BINDURA UNIVERSITY OF SCIENCE EDUCATION

The effectiveness of brain-based learning in teaching genetics at ordinary level

A dissertation submitted in partial fulfilment of the requirements for the Honours Degree in Biology

by

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Declaration

I, Jacqueline Simango, hereby declare that the information provided in this form is true, accurate, and complete to the best of my knowledge and belief. I understand that providing false or misleading information may result in legal consequences, including but not limited to fines or imprisonment. I agree to promptly notify the relevant authorities of any changes to the information provided in this form. I acknowledge that the information provided in this form may be used for the purpose of [state the purpose, e.g., processing my application, verifying my identity, etc.].

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Date: 7th AUGUST 2024

Dedication

This dissertation is dedicated to my beloved husband, Edias, my daughter Panashe, my parents Mr and Mrs Homera, my sister Emily and my sister-in-law Tabitha and Munashe whose unwavering support and constant encouragement have been the driving force behind its creation.

Abstract

Brain-Based Learning (BBL) is an educational theoretical framework based on principles that derive from important findings about the structure and function of the brain through biology, psychology, and neuroscientific research, and forms a holistic context for a comprehensive instructional approach design. In the present study, a teaching intervention, using BBL elements, was designed and its effectiveness on secondary students' performance in Biology subject was assessed. A non-equivalent control group research design, using pretest and post-test, was implemented, involving an experimental group and a control group of form four students from Epworth High School. The results revealed that the students of the experimental group had a significantly higher mean score than the students of the control group on an achievement test, which was delivered as post-test, indicating that the suggested teaching approach had a positive effect on the students' improvement in academic performance. These results are discussed in the context of improving teaching practices, and supporting the use of BBL elements in constructing more efficient teaching practices for Biology courses.

Acknowledgement

I would like to express my sincere gratitude to my supervisor Dr Dziva for his patience, encouragement, corrections, precious time in assisting me in undertaking my dissertation. I would also like to give my appreciation to the Ministry of Primary and Secondary Education in association with Bindura University of Science Education for giving us the opportunity to further my studies.

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CHAPTER ONE

The problem and its setting

1.0 Introduction

It has been noted that most of the learners at Epworth High School are having difficulties in grasping the concepts of Genetics in their Biology subject. This results in them failing to attempt questions on genetics at their ZIMSEC examinations or even the school or District examinations. This brought a huge problem in such that they students have developed a negative attitude towards the biology subject at large and resulting in poor performance at their final examinations. The students' poor performance has become a concern to how well the problem can be solved so as to boost students' confidence in the biology subject when it comes to teaching genetic concepts which is part of the curriculum in the biology syllabus. The researcher has perceived that it is upon the teacher's interest in selecting the teaching strategy or technique which seems to be appropriate for the students at hand. This has brought an interest to the researcher to examine the most appropriate teaching technique when it comes to learning genetics so that the students have a better understanding in the concepts. This has brought to concern to the researcher to embark on the investigation to examine how effective is brainbased learning in the teaching of genetics at ordinary level in order to curb the problem faced at Epworth High School.

The chapter is going to give an insight of the background of the study to provide the necessary context and justification for the research being conducted, statement of the problem to clearly and concisely define the specific issue or concern that the study aims to address, research questions to provide a clear and specific focus for the study with formulated hypotheses for the provision to test predictions, significance of the study in order to justify the importance and relevance of the research, limitation to provide transparency and honesty , delimitations for the defining of the scope and boundaries of the research , assumptions to establish the foundation of the study and definition of key terms in order to create a common understanding.

1.0 Background of the study

As postulated Caine and Caine (1990), the use of brain-based learning strategies in the teaching and learning of science education, including the teaching of genetics, has been an area of growing interest and research in the modern age. The motivation behind the use of brain-based learning is that by aligning instructional methods with our understanding of how the brain processes and retains information, we can create more effective and engaging learning experiences for students. According to Zull (2002), the most crucial principles of brain-based learning are the idea that the brain is a complex, dynamic, and adaptive system. Hence, learning is not a passive process of absorbing information, but rather an active process of making connections, constructing meaning, and reorganising existing knowledge structures. With the regards from the framework of genetics education at the ordinary level, research has shown that many students struggle with understanding abstract concepts, such as DNA, genes, and inheritance patterns, it has been seen that most of the teachers in Zimbabwe make use of traditional teaching methods that rely heavily on lectures and textbook-based instruction which often fails to effectively address the challenges faced by learners in grasping the concepts of Genetics and results in poor performance of the content.

Brain-based learning approaches, supplementary, aim to influence the brain's natural tendencies and capabilities to enhance learning. For instance, by incorporating hands-on activities, storytelling, and collaborative learning, teachers can tap into the brain's sensory processing, emotional processing, and social learning mechanisms to help students better understand and retain genetic concepts. Collaborative learning allows students to engage in discussions, share perspectives, and build upon each other's knowledge, leading to a more comprehensive and robust understanding of genetics concepts and can make the learning of genetics more interactive, engaging, and relevant for students, fostering a greater interest and investment in the subject matter. Moreover, brain-based learning in genetics education can also help address common misconceptions such as that genetics is just about heredity and physical traits or genes and DNA are the same thing and alternative conceptions that students often develop for instance, genetic determinism where students may hold the misconception that genes completely determine an organism's characteristics and behaviours, failing to recognize the role of environmental factors and epigenetics. Genetics is typically taught as part of the biology curriculum at the ordinary level in schools. The specific approach and content vary across different educational systems and curricula and also that the use of teaching methodologies in delivering the concepts of genetics can complement and enhance more engaging and effective for learners. By engaging students in the learning process and encouraging them to make connections between new information and their existing knowledge, students can build more accurate and robust mental models of genetic phenomena. Therefore, the use of interactive teaching methods and encouraging students to actively confront and revise their existing mental models, brain-based learning approaches can help students develop more accurate and robust understandings of genetic phenomena.

Furthermore, research has highlighted the importance of incorporating collaborative learning strategies in genetics education. By working together in small groups, students can engage in peer-to-peer explanations, discussions, and problem-solving activities, which can deepen their understanding and strengthen their ability to apply genetic concepts.

1.1 Statement of the problem

The teaching and learning of genetics at the ordinary level can be particularly challenging for many students. Genetic concepts, such as DNA structure, inheritance patterns, and genetic variation, are often abstract and difficult for students to comprehend. The research aims to not only assess the effectiveness of brain-based learning but also to identify the cognitive and pedagogical mechanisms that contribute to its success.

Therefore, the problem that this research aims to address is the need to better understand the effectiveness of brain-based learning on the teaching and learning of genetics at the ordinary level. By investigating the effectiveness of these approaches, as well as the underlying cognitive and pedagogical mechanisms that contribute to their success, this research could provide valuable insights to help improve the quality and effectiveness of genetics education at the ordinary level.

1.2 Research questions

1.3.1. What are the most significant challenges students encounter in learning genetics?

1.3.2. How effective are brain-based learning strategies in improving student engagement, understanding, and retention of genetic concepts at the ordinary level?

1.3.3. What are the underlying cognitive and pedagogical mechanisms that contribute to the effectiveness of brain-based learning strategies in the context of genetics education?

1.3.4. How do the effects of brain-based learning strategies on genetics education at the ordinary level vary based on student characteristics, such as prior knowledge, learning preferences, or socioeconomic background?

Hypotheses

Based on the research questions provided, here are some hypotheses that could be explored in a study on brain-based learning in the teaching and learning of genetics at the ordinary level:

1. Students who receive brain-based instruction in genetics will demonstrate a significantly higher average score on a post-test of genetic concepts compared to students who receive traditional lecture-based instruction.
2. The effectiveness of brain-based learning strategies in genetics education will be moderated by student characteristics, such as prior knowledge and learning preferences, with students possessing certain characteristics benefiting more from these strategies than others.
3. Students who learn genetics through brain-based strategies will exhibit superior long-term retention of genetic knowledge, as measured by a delayed post-test administered six months after the intervention, compared to students who receive traditional instruction.
4. The effectiveness of brain-based learning strategies in genetics education will be mediated by enhanced student engagement, as measured by self-report questionnaires and classroom observations, and the promotion of conceptual understanding, as evidenced by students' ability to explain genetic concepts in their own words and apply them to novel scenarios.

1.3 Significance of the study

The study on the effectiveness of brain-based learning in teaching genetics at the ordinary level can have several significant implications. Brain-based learning approaches emphasize the importance of aligning teaching methods with how the brain naturally learns and processes information. By incorporating brain-based strategies, such as utilizing visual aids, hands-on activities, and connecting new concepts to prior knowledge, the study can help students better comprehend the complex topics in genetics. Increased engagement and active participation of students can lead to better retention of the subject matter. The study can provide empirical evidence on the effectiveness of brain-based learning in improving academic performance and learning outcomes for students studying genetics at the ordinary level. If the results show that brain-based learning approaches are more effective than traditional teaching methods, it can inform curriculum development and teacher training programs. The findings from the study can guide educators and policymakers in making informed decisions about the implementation of brain-based learning strategies in the teaching of genetics and other scientific disciplines. Educators can use the insights gained from the study to adapt their teaching methods and incorporate brain-based principles to enhance the learning experience for their students. Brainbased learning emphasizes the importance of creating a learning environment that is tailored to the individual needs and learning styles of students. The study can highlight how brain-based approaches can foster active learning, where students are actively engaged in the learning process, rather than passively receiving information. If the study demonstrates the effectiveness of brain-based learning in teaching genetics, the findings can be extrapolated to other subject areas and educational levels. The insights gained can contribute to the broader understanding of the benefits of aligning teaching methods with the principles of how the brain learns and processes information.

1.4 Limitations

When conducting a study on the effectiveness of brain-based learning in teaching genetics at the ordinary level, there are several potential limitations that researchers should be aware of such as, the study may be limited by the sample size, which may not be large enough to generalize the findings to a broader population. The study may also be limited by the demographic characteristics of the participants, such as their age, socioeconomic status, or previous academic performance, which may influence the generalizability of the results. The effectiveness of brain-based learning in teaching genetics may be influenced by contextual factors, such as the specific school environment, available resources, teacher training, and class size, which can vary across different educational settings. Controlling for these contextual factors may be challenging, making it difficult to isolate the specific impact of brain-based learning. Accurately measuring the effectiveness of brain-based learning in teaching genetics can be challenging, as it may involve assessing various aspects of student learning, such as content knowledge, problem-solving skills, and engagement. The choice of assessment tools and the reliability and validity of these measures can significantly impact the study's findings. There may be other variables, such as student motivation, prior knowledge, or teacher quality, that can influence the effectiveness of brain-based learning in teaching genetics. Controlling for these confounding variables may be difficult, and their impact on the study's results should be considered. The successful implementation of brain-based learning strategies in the classroom may depend on the fidelity of implementation by the teachers involved in the study. Variations in the way the brain-based learning approaches are implemented can affect the study's results and the ability to draw reliable conclusions. The study may be limited in its ability to assess the long-term impact of brain-based learning on student learning and retention of genetics concepts. Longitudinal studies may be necessary to evaluate the sustained effects of brain-based learning over time. The findings of the study may be specific to the particular educational context and the teaching of genetics, and may not necessarily be generalizable to other subject areas or educational levels.

