approaches for compatibility and functionality.
4. **Develop Lesson Plans:** Integrate multimedia instructional approach into existing lesson structures for seamless delivery in the form of PowerPoint presentation.

3.2 Integrating Multimedia Instructional Approach in Lessons

1. **Begin with Context:** Use a video or animation to introduce the concepts (e.g., a time-lapse of cell division).
2. **Interactive Engagement:** Incorporate a simulation or quiz to involve students actively.
3. **Discussion:** Facilitate a classroom discussion to reinforce learning and clarify doubts.
4. **Assessment:** Conclude with a quiz or assignment based on the multimedia instructional approach content.

4. Assessment and Evaluation

4.1 Measuring Learning Outcomes

- Conduct pre- and post-tests to evaluate the effectiveness of multimedia approaches.
- Use rubrics to assess skills like critical thinking and problem-solving.
- Observe students' participation and engagement during interactive sessions.

4.2 Collecting Feedback

- **Student Feedback:** Use surveys or focus groups to gather insights on approach usability and content clarity.
- **Peer Reviews:** Share experiences and receive suggestions from colleagues.
- **Self-Reflection:** Evaluate your own teaching performance using multimedia instructional approach.

5. Troubleshooting and Challenges

5.1 Addressing Technical Issues

- **Solution 1:** Provide offline options for multimedia content in case of connectivity issues.
- **Solution 2:** Maintain backups and test approaches beforehand.
- **Solution 3:** Seek technical support or training when needed.

5.2 Overcoming Pedagogical Barriers

- **Resistance to Change:** Demonstrate the benefits of multimedia instructional approaches through real-life examples or pilot lessons.
- **Training Gaps:** Offer workshops to pre-service science teachers on using specific approaches effectively.
- **Balancing Traditional and Modern Methods:** Use multimedia instructional approaches as a supplement, not a replacement, for hands-on activities.

6. Best Practices

6.1 Case Studies and Examples

- **Example 1:** A pre-service science teacher used Labster simulations to teach mitosis, resulting in a 40% improvement in student test scores.
- **Example 2:** Students who watched Bio-Interactive videos on ecosystems created accurate concept maps in group activities.

6.2 Tips for Sustainable Integration

- Regularly update tools and content to stay relevant.
- Encourage collaboration among educators to share resources and lesson plans.
- Create a repository of multimedia approaches for repeated use.

1.1 Purpose of the Manual

This manual is designed to help educators, particularly those training to be biology teachers, understand and implement interactive multimedia instructional approach to enhance their teaching practices and improve student academic performance in Biology. It provides practical, step-by-step guidance on selecting, using, and evaluating these tools, ensuring lessons are engaging and effective.

1.2 Background and Objectives

- **Background:**
The traditional teaching methods in Biology often rely heavily on rote learning and theoretical explanations. However, Biology is a subject that thrives on visualization and experimentation. Interactive multimedia instructional

approach, with its ability to combine animations, videos, and simulations coupled with PowerPoint presentation, bridges the gap between theoretical concepts and practical understanding.

- **Objectives:**

- Equip pre-service science teachers with the skills to integrate interactive multimedia instructional approach into their teaching.
- Demonstrate how interactive multimedia instructional approach can simplify complex Biology concepts.
- Improve students' engagement, understanding and academic performance.

2. Understanding Interactive Multimedia Instructional Approach

2.1 Definition and Components

Interactive multimedia instructional approach refers to the integration of various digital elements such as:

- **Text and Graphics:** Clear explanations and labelled diagrams.
- **Audio:** Narrations or sound effects to aid understanding.
- **Video and Animation:** Dynamic visuals to demonstrate processes like mitosis or meiosis or genetics.
- **Interactivity:** Features like quizzes, drag-and-drop exercises, and simulations that allow learners to engage actively.

These components make learning immersive, engaging and effective for all types of learners.

7. Conclusion and Future Directions

7.1 Summary of Key Points

7.2 Recommended Approaches and Platforms

1. For Visualization:

- **Labster:** Virtual lab simulations for experiments like DNA extraction.
- **PhET Interactive Simulations:** Models for biology processes like photosynthesis.

2. For Teaching Concepts:

- **BioInteractive:** High-quality animations on topics like evolution.
- **YouTube Channels:** Crash Course Biology, Amoeba Sisters.

3. For Collaboration and Quizzes:

- **Google Classroom:** Manage lessons, assignments, and discussions.
- **Kahoot/Quizizz:** Gamified quizzes to test understanding.

Interactive multimedia instructional approach:

- Simplify complex Biology concepts.
- Improve student engagement and understanding.
- Empower pre-service teachers to use modern teaching strategies.

7.3 Recommendations for Continued Development

- Expand the use of AR/VR for immersive Biology lessons.
- Foster partnerships with multimedia providers for better approaches.
- Conduct research to measure the long-term effect of multimedia on learning outcomes.

7.4 Sample Lesson Plan

Strand: Cycle

Sub-strand: The Human Circulatory System

Learning Indicator: Students will be able to describe the structure and function of the heart and blood vessels.

Interactive Multimedia Instructional Approach Activities:

Start with a short introductory video on the circulatory system. Use a 3D model of the human heart to explore its anatomy interactively. Conduct a simulation on blood circulation and the effects of exercise. End with a quiz on the circulatory system.

Conclusion:

By following these steps, you can create a comprehensive teaching manual that leverages interactive multimedia instructional approach to engage students and enhance their understanding of biology. The manual should offer clear instructions for educators, a variety of multimedia approaches, and guidance on best practices for integrating technology into the classroom.

APPENDIX J

WIAWSO COLLEGE OF EDUCATION INFORMED CONSENT FORM

Title of Study: “Using interactive multimedia approach to improve the academic performance of pre-service science teachers in some selected biology concepts”

PARTICIPANTS’ STATEMENT

I acknowledge that I have read or have had the purpose and contents of the participants’ information sheet read satisfactorily explained to me in a language I understand (English: [] ; Twi [] ; Fante []). I fully understand the contents and any potential implications as well as the right to change my mind (i.e., withdraw from the research) even after I have signed this form. I voluntarily agree to be part of this research. I agree to the audio recording of the interview (Yes: [] ; No: [])

Participant’s name or Initials:.....

Participant’s ID code:.....

Participant’s Signature/Thumb print/Mark (Specify):.....

Date:.....

RESEARCHER’S (INTERPRETER’S) STATEMENT

I interpreted the purpose and contents of the Participants’ Information Sheet to the aforementioned named Participant to the best of my ability in (English: [] ; Twi [] ; Fante []) to his proper understanding.

All question asked, appropriate clarification sort by the participant and answers were also duly interpreted to his/her satisfaction.

Name of Interpreter:.....

Signature of Interpreter:.....

Date:.....

Contact Details:.....