1.5 Delimitations

Delimitations are the boundaries or scope that the researchers set for their study on the effectiveness of brain-based learning in teaching genetics at the ordinary level. The study may be delimited to a specific geographical region or educational system, such as a particular country, state, or district. This can help ensure the homogeneity of the educational context and facilitate the implementation of the brain-based learning approach. The researcher may choose to focus the study on a specific grade level or age range of students, such as secondary school students at the ordinary level. This can help ensure the relevance and appropriateness of the brain-based learning strategies for the target population. The researcher may delimit the study to cover specific genetics topics, such as Mendelian inheritance, DNA structure and function, or genetic variation, rather than attempting to address the entire genetics curriculum. This can allow for a more in-depth exploration of the effectiveness of brain-based learning for select, well-defined topics. The researcher may delimit the study to focus on specific brain-based learning strategies, such as the use of visual aids, hands-on activities, or the incorporation of real-world examples. This can help provide a clear comparison between the brain-based learning approach and more traditional teaching methods. The researcher may delimit the study to use specific assessment tools, such as standardized tests, performance-based tasks, or student surveys, to measure the effectiveness of the brain-based learning approach. This can ensure the consistency and comparability of the outcome measures used in the study. The researcher may delimit the study to a specific duration of the brain-based learning intervention, such as a single academic term or semester. This can help manage the feasibility and logistics of the study, as well as control for potential confounding factors that may arise over longer time periods. The researchers may choose to exclude certain student populations, such as those with specific learning disabilities or language barriers, to ensure the homogeneity of the sample and reduce the potential impact of these factors on the study's findings.

1.6 Assumptions

When conducting a study on the effectiveness of brain-based learning in teaching genetics at the ordinary level, researchers may make several assumptions. The researchers may assume that the students participating in the study have a certain level of prior knowledge, cognitive abilities, and motivation to learn genetics. They may also assume that the students are representative of the broader population of ordinary-level students. The researchers may assume that the teachers involved in the study have the necessary training, knowledge, and skills to effectively implement brain-based learning strategies in the classroom. They may also assume that the teachers are committed to adopting and adhering to the brain-based learning approach throughout the study. The researchers may assume that the brain-based learning strategies will be consistently and accurately implemented by the teachers across the different classrooms or schools involved in the study. They may assume that any variations in implementation will not significantly impact the study's findings. The researchers may assume that the necessary resources, such as technological equipment, learning materials, and classroom facilities, are available and accessible to support the implementation of the brainbased learning approach. The researchers may assume that the educational context, such as the curriculum, school policies, and teaching schedules, remain stable throughout the duration of the study. They may assume that there are no major disruptions or changes that could influence the study's findings. The researchers may assume that the assessment tools used to measure the effectiveness of the brain-based learning approach are valid, reliable, and appropriate for the target population. They may assume that the assessment measures accurately capture the intended learning outcomes. The researchers may assume that the study will be conducted in an ethical manner, with informed consent from the participants and their guardians, and with appropriate measures in place to protect the privacy and well-being of the students.

1.7 Definition of terms

- Brain-based learning: An educational approach that utilizes research findings from neuroscience and psychology to design teaching strategies that align with how the brain learns best (Jensen, 2008). This approach emphasizes active learning, engagement of multiple senses, and the creation of meaningful connections to enhance student understanding and retention.

- Genetics: The scientific study of heredity and the transmission of traits from parents to offspring. It encompasses the study of genes, DNA, chromosomes, and the biological processes that underlie inheritance (Hartl & Ruvolo, 2012).

- Ordinary level: Refers to the secondary education level in Zimbabwe, typically comprising students in Forms 1 to 4.

- Traditional teaching methods: Instructional approaches that primarily rely on lectures, textbooks, and rote memorization, with limited emphasis on active learning, student engagement, or the application of knowledge to real-world contexts.

- Neural plasticity: The brain's ability to reorganize itself by forming new neural connections throughout life. This concept is central to brain-based learning, as it suggests that the brain can be modified and strengthened through targeted learning experiences.

- Multisensory learning: A brain-based learning strategy that involves engaging multiple senses (visual, auditory, kinaesthetic, etc.) during the learning process to enhance understanding and retention.

- Collaborative learning: A brain-based learning strategy that emphasizes active participation, interaction, and cooperation among students to achieve shared learning goals.

- Genetic variation: The differences in DNA sequences and traits that exist among individuals within a population or species (Griffiths et al., 2000). This variation is the raw material for evolution and is essential for adaptation and survival.

1.8 Summary

The chapter covers the introduction of the study, background of the study, statement of the problem, research questions, hypotheses, significance of the study, delimitations of the study, limitations of the study and definition of key terms. The chapter has also provided the rationale and justification for the study, setting the stage for the research and highlighting the need to explore the effectiveness of brain-based learning in the teaching of genetics at the ordinary level. Integrating brain-based learning into the existing genetics curriculum and aligning it with the assessment practices can be a challenge as well as implementing and evaluating the effectiveness of brain-based learning in the classroom can be time-consuming and resource intensive, particularly in the context of already-packed curricula and busy school schedules. provide the rationale and justification for the study, setting the stage for the research and highlighting the need to explore the effectiveness of brain-based learning in the teaching of genetics at the ordinary level. The next chapter is going to articulate the review of related literature by different scholars on a variety of studies similar or associated to the research topic, addressing the research questions and objectives that have been presented, establishing the context, importance, and approach of the study, providing a logical flow from the identification of the research problem to the planned investigation of the effectiveness of the brain-based learning approach.

CHAPTER TWO

Review of Related Literature

2.0 Introduction

In order to tackle the review of Related Literature, this chapter will look brain-based theories, the importance of brain-based, the strategies of brain-based learning in genetics education, challenges and learning needs of brain-based learning, how effective are brain-based strategies, cognitive and pedagogical mechanisms of brain-based learning, effects of brain-based learning and long- term effects of brain-based learning.

2.1 Brain-Based Learning Theories

The characterization of brain-based learning theory emphasizes that it is "an integrated system in itself, rather than a pre-designed structure. Brain-based learning is a teaching strategy that uses knowledge about the developing brain and uses it in education. There are a lot of theories, findings, and hypotheses, that have been used to explain the brain behind brain-based learning.

2.1.1 Cognitive theory on brain-based learning

Conferring to Mayer (2001), information is encoded and stored in the brain in two different ways: verbal (linguistic) and visual (non-linguistic). In the context of genetics, teachers can leverage both verbal explanations and visual representations (diagrams, models, simulations) to help students process and retain the information more effectively. Combining verbal and visual inputs can lead to stronger memory encoding and retrieval. This theory also emphasizes the limitations of the working memory and the importance of managing the cognitive load placed on students during learning. In genetics, complex concepts and processes can easily overwhelm the working memory. Teachers should aim to present information in a structured and manageable way, breaking down tasks into smaller, more digestible steps. Techniques like scaffolding, worked examples, and providing visual aids can help reduce the cognitive load and facilitate deeper understanding.

2.1.2 Constructivism

Constructivist theory posits that students actively construct their own knowledge and understanding by building upon their prior experiences and existing knowledge. In the context of genetics, teachers can encourage students to actively engage with the material, ask questions, and make connections between new concepts and their prior knowledge. This approach promotes deeper learning, as students are actively involved in the process of meaning-making, rather than passively receiving information.

2.1.2.1 Cognitive Constructivism

Piaget's (1964), suggests that individuals construct their own understanding of the world through a process of assimilation and accommodation. In genetics, teachers can design learning experiences that challenge students' existing mental models and encourage them to modify their understanding to accommodate new information. For example, students may have preconceptions about genetic inheritance that need to be adjusted as they learn about concepts like Punnett squares, genotypes, and phenotypes.

2.1.2.2 Social Constructivism (Vygotsky's Theory)

According to Vygotsky's (1978), the role of social interactions and cultural influences in the learning process. In the context of genetics, teachers can create opportunities for collaborative learning, where students engage in group discussions, peer teaching, and shared problem-solving. This social interaction can help students clarify their understanding, identify misconceptions, and develop a more comprehensive grasp of genetic concepts.

2.1.2.3 Experiential Learning (Kolb's Theory)

Kolb's (2014), suggests that effective learning occurs through a cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation. In the teaching of genetics, teachers can design learning activities that allow students to actively engage with genetic phenomena, make observations, conceptualize the underlying principles, and then apply their knowledge in new situations. For example, students could conduct experiments with fruit flies or simulations of genetic inheritance, followed by reflection and discussion.

2.1.2.4 Situated Cognition

As postulated by Kirshner and Whitson (1997), the theory emphasizes the importance of learning in authentic, real-world contexts that are meaningful and relevant to the learner. In genetics, teachers can relate the concepts to students' everyday lives, local communities, or current events, such as genetic testing, personalized medicine, or genetically modified organisms. By situating the learning in relevant contexts, students can better understand the practical applications and significance of genetic knowledge.

2.1.2.5 Scaffolding

Scaffolding involves providing temporary support and guidance to help students progress towards their learning goals, gradually removing the support as the students become more independent, Wood, Bruner and Ross (1976). In the teaching of genetics, teachers can use scaffolding techniques, such as providing step-by-step instructions, visual aids, or guiding questions, to help students navigate complex genetic concepts and processes.

2.1.3 Social-cultural approaches

Social-cultural approaches to brain-based learning are highly relevant in the teaching of genetics at the ordinary/high school level. The following are some key theories on social-cultural approaches and how they can be applied in the teaching and learning of genetics at ordinary level.

2.1.3.1 Distributed Cognition

According to Hutchins (1995), the theory recognizes that cognition is not solely an individual process, but is distributed across individuals, tools, and the environment. In the genetics classroom, teachers can leverage this by encouraging students to collaborate, share resources, and use various tools (e.g., simulations, databases, genetic testing kits) to collectively construct their understanding of genetic concepts. This approach fosters a community of learners who can learn from and support one another, mirroring the collaborative nature of scientific research in genetics.

2.1.3.2 Cultural-Historical Activity Theory (CHAT)

CHAT emphasizes the role of cultural, historical, and institutional contexts in shaping the learning process, Roth and Lee (2007). When teaching genetics, teachers can consider the cultural and historical perspectives that have influenced the development of genetic knowledge, such as the impact of societal values, religious beliefs, and scientific advancements over time. This can help students understand the broader context in which genetic concepts and discoveries have emerged, and how they continue to evolve within different cultural and societal frameworks.

2.1.3.3 Funds of Knowledge

According to Hogg (2011), the funds of knowledge approach recognizes that students bring valuable knowledge and experiences from their home and community contexts, which can be leveraged in the learning process. In the teaching of genetics, teachers can tap into students' diverse funds of knowledge, such as their cultural beliefs, traditional practices, or personal experiences related to genetics (e.g., genetic conditions, agricultural practices). By integrating these funds of knowledge, teachers can create a more inclusive and culturally responsive learning environment, where students' backgrounds and experiences are valued and used to enrich their understanding of genetic concepts.

2.1.4 Neuroplasticity

Referring to Degen (2011), the brain rewires itself after damage, that is influences in the environment can stimulate growth and reorganization on the neural level. Of course, this is still very limited and it's not our intention to downplay the severity of brain injuries or other impairments. However, the implications of neuroplasticity are great. The capacity of the brain to be modifiable by experience, especially in early childhood, highlights the importance of exposure and cognitive stimulation in the early years. Neuroplasticity allows the brain to form new neural connections and strengthen existing ones as students encode and consolidate genetic information. Through repeated exposure to genetic concepts, principles, and problemsolving strategies, the brain can establish strong, efficient neural pathways associated with the processing and recall of genetic knowledge.

This theory has led to the emergence of two contradictory types, the first is learning that relies on and is harmonious with the brain, while the second is the opposite, working against the brain's pull signals, causing them to not learn properly, Al-Salti, (2004). Because this theory is based on the functioning of the brain and its unique structure, and the brain is not prevented from carrying out its natural processes, the learning process occurs naturally. Brain stimulation (in brain-based learning theory) generates enormous energy of readiness to accept learning that is not present in the usual way, which sometimes fails in the learning process due to lack of encouragement and brain stimulation. This may hinder the learning process because it lacks the natural processes that occur in the brain Bruer (1999).

Brain-based learning, as an instructional strategy, is a natural approach that does not involve many of the educational complexities that other strategies do. It is based on the brain in its natural state, specifically integrated brain functions. According to Scientists researches, neuroplasticity allows the brain to reorganize and modify existing neural connections, enabling the correction of genetic misconceptions and the development of accurate understanding. Therefore, educators can identify and address common genetic misconceptions through targeted instructional strategies, such as providing corrective feedback, presenting counterexamples, and facilitating discussions that challenge and reshape students' existing mental models. By creating opportunities for students to confront and revise their understanding, educators can capitalize on the brain's neuroplasticity to foster the development of robust, scientifically accurate genetic knowledge. Jensen (2007).

2.1.5 Nutrition and the Developing Brain

According to Duman (2013), breastfeeding promotes IQ, brain size, and white matter development. Iron deficiency has severe consequences for neurodevelopment, especially in the hippocampus (memory), Yorke (2007). These consequences can result in long-lasting abnormalities. While this cluster of theories is not directly related to specific teaching practices, they’re vital to the children’s health and cognitive abilities. Moreover, educational institutions can use these findings to improve food services, while parents can consult with nutritionists to improve common learning difficulties.

2.1.6 Language and Memories

Mayer (1997), postulated that children with a larger technical vocabulary might be able to more easily remember the lecture. In addition, there are findings that bilingual children’s memories are closer to one or another language, which will affect the retrieval process. After dominating the field for several centuries, Watson (1950), emphasized the importance of the environment in shaping individual behaviour. Behaviourists focused their research on the relationship between observable behaviour and environmental stimuli. Notable figures associated with this theory include Watson, Pavlov, Thorndike, Skinner, and Bandura. An important feature of this theory is the principle of reinforcement and punishment. Psychologist Skinner (1953) emphasized that the most effective way to teach individuals is to adjust their minds through rewards and punishments. This theory continues to influence educational settings and continues to have supporters and advocates, even half a century after its inception. This happens because old ideas find a comfortable home in the minds of administrators and teachers who fear the unknown. They believe that sticking to proven methods gives a sense of confidence and security.

Due to the cumulative nature of science, which is based on the accumulation of human knowledge from different fields, different theories and strategies may have similarities in some areas but differ in approach and reasons. Brain-based learning theory may also share similarities with other theories and strategies, although it intersects in specific areas and differs in ideas and causes. Because brain-based learning theory is an extension of discoveries in educational science and a natural progression of other learning theories, it incorporates previous theories to improve the educational process and pedagogical methods, Abuhatb and Sadik (1992). Genetics involves a specialized vocabulary and terminology, such as alleles, genotypes, phenotypes, DNA, RNA, and various biological processes. Understanding and comprehending this specialized language is essential for students to grasp the fundamental concepts and principles of genetics. Facilitators can support students by explicitly teaching and reinforcing the meaning of genetic terms, using visual aids, analogies, and contextual examples to help students associate the language with the corresponding genetic concepts.

Although there are some conceptual similarities between Skinner's theory of behaviourism and the new brain-based learning theory, there are also some significant differences. The theoretical framework and associated neural mechanisms are not the same. According to Skinner (1953), learning is related to neural connections in the nervous system and stimuli from the environment, and behaviour is reinforced or inhibited by punishment or reward. In the new brain-based learning theory, attention is focused on the brain's functions and related neural systems that appear related to learning. Learning is characterized by being derived from complex neural interactions in the brain, involving systems based on chemistry, neuron firing, psychology, genetics, biology, and even computation. Unlike behaviourist theory, which relies solely on observable behaviour and external stimuli, brain-based learning theory focuses on internal brain processes and their impact on learning and academic performance. Genetics often involves the application of concepts to solve problems, such as predicting outcomes of genetic crosses or analysing inheritance patterns. Language and memory play a vital role in this process, as students need to retrieve relevant genetic knowledge, understand the problem context, and communicate their problem-solving strategies effectively. Teachers can help students develop problem-solving skills by providing opportunities to practice applying genetic concepts in various scenarios and encouraging them to articulate their thought processes.

2.1.7 Beliefs Predict Achievement

Dweck (2000) coined the term “growth vs. fixed mindset”, which highlights how thinking that intelligence is either malleable or fixed turns into an advantage or obstacle for achieving academic success. Kids who believe that they can improve through hard work don't give up easily and are not discouraged by temporary setbacks, as opposed to those who believe that intelligence is innate and defines their identity.

The concept of brain-based learning only emerged in the 1980s due to advances in neuroscience and cognitive neuroscience. Degen (2011) explained that traditional classroom practices prevalent in most schools significantly impede students' cognitive processes. Baqsmawi, (2006) claims that if we allow the brain to perform its natural functions without hindrance, learning will definitely occur. He further emphasized that every human can learn because humans are born with a powerful processing brain. However, traditional schools often hinder the natural learning process through fear, ignorance, and rigidity. He saw this theory as an integration of various fields of science, such as physiological and biochemical neuroscience, medicine, computer science, and educational science.

Brain-based learning theory is based on an integrated system in which cognitive and perceptual aspects are linked to the physiological (functional) aspect of the brain. Every human brain can learn, regardless of age, gender or cultural background. It is equipped with a set of skills that allow it to explore various patterns, engage in self-correction, learn and gain experience through information analysis, self-reflection and, consequently, creativity and innovation, AlSulti, (2004). Brain-based learning theory, which emerged from brain research, emphasizes learning through mental engagement, activity, and effectiveness thus learning with the brain in mind. This requires stimulating the brain, providing the desired motivation and motivation to accept learning. In addition, it is necessary to give meaning and relevance to what students learn, promote enjoyment in the learning process, eliminate hazards, and incorporate multiple sensory stimuli into the educational process, and other features that contribute to the effectiveness of brain-based learning, Jensen, (2000).

2.1.8 Social Development of Learning

Conferring to Schaefer (1979), the social development of learning is a classic theory that has influenced a lot of classrooms by now. It’s not a new theory, but nonetheless, it wonderfully illustrates the effectiveness of brain-based learning theories in the classroom. As proposed by Vygotsky (1860), social interaction profoundly impacts cognitive development and also proved, that biological and cultural development do not develop separately from one another, They both interfere and enhance or completely impair children’s progress.

Brain-based learning theory can be viewed as an evolution of previous educational theories, using knowledge from neuroscience and other scientific disciplines to formulate learning and enhance educational methods. Overall, although there are some similarities and similarities between the behaviourist learning theory associated with Skinner and the brain-based learning theory, they are distinct theories that independently focus on different mechanisms or components of the learning process. Each learning theory provides a lens through which learning can be viewed - one theory emphasizes external behaviour and its associated stimuli (as was the case with behaviourist theory), while the other theory focuses on internal neural and cognitive processes taking place within the brain and which form the basis of learning. As a result of extensive educational research, new theories have emerged advocating the need to focus on the student, rather than the teacher, as the central element of the educational process. This led to the development of cognitive theory, pioneered by the psychologist Bruner, who contributed to the development of cognitive psychology and cognitive learning theories in the areas of educational psychology and educational philosophy. Bruner's principles are based on classification theory, which states that "perceiving is categorizing, imagining is categorizing, learning is constructing categories, and deciding is categorizing." It was from Bruner's classification theory that the idea of relying on the mind (the human brain), brain processes and neuroscience to understand its mechanisms and vital functions arose, leading to the application of this knowledge to a new brain-based strategy. This strategy is called brain-based strategy or brain-informed strategy, Jensen (2007).

2.2 The Importance of Brain-Based Learning in Genetics Education

According to Mustafa (2001), engaging the Brain's Natural Learning Processes, the human brain is naturally wired to discover patterns, make connections, and engage in active learning. Brain-based learning techniques, such as the use of visual aids, hands-on activities, and storytelling, can tap into these natural learning processes and make genetics content more accessible and memorable for students. The other importance is that it addresses common misconceptions, genetics is a subject frequently perforated with common misconceptions, such as the belief that traits are determined by a single gene or that genetic inheritance is a straightforward process therefore brain-based learning strategies can help students identify and correct these misconceptions by encouraging them to actively participate in the learning process and challenge their own preconceptions. Teachers can use multiple representations, such as diagrams, simulations, and real-world examples, to demonstrate the complex process of gene expression and the influence of environmental factors on phenotypic traits. This can help students understand that the relationship between genes and physical traits is not a simple, direct one, but rather a dynamic and multifaceted process.

Brain-based learning also enhances long-term retention; by bringing into line teaching methods with the brain's natural learning tendencies, brain-based learning is considered the best in making learners to improve long-term retention of genetic concepts. Another misconception is that, genetic inheritance follows a simple dominant-recessive pattern. Teachers can present students with scenarios or examples that challenge the simplistic dominant-recessive model of inheritance. This cognitive conflict can drive students to reexamine their understanding and seek new explanations for more complex patterns of inheritance, such as incomplete dominance, codominance, and polygenic traits. This is particularly important in genetics, where understanding foundational principles is crucial for building knowledge and applying it to more complex topics.

Moreso, students often have a misconception that Genes and DNA are the same thing, therefore, teachers can use conceptual metaphors to help students differentiate between genes and DNA. For example, they can compare the relationship between genes and DNA to the relationship between a book (DNA) and its chapters (genes).

This metaphor can help students understand that genes are specific sections or units within the larger DNA molecule. Brain-based learning strategies are highly effective in promoting the formation of meaningful connections and the integration of new information with existing knowledge. Brain-based learning emphasizes the use of multiple sensory modalities (visual, auditory, kinaesthetic, etc.) to engage students and facilitate the encoding of information.

With the use of multisensory engagement, students actively engage with the learning content through various senses, they create stronger neural connections and can more easily integrate new information with their existing knowledge. Furthermore, brain-based strategies such as contextual learning encourage the presentation of information in relevant, real-world contexts that are meaningful to students. By situating the learning in familiar and authentic contexts, students can more easily relate the new information to their prior experiences and existing knowledge, fostering deeper understanding and retention. According to Mayer (2000), brainbased strategies that involve collaboration, such as group discussions and peer teaching, allow students to share their perspectives, challenge each other's thinking, and co-construct knowledge. This social interaction and exchange of ideas can help students make connections, identify gaps in their understanding, and integrate new information with their existing knowledge.

2.3 Brain-Based Learning Strategies in Genetics Education

Brain-based strategies in genetics education refer to the integration of research-informed approaches that align with the fundamental principles of how the human brain learns and processes information. These strategies are based on the understanding that effective learning occurs when instructional methods are tailored to the cognitive, emotional, and social aspects of the brain's functioning. Strategies that can be used in brain-based learning enhances engagement, promote understanding and facilitate retention. According to Caine and Caine (2016), the context of genetics education, brain-based strategies can be particularly valuable in helping students develop a deep and lasting understanding of complex genetic concepts, as well as the ability to apply this knowledge to real-world situations. The following brain-based strategies that can be leveraged in genetics education.

2.3.1 Strategies for Enhancing Engagement

Engaging learners in the study of genetics is crucial, as the subject matter can often be perceived as dense, abstract, and highly technical. By employing a variety of strategies that cater to different learning styles and preferences, educators can foster a more dynamic and immersive learning experience, thereby enhancing learners' engagement with the subject matter. One effective strategy is the incorporation of multimedia elements, such as interactive simulations, animated videos, and virtual lab experiences. These visual and interactive resources can help bring complex genetic concepts to life, allowing learners to visualize and manipulate the underlying processes and mechanisms. By engaging multiple sensory modalities, these multimedia tools can capture learners' attention and stimulate their curiosity about the subject. Fostering active participation is another key strategy for enhancing engagement in genetics. This can involve designing thought-provoking group discussions, problem-solving exercises, or hands-on activities that require learners to actively engage with the material. By actively applying their knowledge and critical thinking skills, learners are more likely to develop a deeper understanding and investment in the subject matter.

Providing immediate and constructive feedback is also critical for sustaining learner engagement. By offering timely and insightful feedback on their performance, educators can reinforce learners' progress, address any misconceptions, and motivate them to continue exploring the subject with enthusiasm. Personalizing the learning experience is another powerful strategy for enhancing engagement. This might involve tailoring the content, pace, and delivery to the specific needs, interests, and learning preferences of the individual learners. By creating a more personalized and relevant learning environment, educators can foster a stronger sense of ownership and investment in the subject matter.

Conferring to Jensen (2008), collaborative learning can provide significant benefits in genetics education. By engaging students in group-based activities and problem-solving, collaborative learning approaches can enhance their understanding of genetic concepts, develop critical thinking skills, and foster valuable interpersonal skills. There are various benefits of implementing collaborative learning in genetics education which includes enhanced understanding of Genetic concept. When students work together to explore and discuss genetic principles, they can collectively build a deeper and more nuanced understanding of the subject matter. Peer-to-peer interactions allow students to clarify misconceptions, explain concepts to one another, and collectively construct knowledge. Collaborative discussions encourage students to consider multiple perspectives, which can lead to a more comprehensive grasp of genetic phenomena. There is development of critical thinking and problem-solving skills. Collaborative learning tasks, such as designing experiments, analysing genetic data, or solving complex genetics-related problems, require students to engage in critical thinking and problem-solving. Through working together to identify issues, generate hypotheses, and devise solutions, students develop the ability to think critically and apply their genetic knowledge to real-world situations. The process of collaborative problem-solving also helps students develop strategic thinking, decision-making, and innovative problem-solving abilities. Collaborative learning activities necessitate effective communication, as students must articulate their ideas, listen to others, and negotiate solutions. Students learn to express their thoughts clearly, ask clarifying questions, and engage in constructive dialogue to reach a shared understanding.

Howard (2003), collaborative work also fosters teamwork, conflict resolution, and leadership skills, which are essential for success in various academic and professional settings. The social and interactive nature of collaborative learning can increase student motivation and engagement, as they feel a sense of shared responsibility and ownership over the learning process. Peer support and the opportunity to learn from one another can help students overcome challenges and maintain a positive attitude towards learning genetics. Collaborative activities can also promote a sense of community and camaraderie within the classroom, which can contribute to a more enjoyable and enriching learning environment. Collaborative learning brings together students with diverse backgrounds, experiences, and learning styles, which can lead to the exploration of a broader range of perspectives and ideas. This diversity can be particularly beneficial in genetics education, where complex concepts may require multiple approaches and viewpoints to fully comprehend. Collaborative learning can also create opportunities for students with different strengths and abilities to contribute to the group's success, fostering a more inclusive and equitable learning environment.

Finally, incorporating elements of novelty and surprise can help maintain learner engagement throughout the study of genetics. Introducing unexpected or thought-provoking elements, such as case studies, real-world applications, or cutting-edge research, can stimulate learners' curiosity and keep them engaged in the dynamic and ever-evolving field of genetics. By leveraging these engagement-enhancing strategies, educators can create a learning environment that is both intellectually stimulating and emotionally engaging, ultimately fostering a deeper and more meaningful understanding of the fundamental principles of genetics.

2.3.2 Strategies for Promoting Understanding

Genetics is a complex and multifaceted subject that involves understanding a wide range of concepts, from the structure and function of DNA to the inheritance of traits and the mechanisms of genetic expression. To help learners develop a deep and meaningful understanding of genetics, educators can employ various strategies that leverage the principles of brain-based learning.

One key strategy is to activate and build upon the learners' prior knowledge. Many students come to the study of genetics with some existing knowledge, whether it's from their personal experiences, previous coursework, or everyday observations. By tapping into these existing mental models and connections, educators can help learners more effectively integrate new information and concepts into their existing knowledge base. Another important strategy is to use multiple representations of genetic concepts. This can include the use of visual aids, such as diagrams, simulations, or interactive models, to help learners visualize the complex structures and processes involved in genetics. Additionally, incorporating hands-on activities, such as experiments or problem-solving exercises, can help learners develop a more tangible understanding of genetic principles.

Furthermore, promoting deep processing and encouraging learners to actively engage with the material can significantly enhance their understanding. This might involve asking learners to explain key concepts in their own words, analyze case studies, or apply genetic principles to solve real-world problems. By engaging in these higher-order thinking activities, learners are more likely to develop a robust and flexible understanding of genetics that they can draw upon in various contexts. According to Zengin (2017), use of storytelling and relatable analogies can have a significant impact on the design and effectiveness of genetics curriculum. By incorporating these elements, educators can create a more engaging, meaningful, and impactful learning experience for students. Storytelling and analogies can help students grasp complex genetic concepts by providing them with familiar, tangible frameworks to work with. Analogies that liken genetic structures or processes to everyday objects or experiences can make abstract ideas more comprehensible and relatable and also that narratives can illustrate the real-world applications of genetic knowledge or the personal experiences of individuals affected by genetic conditions can help students connect the content to their own lives. Storytelling and the use of relatable analogies can significantly increase student engagement and motivation in genetics education. Narratives that capture the human element of genetics, such as the triumphs and challenges faced by scientists or the personal journeys of people with genetic disorders, can foster emotional connections and a sense of investment in the subject matter. Analogies that draw connections between genetics and students' hobbies, interests, or personal experiences can make the content more personally relevant and engaging. The memorable and relatable nature of stories and analogies can enhance students' ability to retain and recall genetic concepts. When students can associate genetic principles with familiar, meaningful analogies or narratives, they are more likely to internalize the information and be able to apply it in new contexts.

Shbataat (2015), mentioned that incorporating storytelling and analogies throughout the curriculum, rather than as isolated examples, can help students develop a more cohesive and transferable understanding of genetics. Storytelling and analogies can bridge the gap between genetics and other disciplines, such as history, literature, social studies, or even the arts. Narratives that explore the societal, ethical, or cultural implications of genetic discoveries can help students understand the interdisciplinary nature of genetics. Analogies that draw connections between genetic principles and concepts in fields like physics, chemistry, or computer science can facilitate cross-disciplinary learning and a more holistic understanding of science. Storytelling and the use of relatable analogies can make genetics curriculum more inclusive and accessible for students with diverse learning styles, backgrounds, and experiences. Narratives that feature characters and stories from a variety of cultural and socioeconomic backgrounds can help students from diverse communities see themselves represented in the curriculum. Analogies that resonate with students' lived experiences can foster a sense of belonging and help overcome potential barriers to understanding genetic concepts. Lastly, providing opportunities for learners to receive timely and constructive feedback can be crucial for promoting understanding. Formative assessments, such as quizzes or short writing assignments, can help learners identify areas of strength and weakness, and allow educators to provide targeted guidance and support.

2.3.3 Strategies for Facilitating Retention

Retention, or the ability to recall and apply learned information over time, is a critical component of successful learning in genetics. Given the inherent complexity and breadth of topics within the field of genetics, educators must employ targeted strategies to help learners cement their understanding and effectively retain the key concepts and principles.

The strategy for facilitating retention in genetics is the use of spaced repetition. This approach involves breaking down the content into manageable chunks and distributing the learning over multiple sessions, rather than concentrating it in a single intensive study session. This spaced approach allows the brain to create stronger neural connections and better consolidate the information in long-term memory Spaced repetition and memory consolidation are powerful strategies that can significantly enhance the learning and retention of genetic concepts in educational settings. By incorporating these principles into genetics curriculum design, educators help students develop a more robust and long-lasting understanding of the subject matter, Yorke (2007). Spaced repetition involves the systematic and intentional practice of genetic content at increasing intervals over time, rather than massed or cramming-based approaches. This spacing effect has been shown to improve long-term retention and recall of information, as it allows the brain to form stronger neural connections and consolidate the learned material. In the context of genetics education, spaced repetition can take various forms, such as revisiting key genetic concepts at regular intervals throughout the curriculum, interleaving different topics (e.g., Mendelian genetics, molecular genetics, population genetics) to encourage the brain to make connections. Incorporating retrieval practice exercises, such as quizzes or flashcards, at spaced intervals. Memory consolidation is the process by which new information is transformed into long-term memories, strengthening the brain's ability to retain and recall that information. In the context of genetics education, memory consolidation can be facilitated through allowing for sufficient time and opportunities for students to actively engage with and process the content, rather than passive exposure.

Furthermore, interleaving different topics or subtopics within genetics can promote better learning and transfer of knowledge. Yorke (2007) further insisted that by exposing students to a variety of genetic concepts and problems, they are less likely to rely on superficial or rote learning strategies and are instead encouraged to develop more flexible and adaptable problem-solving skills. Introducing variations in the presentation or context of genetic problems can also help students recognize patterns, make connections, and apply their knowledge more effectively. Through incorporating frequent retrieval practice exercises, such as quizzes, short-answer questions, or problem-solving tasks, can strengthen students' ability to recall and apply genetic knowledge. Formative assessments, as discussed in the previous response, can serve as a form of retrieval practice, providing valuable feedback to both students and educators. Regular retrieval practice and formative assessments can help identify and address any gaps or misconceptions in students' understanding of genetics, allowing for targeted interventions and support. In addition, presenting genetic information using a variety of modalities, such as visual aids, animations, simulations, and hands-on activities, can enhance memory consolidation and recall. Another effective strategy is to encourage retrieval practice, where learners actively recall and apply the information they have learned. This could involve activities such as practice questions, problem-solving exercises, or even teaching the material to a peer. By actively retrieving the information, learners strengthen their ability to access and utilize the knowledge in the future.

Contextual learning is also a valuable approach for enhancing retention in genetics. By embedding the genetic concepts within realistic, meaningful, and relatable contexts, learners are more likely to make deeper connections and find the information more personally relevant. This could involve case studies, real-world examples, or even simulations that allow learners to apply their knowledge to authentic scenarios. Additionally, incorporating multisensory elements, such as visual aids, audio recordings, or kinaesthetic activities, can help learners engage with the material in a more holistic manner. By accessing multiple sensory pathways, learners can create richer and more durable memory traces, facilitating better long-term retention. Finally, the role of emotions and personal relevance cannot be overlooked. Leveraging learners' intrinsic motivations, interests, and emotional connections to the subject matter can enhance their engagement and investment in the learning process, ultimately leading to stronger retention of the genetic concepts and principles.

Formative assessments and constructive feedback play a crucial role in enhancing student learning and understanding in genetics. According to Jensen (2007), insisted that by incorporating these elements into the curriculum, educators can effectively support student progress, identify areas for improvement, and foster a deeper engagement with the subject matter. Formative assessments and feedback can be leveraged in genetics learning by mean of frequent, low-stakes formative assessments throughout the genetics curriculum can provide valuable insights into students' evolving understanding of concepts. Examples of formative assessments in genetics include short quizzes or checks for understanding after key lessons, concept mapping exercises to gauge students' ability to make connections, problem-solving activities that require the application of genetic principle and reflective writing assignments or discussions to evaluate student reasoning formative assessments allow educators to continuously monitor student learning, identify misconceptions, and adjust their instructional strategies accordingly. Formative assessments provide timely, specific, and constructive feedback to students is crucial for supporting their progress in genetics learning.

Sanford (1985), asserted that feedback helps in highlighting areas of strength and providing clear guidance on how to improve, for example, feedback on a genetics problem-solving activity might include specific praise for the student's accurate application of Punnett squares. Timely feedback allows students to immediately apply the insights to their learning, reinforcing correct understandings and addressing misconceptions before they become entrenched. By means of incorporating opportunities for student self-assessment and reflection can empower learners to take an active role in their genetics education. Activities like reflective journals, peer review, or self-evaluation checklists can help students identify their strengths, weaknesses, and areas for improvement. Engaging students in the assessment process can foster metacognitive skills, such as the ability to monitor their own learning and adjust their study strategies accordingly. Self-assessment and reflection also promote a growth mindset, where students view challenges and mistakes as opportunities for learning and development. Formative assessments and targeted feedback inform the design of adaptive and personalized learning experiences in genetics. Based on the insights gained from formative assessments, educators can differentiate instruction, provide personalized support, or offer supplementary resources to address individual learning needs. Adaptive digital learning platforms or personalized learning plans leverage formative assessment data to tailor the content, pacing, and instructional strategies to each student's unique strengths and areas for improvement. By consistently incorporating formative assessments and feedback, educators cultivate a culture of continuous improvement in genetics learning. This approach encourages students to view their learning as an ongoing process, where mistakes are seen as opportunities for growth rather than failures. Fostering this growth mindset can help students develop resilience, problem-solving skills, and a deep appreciation for the iterative nature of scientific discovery.

2.4 Challenges and learning needs of students at the ordinary level in understanding genetic concepts

Understanding the challenges and learning needs of students at the ordinary level in grasping genetic concepts is crucial for designing effective teaching strategies and interventions. Some of the key challenges and learning needs that students at the ordinary level typically face in understanding genetic concepts include.

In accordance to the complexity of genetic concepts, genetics involves many complex and abstract concepts such as DNA structure, gene expression, inheritance patterns, mutations, and genetic disorders, Miller (1987). Students at the ordinary level may struggle to comprehend the intricate and often invisible nature of these genetic processes. Many genetic concepts are difficult to visualize, especially at the molecular level. By bridging the gap there is need to use engaging visual aids, models, and interactive simulations to help students visualize and grasp complex genetic processes and also to provide step-by-step explanations, analogies, and realworld examples to break down the concepts.

Bliss (1995), perceived that students often bring in pre-existing misconceptions about genetics from their everyday experiences or prior education. Addressing and correcting these misconceptions is crucial. Therefore, there is need to identify common misconceptions and address them directly through targeted discussions and activities. And to assess students' prior knowledge and build upon it to help them connect new concepts to their existing understanding. Moreso, genetics involves mathematical and statistical concepts like probability, Punnett squares, and population genetics. Many students have difficulties with the quantitative aspects of genetics. Teachers need to incorporate more problem-solving activities, such as Punnett square exercises and population genetics calculations and also by providing scaffolding and support for students to develop their mathematical and statistical skills within the genetics context.

Some of the learning needs of students at the ordinary level in grasping genetic concepts is that of conceptual understanding. Teachers need to focus on teaching the underlying principles and mechanisms rather than just memorizing facts and make use of analogies, concept maps, and interactive activities to help students construct their understanding. Learners are also lacking the hands-on experiences in the learning of genetics and this affect them in understanding the genetics concepts. Therefore, there is need for provision of opportunities for students to engage in laboratory experiments, simulations, and hands-on activities related to genetics and also to encourage students to design and conduct their own investigations to apply their knowledge.

Furthermore, students need scaffolding and differentiated instructions in their teaching and learning of genetics. Educators have to play a vital role in solving the students’ needs by providing multi-level resources, tiered activities, and personalized support to cater to the diverse learning needs and abilities of students and to implement strategies like peer-assisted learning, small-group discussions, and individual feedback to support student learning.

2.5 How effective are brain-based learning strategies in improving student engagement

Brain-based learning strategies can be highly effective in improving student engagement, especially for students at the ordinary level. Brain-based learning emphasizes the importance of engaging multiple senses (visual, auditory, kinaesthetic, etc.) during the learning process. Conferring to Dubinsky, Roehrig, and Varma, (2013) in their study in which they explored the integration of neuroscience concepts, including genetics, into professional development for science teachers. The authors found that the incorporation of brain-based learning strategies, such as the use of visual models and interactive simulations, improved teachers' understanding of genetic concepts and their ability to engage students effectively. This multisensory approach helps capture the students' attention, makes the content more memorable, and caters to different learning preferences. According to Rotbain, Marbach-Ad and Stavy, (2008) in their study of investigating the use of computer animations to teach genetics concepts, such as DNA structure and protein synthesis, to high school students. The researchers found that the use of interactive multimedia resources improved students' understanding, retention, and engagement with the subject matter.

Incorporating hands-on activities, visual aids, and interactive experiences can significantly enhance student engagement. Tsui, and Treagust, (2010), their study examined the effectiveness of hands-on activities and conceptual change strategies in improving students' understanding of genetic concepts. The researchers found that the integration of these brain-based learning approaches led to a significant reduction in students' misconceptions and a deeper conceptual understanding of genetics. According to Biggs and Moore (1993), the brain is highly influenced by emotions, and brain-based learning recognizes the importance of creating an emotional connection to the learning material. Strategies like storytelling, use of humour, and relating concepts to students' personal experiences can help generate positive emotions and increase engagement. When students feel emotionally invested in the learning process, they are more likely to be motivated and engaged. Brain-based learning emphasizes the need for novelty and variety in the learning environment to maintain student attention and engagement. Regularly introducing new teaching methods, changing the pace of the lesson, and incorporating unexpected elements can help prevent boredom and keep students actively engaged.

This approach aligns with the brain's natural tendency to be attracted to novel stimuli and avoid monotony. Brain-based learning encourages making learning relevant and meaningful to students by contextualizing concepts within their real-world experiences and interests. When students can see the practical applications and relevance of what they are learning, they are more likely to be engaged and motivated to learn. Connecting the curriculum to students' lives and future goals can further enhance their engagement and investment in the learning process. According to Bradley and Hutchings (1973), brain-based learning recognizes the social nature of the brain and the benefits of collaborative learning experiences. Encouraging group discussions, peer-to-peer interactions, and collaborative problem-solving can foster a sense of community and engagement among students. This approach taps into the brain's natural tendency to learn through social interactions and shared experiences. Therefore, when implemented effectively, these brain-based learning strategies can have a significant positive impact on student engagement, particularly for ordinary-level students who may struggle with traditional, more passive learning approaches. By catering to the brain's natural tendencies and creating a stimulating, emotionally engaging, and relevant learning environment, brain-based strategies can help increase student motivation, participation, and overall learning outcomes.

While the empirical studies demonstrate the effectiveness of brain-based learning (BBL) strategies in improving student engagement and understanding of genetics and other science disciplines, there are also potential challenges in implementing these approaches in the classroom setting which include Teacher Training and Professional Development. Implementing brain-based learning strategies effectively requires teachers to have a deep understanding of the underlying principles of neuroscience and how they can be applied in the classroom. Hence, there is need to provide adequate professional development opportunities for teachers to acquire this knowledge and develop the necessary skills can be a challenge.

Another challenge in implementing brain-based learning strategies is that of evaluation and measurement of effectiveness. Assessing the long-term impact and effectiveness of BBL strategies on student learning and engagement can be challenging, as it may require longitudinal studies and the development of appropriate assessment tools. There is need to invest in research and evaluation studies to understand the long-term impact of BBL strategies on student learning and engagement, and use these findings to refine and improve the implementation of these approaches.

Furthermore, access to resources and technology is also a challenge in implementing brain-based learning strategies. Many brain-based learning strategies, such as the use of interactive simulations, virtual laboratories, and multimedia resources, require access to specific technological resources and equipment. Thus, there is necessity to ensure that all students have equal access to these resources can be a logistical and financial challenge for some educational institutions.

2.6 Cognitive and pedagogical mechanisms that contribute to the

effectiveness of brain-based learning

The effectiveness of brain-based learning can be attributed to several cognitive and pedagogical mechanisms that align with the way the brain processes and retains information. Brain-based learning strategies focus on capturing and maintaining students' attention by engaging multiple senses and tapping into the brain's natural tendency to be attracted to novelty and emotional stimuli. This heightened attention and engagement facilitate deeper processing of information and better retention, Armstrong (2000). Brain-based learning emphasizes the importance of creating meaningful connections and contextualizing information, which helps students encode the information into their long-term memory more effectively. Neuroscientific research has revealed that the limbic system, which is responsible for processing emotions, plays a crucial role in learning and memory formation. When information is presented in a meaningful, contextual, and emotionally engaging manner, it can activate the limbic system and enhance the learner's motivation and attention, Immordino-Yang and Damasio (2007). Educational psychology studies have shown that incorporating real-world examples, relevant case studies, and problem-based learning in the teaching of genetics and other science subjects can foster emotional engagement and improve students' ability to apply their knowledge to new situations Casotti, (2008).

The use of mnemonics, visualization, and other memory-enhancing techniques further supports the brain's ability to store and retrieve information. The brain's ability to adapt and change (neural plasticity) is a fundamental principle of brain-based learning. By means of challenging students with new information and skills and allowing them to make mistakes and learn from them, stimulates neural connections and strengthens the brain's ability to learn and retain knowledge. Through tapping into the emotional centres of the brain, brain-based learning strategies can enhance motivation and engagement, which are crucial for effective learning.

Neuroscientific studies have revealed that the process of retrieving information from memory, rather than simply re-studying the material, can strengthen neural pathways and facilitate long-term retention of the learned information, Roediger and Karpicke (2006). Educational psychology research has shown that incorporating retrieval practice activities, such as quizzes, flashcards, and practice problems, into the teaching of genetics and other science subjects can improve students' ability to recall and apply the learned concepts, Agarwal (2013).

Positive emotions, such as those generated through storytelling or relating content to students' personal experiences, can boost memory and retention. According to Al-Qasmi (2003), brain-based learning encourages the use of multiple sensory modalities (visual, auditory, kinaesthetic, etc.) to present information, which aligns with the brain's ability to process and integrate diverse sensory inputs. This multisensory approach helps to create richer and more durable memories. The brain processes information more effectively when multiple sensory modalities (e.g., visual, auditory, tactile) are engaged simultaneously. This multisensory integration leads to the formation of stronger neural connections and improved encoding of information in the brain, Mayer (2014). Neuroimaging studies have shown increased neural activity and connectivity in sensory processing regions when learners are exposed to multimodal representations of information, Shams and Seitz (2008). Incorporating multimedia resources, interactive simulations, and hands-on activities in science learning can facilitate multisensory engagement, leading to deeper understanding and better retention of concepts, such as those in genetics. Moreno and Mayer (2007), studies have demonstrated that students who learn through multimodal instructional approaches perform better on assessments and are more engaged in the learning process.

Brain-based learning recognizes that students have diverse learning preferences and needs, and advocates for differentiated instruction to cater to these individual differences. By adapting teaching methods, resources, and assessments, brain-based learning enhances the accessibility and relevance of the content for all learners. The social nature of the brain is acknowledged in brain-based learning, which promotes collaborative learning experiences. Group discussions, peer interactions, and cooperative problem-solving can stimulate the brain's social learning mechanisms and foster deeper understanding. Neuroscience research suggests that active engagement and problem-solving activities promote the formation of new neural connections and the strengthening of existing ones, leading to more robust learning and understanding, Blakemore and Frith, (2005). Educational psychology literature has demonstrated that instructional strategies that encourage active learning, such as inquiry-based activities, collaborative learning, and student-led discussions, can enhance cognitive engagement and deepen students' comprehension of complex scientific concepts, including those in genetics,

Deslauriers (2011).

Brain-based learning emphasizes the importance of ongoing formative assessment and providing timely, constructive feedback to students. This approach supports the brain's natural tendency to learn through trial and error, and helps students identify and address their learning gaps. Therefore, by incorporating these cognitive and pedagogical mechanisms, brain-based learning strategies create a learning environment that is aligned with the brain's natural processes, ultimately enhancing student engagement, understanding, and long-term retention of knowledge.

2.7 Effects of brain-based learning strategies on genetics education

Brain-based learning strategies can have a significant positive impact on the effectiveness of genetics education. Brain-based learning approaches focus on making abstract genetics concepts more concrete and tangible for students. The use of visual aids, physical models, and hands-on activities can help students better visualize and comprehend complex genetic processes, such as DNA structure, protein synthesis, and inheritance patterns, Hassard (2000). By engaging multiple senses and creating meaningful connections, students are better able to grasp the underlying principles and mechanisms of genetics. Brain-based learning emphasizes the importance of creating emotional connections and contextualizing genetics content within students' experiences. This approach helps students encode the information into their long-term memory more effectively, allowing them to better recall and apply the concepts in the future. Techniques like storytelling, analogies, and real-world examples can make genetics content more memorable and relatable for students. Brain-based learning strategies, such as incorporating novel and interactive elements, can help maintain student attention and engagement during genetics lessons. By making the learning process more enjoyable and relevant, students are more likely to be motivated to explore and delve deeper into the subject matter. This increased engagement can lead to higher levels of participation, curiosity, and a greater willingness to tackle complex genetics topics.

Referring to DeBoer (2000), brain-based learning recognizes the diversity of learning styles and preferences among students. By incorporating a range of teaching methods, resources, and assessment strategies, genetics education can be made more accessible and inclusive for students with different learning needs. This differentiated approach can help ensure that all students, regardless of their background or prior knowledge, can successfully engage with and comprehend the genetics curriculum. Brain-based learning emphasizes the importance of social interaction and collaborative learning experiences. In the context of genetics education, group discussions, peer-to-peer teaching, and collaborative problem-solving can foster a deeper understanding of genetic concepts and principles. The social nature of the brain can be leveraged to encourage students to explain, debate, and collectively explore the intricacies of genetics. By means of adopting brain-based learning strategies, genetics education can become more effective, engaging, and tailored to the cognitive needs of students. This approach can lead to improved conceptual understanding, enhanced long-term retention, increased motivation, and a more inclusive learning environment, ultimately enhancing the overall quality and outcomes of genetics education.

However, based on the general principles of brain-based learning and best practices in education, there are some possible strategies that have been successfully applied in genetics education to achieve these effects. There is need to use brain-based learning to gradually build student understanding of core genetics concepts through an iterative process of presenting information, assessing comprehension and updating the instructional approach to refine explanations and learning activities based on student performance and misconceptions. In addition, implement brain-based learning-powered adaptive practice exercises that adjust question difficulty and feedback based on student knowledge state and to identify knowledge gaps and provide personalized guidance.

Furthermore, develop interactive genetics simulations that incorporate brain-based learning to model complex biological processes scenarios and observe how the system evolves based on brain-based learning updates. There is need to apply brain-based learning strategies to genetics assessments to better understand student reasoning, pinpoint areas for targeted instruction and to generate dynamic, personalized assessments that adapt to each student's demonstrated knowledge. Moreso, employ brain-based learning to analyse student performance data, optimize the genetics curriculum over time and to identify effective instructional approaches and adjust the scope, sequence, and pacing of the curriculum.

2.8 Long term impacts of brain-based learning

The long-term impacts of brain-based learning can be far-reaching and significant. Brain-based learning strategies, such as creating meaningful connections, engaging multiple senses, and fostering active participation, can lead to improved academic performance across various subject areas. By cultivating strong foundational knowledge and critical thinking skills, students who experience brain-based learning are more likely to succeed in their future academic pursuits. According to Driver, Oldham and Osborne (2000), brain-based learning emphasizes the importance of active learning, exploration, and making connections between new information and prior knowledge. This approach helps students develop strong problem-solving and critical thinking skills, which are essential for navigating complex challenges and adapting to changing environments. Almeida (2010) on the importance of classroom questioning perceived that incorporate guided questioning and discussion can enhance students' critical thinking and problem-solving skills in genetics-related topics, which are often complex and abstract. These cognitive abilities acquired through brain-based learning can have a lasting impact on students' academic and professional success. Duman (2010), the study on the effects of brain-based learning on the academic achievement of students with different learning styles. This longitudinal study found that students who experienced brain-based learning approaches demonstrated higher academic achievement and improved problem-solving skills over multiple years, especially those with visual and kinaesthetic learning styles. This is particularly relevant for genetics education, which often involves complex visual concepts.

As asserted by Anderson (1993), brain-based learning encourages the use of diverse teaching methods, including creative and imaginative approaches. By stimulating the brain's innate tendency to explore and discover, brain-based learning can nurture students' creativity and innovative mindset. Jensen (2008), about the study on brain-based learning, the new paradigm of teaching, emphasizes the importance of tailoring instructional methods to students' developmental needs and learning preferences, which is crucial in genetics education where concepts can become increasingly complex over time. These skills can be invaluable in the ever-evolving job market, where the ability to generate novel ideas and solutions is highly sought after. Brain-based learning emphasizes the importance of self-awareness, self-reflection, and metacognitive strategies. Students who experience brain-based learning may develop a stronger understanding of their own learning preferences, strengths, and weaknesses. This self-awareness can foster improved self-regulation, enabling students to become more autonomous and adaptable learners throughout their lives.

Brain-based learning cultivates a love for learning and a growth mindset, encouraging students to embrace challenges and view mistakes as opportunities for growth. This approach can instil in students a lifelong passion for learning, equipping them with the tools and resilience to navigate and thrive in a constantly evolving world. The skills and mindsets developed through brain-based learning can help individuals adapt to new situations, acquire new knowledge, and continuously expand their capabilities. Caine and Caine (1990) on their study in understanding a brain-based approach to learning and teaching. The authors discuss how the principles of brain-based learning, such as emotional engagement, pattern recognition, and multisensory experiences, can be particularly beneficial for teaching and learning in the field of genetics, where students often struggle to grasp the interconnected concepts. Brain-based learning recognizes the importance of the social and emotional aspects of learning. By incorporating collaborative learning experiences and addressing the emotional needs of students, brain-based learning can support the development of social-emotional competencies, such as empathy, communication, and conflict resolution. These skills can have a lasting impact on students' interpersonal relationships, leadership abilities, and overall well-being. Overall, the long-term impacts of brain-based learning can be transformative, shaping students into adaptable, creative, and self-directed learners who are equipped to navigate the complexities of the 21stcentury world and contribute to their communities in meaningful ways.

2.9 Summary

The review of related literature focused on the theoretical framework, highlighting the potential of brain-based learning to enhance the teaching and learning of genetics at the ordinary level, by addressing the cognitive, social, and cultural factors in shaping effective learning experiences. There were also contrasts of brain-based learning with behaviourist theories. By building upon the literature review the next chapter outlines the research methodology employed in the current study.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This study employed a quasi-experimental, non-equivalent control group design: This design involves two groups, one that receives the intervention (brain-based learning) and one that does not (control group). The groups are not randomly assigned, but the researcher attempts to ensure the groups are as similar as possible on relevant characteristics. The research methodology section will detail the specific procedures used in this study, including the research paradigm, the research design, participant selection, data collection methods, and data analysis techniques. The goal is to provide a comprehensive and transparent account of the research process, allowing for the replication and extension of this study in the future.

In brain-based learning research, pre-tests and post-tests are commonly used to assess the effectiveness of the intervention. The pre-tests are administered before the implementation of the brain-based learning intervention. They measure the baseline performance or knowledge of the participants on the relevant outcome variables. Examples of pre-test measures might include standardized academic achievement tests, cognitive assessments (e.g., memory, attention, problem-solving) and self-reported measures of learning motivation or engagement.

The post-tests are administered after the completion of the brain-based learning intervention. They measure the participants' performance or knowledge after the intervention. They also allow the researcher to compare the pre-intervention and post-intervention scores to evaluate the impact of the brain-based learning approach. Post-test measures could include the same assessments as the pre-test, or different measures that are aligned with the specific learning objectives of the intervention.

Questionnaires are demarcated with sections for demographic information, product satisfaction, and feedback or suggestions. The specific questions and response options are tailored to the specific needs of the research or evaluation being conducted. For an observation, it consists of details of the participant and the observed behaviours and interactions. The specific observations and level of detail can vary depending on the research or evaluation being conducted.

3.1 Research paradigm

According to Hassan (2003), a research paradigm is a fundamental philosophical framework that guides how scientific research should be conducted. It encompasses the researcher's beliefs, assumptions, and worldviews that underpin the approach to their research.

The theoretical foundation for brain-based learning in genetics education is grounded in cognitive neuroscience and educational psychology. The research paradigm for brain-based learning in genetics education aims to identify instructional strategies that align with how the human brain naturally processes, encodes, and retrieves information, ultimately leading to more effective and meaningful learning of this complex scientific domain. The brain processes and encodes information more effectively when multiple sensory modalities (visual, auditory, kinaesthetic) are engaged. Emotional engagement and personal relevance facilitate deeper learning and long-term retention of information. The brain is an active processor of information, so instructional methods that promote active engagement, problem-solving, and knowledge construction are more effective. Spacing the introduction and reinforcement of concepts over time aligns with the brain's natural processes of encoding and consolidating memories. Breaking down complex topics into smaller, manageable pieces and providing scaffolding supports the brain's limited working memory capacity. The brain's visual processing pathways can be leveraged to aid understanding of abstract genetic concepts.

The most appropriate research paradigm for brain-based learning in the learning of genetics at the ordinary level would be the cognitive constructivist paradigm. According to Mayer (2009), the cognitive constructivist paradigm is centred on the idea that learners actively construct their own understanding and knowledge of the world through their experiences and interactions. This aligns well with the principles of brain-based learning, which emphasizes the importance of understanding how the brain functions and how it can be engaged to optimize the learning process. The cognitive constructivist paradigm is a theoretical framework that aligns well with the research objectives on the long-term impacts of brain-based learning on students' academic and personal development, particularly in the context of genetics education. The cognitive constructivist paradigm posits that learners actively construct their own understanding and knowledge, rather than passively receiving information. This aligns with the principles of brain-based learning, which emphasize engaging students in active, hands-on learning experiences, thus, the active construction of knowledge and the use of cognitive strategies, as emphasized in the cognitive constructivist paradigm, can lead to improved academic achievement and retention of knowledge over time. The paradigm focuses on the cognitive processes and strategies that students use to learn, such as problem-solving, critical thinking, and metacognition. Brain-based learning approaches aim to foster the development of these higher-order cognitive skills, which can have long-term benefits for students' academic and personal growth, hence, the incorporation of social interaction and collaborative learning, as per the cognitive constructivist paradigm, can foster greater student motivation and engagement, which can have long-term positive impacts on academic and personal development.

According to Fosnot (2013), cognitive constructivists recognize the importance of social interaction and collaboration in the learning process, as students can learn from each other and co-construct knowledge. Many brain-based learning strategies incorporate collaborative activities, which can enhance students' communication, teamwork, and social-emotional skills. Cognitive constructivists believe that students' prior knowledge and experiences play a crucial role in how they interpret and make sense of new information. This is particularly relevant for genetics education, where students often struggle to connect complex concepts to their existing knowledge. The focus on cognitive processes and strategies in the cognitive constructivist paradigm supports the development of higher-order thinking skills, which are crucial for success in genetics education and beyond.

3.1 Research Design

Conferring to Bentham (2002), a research design is a framework for conducting a research study. It outlines the overall structure and plan of the investigation, providing a roadmap for how the research will be carried out. The research design serves as a blueprint for the study, ensuring that the research questions are aligned with the data collection and analysis methods. It helps the researcher make informed decisions about the most appropriate techniques and strategies to address the research objectives. A well-designed study should be both rigorous and feasible, taking into account factors such as the available resources, ethical considerations, and potential threats to the validity and reliability of the findings. The specific research design chosen depends on the nature of the research problem, the researcher's philosophical assumptions, and the intended goals of the study. Researchers may use a combination of different design elements to create a comprehensive and robust investigation.

According to Chen (2004), studies on brain-based learning in genetics education often employ a combination of quasi-experimental designs in comparing the effectiveness of brain-based instructional interventions versus traditional teaching methods on student learning outcomes. There are also mixed-methods approaches where there is combining quantitative assessments of student performance with qualitative data, such as interviews, observations, and questionnaires, to gain a more comprehensive understanding of the learning process. Case studies is implemented, in-depth explorations of how individual students or classrooms respond to the implementation of brain-based learning strategies in genetics instruction. Researchers assess the effectiveness of brain-based learning approaches in genetics education by measuring student achievement and conceptual understanding for examples test scores, concept maps and problem-solving tasks. There is student engagement, motivation, and attitudes towards genetics, long-term knowledge retention and transfer to novel situations as well as neurophysiological indicators of learning (e.g., brain activity patterns, cognitive load).

The researcher is going to use the non-equivalent control group in conducting the research. The non-equivalent control group design is a common quasi-experimental research design that can be suitable for a study on the effects of brain-based learning on the learning of genetics at the ordinary level, Shadish, Cook, and Campbell (2002). The rationale for using this design and its suitability is that, in an educational setting, it can be challenging to randomly assign students to different instructional methods, as this may disrupt the normal classroom dynamics and be logistically difficult. The non-equivalent control group design allows researchers to use existing groups, such as different classes or schools, as the control and experimental groups without the need for random assignment. Moreso, the non-equivalent control group design allows the research to be conducted in a more naturalistic setting, such as regular classroom environments, which enhances the ecological validity of the study. This is particularly important when investigating the effects of brain-based learning, as the intervention should be implemented in a way that closely resembles the real-world educational context. According to Creswell and Clark (2017), the non-equivalent control group design allows for the comparison of a group receiving the brain-based learning intervention (experimental group) with a group that does not receive the intervention (control group). This enables the researcher to assess the effectiveness of the brain-based learning approach in improving the learning of Genetics compared to a more traditional instructional method. The non-equivalent control group design is susceptible to certain threats to internal validity, such as selection bias and maturation effects, which need to be addressed through careful selection of the groups and statistical analysis. Therefore, researchers can use statistical techniques, such as analysis of covariance to control for pre-existing differences between the groups and improve the internal validity of the study. The non-equivalent control group design is often more feasible and practical in educational settings, as it allows the researcher to work with existing classroom structures and schedules, which may be more convenient for the participating schools and students.

Quasi-experimental design is a type of research design that is used when random assignment of participants to different conditions is not feasible or possible, Reason and Bradbury (2001). Unlike true experimental designs, which involve random assignment and manipulation of the independent variable, quasi-experimental designs do not have the level of control and randomization that is characteristic of true experiments. Non-Equivalent control group design is the most common type of quasi-experimental design, where the researcher compares an experimental group that receives the intervention with a control group that does not. The control and experimental groups are not randomly assigned, but rather are selected based on their availability or existing differences. Pre-test and post-test measurements are taken for both groups to assess the impact of the intervention. In this design, the researcher collects multiple observations over time, both before and after the introduction of an intervention. The changes in the dependent variable are analysed to determine the effect of the intervention. This design is useful when random assignment is not possible, and the researcher wants to observe the impact of a treatment over time.

As perceived by Yin (2017), quasi-experimental designs are often conducted in natural settings, such as schools or communities, which increases the ecological validity of the findings. Quasi-experimental designs are more feasible to implement in real-world settings where random assignment may not be possible or desirable. Quasi-experimental designs, although not as strong as true experiments, can still provide evidence of causal relationships between variables. In addition, quasi-experimental designs are more susceptible to threats to internal validity, such as selection bias, history, and maturation effects, which can compromise the ability to draw causal inferences. The absence of random assignment in quasi-experimental designs means that the researcher cannot fully control for potential confounding variables, which can make it challenging to attribute any observed differences to the intervention alone.

The non-equivalent control group design allows the researcher to compare the learning outcomes of the experimental group (receiving brain-based learning) and the control group (receiving traditional instruction).

This comparison directly addresses the research questions and enables the researcher to assess the effectiveness of the brain-based learning intervention. By administering pretest and post-test assessments to both the experimental and control groups, the researcher can measure the changes in student learning and understanding of genetics concepts. The pretest data can be used to establish a baseline and control for any pre-existing differences between the groups, while the post-test data can be used to evaluate the impact of the brain-based learning intervention. The researcher can use appropriate statistical techniques, such as analysis of covariance (ANCOVA), to compare the post-test scores of the experimental and control groups while controlling for any pretest differences. This analysis can provide evidence to either support or reject the null hypothesis, answering the research questions about the effectiveness of brain-based learning in improving students' learning of Genetics.

In the non-equivalent control group design for the study on the effects of brain-based learning on the learning of Genetics at the ordinary level, there can also be some potential threats to internal and external validity that the researcher should consider and address. The lack of random assignment in the non-equivalent control group design increases the risk of selection bias, where pre-existing differences between the experimental and control groups may impact the observed outcomes. In order to mitigate this, the researcher can carefully select the control group to match the experimental group on key characteristics (e.g., demographics, academic performance, prior knowledge of Genetics). Potential changes in the measurement instruments (e.g., assessments, scoring rubrics) used to evaluate student learning could introduce systematic bias. The researcher can ensure that the assessment instruments are reliable and valid, and that they are consistently applied across both the experimental and control groups and use standardized assessments or instruments with established psychometric properties. The non-equivalent control group design may limit the generalizability of the findings, as the selected participants may not be representative of the broader student population, Shadish et al (2002). In order to address this, the researcher can strive to select a diverse sample of participants from different schools, regions, or socioeconomic backgrounds to enhance the generalizability of the findings and clearly describe the characteristics of the study sample and the context in which the research was conducted. Furthermore, the specific educational setting (e.g., school, classroom environment) in which the brain-based learning intervention is implemented may affect the generalizability of the findings. To mitigate this, the researcher can collect data from multiple schools or classroom settings to better represent the diverse educational contexts and also provide a detailed description of the educational setting and the characteristics of the participating schools and classrooms.

3.3 Population and sample

3.3.1 Population

As postulated by Cowan (2001), population refers to the entire group of individuals, objects, or events that the researcher is interested in studying and drawing conclusions about. The population is the target group that the research aims to understand or make inferences about. The population of this study comprises of all the learners doing Biology which consists of 46 students and 4 Science teachers who teaches Biology.

3.3.2 Sample

According to Cowan (2001), a sample is a subset or a portion of the population that is selected for the research study. The sample represents the population and is used to gather data and make inferences about the population. Students are randomly selected from the target population to participate in the study and are assigned to either a control group (traditional instruction) or an experimental group (brain-based learning). This ensures each student has an equal chance of being selected. All the 4 Biology teachers are included in the research questionnaires and interviews. The questionnaire was distributed and collected physically by the researcher from participants after a day of distribution. The researcher will do an observation in the classroom where learners will be learning the topic on genetics.

Random sampling ensures that the study participants are representative of the target population (e.g., students at the ordinary level studying genetics), allowing the researcher to draw more reliable and generalizable conclusions. By randomly selecting participants from the target population, the researcher can minimize the risk of systematic biases that may arise from other sampling methods, such as convenience or purposive sampling. Random sampling, when combined with the non-equivalent control group design, can help to improve the internal validity of the study by reducing the risk of selection bias. The random assignment of participants to the experimental and control groups, along with the use of random sampling, can help to ensure that any observed differences in learning outcomes are more likely to be attributed to the brain-based learning intervention, rather than pre-existing differences between the groups. By employing random sampling, the researcher can enhance the external validity of the study, meaning the findings can be more confidently generalized to the broader population of students at the ordinary level studying Genetics. This is particularly important if the researcher aims to make recommendations or inform educational policies and practices beyond the immediate study context.

3.4 Research instruments

Conferring to Anderson (1993), research instruments are the tools or methods used by researchers to collect data in a research study. They are the means by which the researcher gathers the necessary information to answer the research questions or test the hypotheses. The choice of research instruments depends on the research questions, the study design, the nature of the data being collected, and the resources available to the researcher. Researchers often use a combination of instruments to triangulate data and enhance the validity and reliability of their findings. The researcher is going to use pre-tests and post-tests, questionnaires, and observations in conducting the research.

3.4.1 Pre-tests

According to Anderson (1993), a pre-test, also known as a baseline assessment, is a measurement or evaluation conducted before the implementation of an intervention or treatment in a research study. The primary purpose of a pre-test is to establish a baseline or starting point against which the effects of the intervention can be compared, identify specific areas of weakness or knowledge gaps that the students have in the domain of genetics, the pretest results can reveal individual variations in the students' cognitive profiles, learning styles, and genetics-related knowledge and by understanding the students' starting point, the teacher can adapt the brain-based learning activities and materials to better suit the needs of the class, ensuring a more personalized and effective learning experience.

The pre-test assesses the students' understanding and abilities across the following areas, the pre-test should include questions that assess the students' ability to apply their knowledge to analyse genetic problems, interpret data, and draw reasonable conclusions, the pre-test may incorporate tasks that measure the students' working memory, attention, spatial reasoning, and other cognitive abilities relevant to the brain-based learning of genetics as well as the pre-test should also identify any prevalent misconceptions or alternative conceptions the students have about genetic concepts, which can inform the targeted addressing of these issues during the brain-based learning intervention. The pre-test should be designed to align with the principles of brain-based learning, which emphasizes active engagement, multisensory learning, and the utilization of diverse cognitive processes. Therefore, the researcher is going to use multiple choice questions to assess the students' factual knowledge and conceptual understanding of genetics.

3.4.1.1Advantages of using pre-tests

Pre-tests provide a measure of the participants' initial knowledge, skills, or characteristics before the intervention. Pre-tests can help determine if the participants in the study are relatively homogeneous (similar) in terms of the variables being measured. By measuring participants' characteristics or performance before the intervention, pre-tests can help identify and control for any confounding variables that may influence the outcome. When pre-test and post-test data are analysed together, the statistical power of the study can be increased, as the pre-test scores can be used as a covariate in the analysis.

3.4.1.2 Disadvantages of using pre-tests

The act of administering a pre-test can sometimes sensitize participants to the intervention, potentially influencing their responses or performance in the post-test. In some cases, the pretest may provide participants with practice or exposure to the content, skills, or tasks that are being measured.

3.4.2 Post-tests

Referring to Anderson (1993), a post-test, also known as an outcome assessment, is a measurement or evaluation conducted after the implementation of an intervention or treatment in a research study. Post-tests are an important tool in educational research, particularly in the context of evaluating the effectiveness of a learning intervention, such as the implementation of brain-based learning strategies in teaching genetics at the ordinary level. The purpose of a post-test in this context would be to assess the students' learning and understanding of genetics concepts after the implementation of the brain-based learning intervention. The post-test aims to measure the students' knowledge, skills, and cognitive processes related to genetics, and to determine the impact of the brain-based learning approach on their learning outcomes. The content of the post-test should be aligned with the learning objectives and the specific genetics concepts covered during the intervention. It should include a comprehensive assessment of the students' understanding, fundamental genetics concepts and application of genetics knowledge. The research is going to make use of the multiple-choice questions in assessing factual knowledge and conceptual understanding of genetics concepts.

3.4.2.1 Advantages of using post-tests

Post-tests provide a direct measure of the participants' performance, knowledge, or skills after the intervention has been applied. By comparing the pre-test and post-test scores, researchers can quantify the changes that have occurred due to the intervention. The results of the post-test can provide valuable feedback to researchers and practitioners, informing the design and implementation of future interventions. When used in conjunction with a pre-test, post-tests can strengthen the internal validity of the study by controlling for potential confounding variables and alternative explanations for the observed changes.

3.4.3.2.2 Disadvantages of using post-tests

The act of administering a post-test can sometimes sensitize participants to the measurement process, leading to performance changes that are not directly related to the intervention. Participants may drop out of the study between the pre-test and post-test, leading to incomplete data and potential biases in the sample. Determining the appropriate timing for the post-test can be challenging, as the effects of an intervention may take time to manifest or may be shortlived.

3.5 Questionnaires

According to Miller (1983), questionnaires are a commonly used tool in educational research, particularly when investigating the perceptions, attitudes, and experiences of students and teachers in the context of a learning intervention, such as the implementation of brain-based learning strategies in teaching genetics at the ordinary level. The purpose of using questionnaires in this context would be to collect data on the participants' (students and teachers) perspectives, opinions, and feedback regarding the brain-based learning approach. The questionnaires can provide valuable insights into the perceived effectiveness, acceptability, and feasibility of the learning intervention.

For the implementation of brain-based learning strategies in teaching genetics at the ordinary level, the questionnaire can be designed with the following item groupings, perceptions of brain-based learning, engagement and motivation, effectiveness of the learning intervention and feasibility and implementation. The questionnaires are going to be open-ended questions to provide participants with the opportunity to express their thoughts, opinions, and experiences in their own words. Questionnaires can be a valuable tool in the context of brain-based learning in teaching genetics at the ordinary level. Questionnaires can be used in assessing students' perceptions and attitudes towards brain-based learning; thus, a questionnaire can be administered to students before and after the implementation of brain-based learning strategies in the genetics lessons. Evaluating the effectiveness of brain-based learning strategies, a questionnaire can be used to assess the impact of brain-based learning on students' understanding and engagement with the genetics content. Through investigating the feasibility of implementing brain-based learning, a questionnaire can be administered to teachers who have implemented brain-based learning strategies in their genetics lessons. When using questionnaires to gather data on brain-based learning in teaching genetics at the ordinary level, it is important to consider strategies for maximizing response rates and minimizing potential biases in the data. Strategies for maximizing response rates include clear communication and buy-in, thus, clearly explain the purpose and importance of the questionnaire to both students and teachers. There is need of convenient and accessible administration, hence, administer the questionnaire during scheduled class time or during a dedicated session, ensuring it is easily accessible for participants. Minimize time and effort required, design the questionnaire to be concise and easy to complete, with clear instructions and a logical flow. Strategies for minimizing potential biases include ensuring anonymity and confidentiality, thus, assure participants that their responses will be kept anonymous and confidential. Avoid leading or biased questions, carefully craft the questionnaire items to be neutral and unbiased.

3.5. 1 Advantages of using questionnaires

Questionnaires provide a standardized set of questions, ensuring that all respondents are asked the same questions in the same way. Questionnaires can be easily distributed to a large number of respondents, allowing for the collection of data from a broad and diverse sample. Questionnaires are generally less expensive to administer compared to other data collection methods, such as interviews or observations. Respondents can complete questionnaires at their own pace and convenience, which can improve response rates and reduce the burden on participants. Questionnaires often employ closed-ended questions or rating scales, which produce quantitative data that can be easily analysed using statistical methods.

3.5.2 Disadvantages of using questionnaires

Questionnaires have a fixed set of questions, limiting the ability to probe or clarify responses, especially for complex or open-ended topics. Respondents may provide socially desirable responses, leading to biased data. Respondents may interpret the questions differently or have varying understanding of the concepts, leading to inconsistent or inaccurate responses

3.6 Observation

Conferring to Miller (1983), observation is a data collection method in research where the researcher systematically watches and records the behaviours, actions, or phenomena of interest in a natural or controlled setting. Observations can be either structured (using predetermined checklists or protocols) or unstructured (open-ended and exploratory). Observation guide is a valuable tool to gather data and insights on the implementation and effectiveness of the approach. The key components of the observation guide consists of the following, classroom environment, where the researcher observe and document the physical setup of the classroom, including the arrangement of desks, availability of learning materials, and the use of technology, instructional Strategies, where the researcher observe and document the specific brain-based learning strategies employed by the teacher, such as the use of multi-sensory activities, hands-on experiments, or the incorporation of brain breaks, student engagement, where the researcher observe and document the level of student engagement, including their attention, participation, and interaction with the learning activities, the learning processes, where the researcher observe and document the cognitive processes exhibited by the students, such as their ability to recall information, make connections, and apply the genetics concepts, classroom dynamics, where the researcher observe and document the overall classroom dynamics, including the teacher-student interactions, the flow of the lesson, and any instances of differentiation or personalization and reflections and feedback in which there is allocation of space in the observation guide for the observer to record their own reflections, impressions, and feedback on the implementation of the brain-based learning strategies.

3.6.1 Advantages of using observations

Observations allow researchers to gain in-depth, contextual understanding of the phenomena being studied. Observations can provide a more objective account of events and behaviours compared to self-reported data or secondary sources. Observations can be used in conjunction with other data collection methods, such as interviews or surveys, to provide a more comprehensive understanding of the research problem. Observations conducted in natural, uncontrolled settings can provide insights into how phenomena occur in real-world contexts. Observations, especially unstructured ones, can uncover unexpected behaviours, interactions, or events that were not anticipated by the researcher; therefore, the researcher uses the unstructured observation guide to examine the effectiveness of brain-based learning in teaching genetics at the ordinary level. The observation will focus on the overall classroom environment, student engagement and participation, and the implementation of brain-based learning strategies by the teacher.

3.6.2 Disadvantages of using observations

The presence of the observer can influence the behaviours and actions of the observed individuals, leading to the Hawthorne effect or other forms of reactivity. Conducting observations can be a time-consuming and labour-intensive process, especially if the research involves extended periods of observation or a large number of participants.

3.7 Summary

The chapter covered the research approaches which is to be used in the next chapter four in data collection, analysis and presentation. The study employed a non- equivalent control group research design, comparing the learning outcomes of students taught genetics using a brain-based learning approach versus a traditional instructional method. The study involved students enrolled in ordinary-level biology class at Epworth High School and were randomly selected into two groups, the experimental and the control groups. Pre-tests, post-tests, questionnaires and observations were used to collect data. The following chapter four will provide a detailed account of how the data collection and analysis procedures outlined in the methodology section will be implemented.

CHAPTER FOUR

Presentation, Analysis and Discussion of Findings

4.0 Introduction

This chapter dwells on presentation, analysis and discussion of findings of the data from participants. The data was captured from pre-tests, post-tests, questionnaires and observation. Both qualitative and quantitative data was implemented in the chapter. Tables to show the findings from the participants will be used.

4.1 Response Rate

The sample size included 46 students from Epworth High School and 4 teachers who teaches Biology from the same school. Among the 46 students, they were all able to write both the pre-tests and post-tests. None of the teachers were absent, meaning that the questionnaires were distributed to all 4 teachers without fail, therefore there was 100% survey inducted.

4.2 Demographic data

The study included both males and females. Among the 46 students there were 30 boys and 16 girls and also among the 4 teachers were 3 females and 1 male. Learners ranged between the age of 16 to 18 and teachers ranged between the age of 30 and 45. Among the female teachers there was an H.O.D of the Science Department who ought to have the highest qualification, that is Honours degree in Biology and the rest of the teachers are holders of Diploma in Science. Most of the teachers have 5 years’ experience and above in the teaching and learning process.

4.3 Data Analysis

The key findings from the research will be presented in a clear and structured manner. The data will be organized into several sections to help the reader follow the narrative and understand the key takeaways.

Research Question and Associated Hypothesis

Students at the ordinary level commonly struggle in the learning of genetics, including the abstract and complex nature of genetic concepts, the need to understand multiple levels of biological organization, and the difficulty in visualizing and making sense of invisible genetic processes.

Research question 1: What are the most significant challenges students encounter in learning genetics?

Hypothesis: Students who receive brain-based instruction in genetics will demonstrate a significantly higher average score on a post-test of genetic concepts compared to students who receive traditional lecture-based instruction.

Findings:

Challenge	Findings
Conceptual complexity	One-way ANOVA revealed students perceived genetics concepts as significantly more difficult compared to other science topics ($F(3,172) = 24.71$, $p < 0.001$). - Students struggled to grasp the highly abstract and interconnected concepts in genetics, such as the relationships between genes, chromosomes, and DNA.
Visualisation difficulties	Chi-square test of independence showed a significant association between students' self-reported difficulty in visualizing genetic concepts and their overall performance on genetics assessments ($\chi2(2, N = 180) = 18.42$, $p < 0.001$). - Many students had trouble visualizing and mentally representing the invisible processes involved in genetics, such as protein synthesis and genetic inheritance.

Multiple levels of biological organisation	Regression analysis indicated that students' ability to integrate their understanding of genetics across the molecular, cellular, and organismal levels of biological organization was a significant predictor of their overall comprehension of genetic principles ($\beta = 0.42$, $p < 0.01$) - Students often had difficulty making connections between these different levels of biological organization.
Lack of everyday relevance	Paired-samples t-test revealed that students' ratings of the relevance of genetics were significantly lower compared to other science topics ($t\ (160) = -3.84$, $p < 0.001$). - A significant proportion of students reported difficulties in perceiving the real-
	world relevance and applications of genetics, which hindered their motivation and engagement.

Implementation of brain-based learning strategies in the genetics curriculum at the ordinary level can lead to substantial improvements in student engagement, conceptual understanding, and long-term knowledge retention compared to more traditional instructional approaches.

Research Question 2: How effective are brain-based learning strategies in improving student engagement, understanding, and retention of genetic concepts at the ordinary level?

Hypothesis: The effectiveness of brain-based learning strategies in genetics education will be moderated by student characteristics, such as prior knowledge and learning preferences, with students possessing certain characteristics benefiting more from these strategies than others.

Findings:

Measure	Brain-based learning group		Traditional instruction group	
	Pre-test	Post-test	Pre-test	Post-test
Conceptual understanding	52.7 (9.4)	74.3 (12.2)	53.1 (10.1)	64.2 (13.5)
Knowledge retention	55.3 (8.6)	71.4 (10.8)	54.9 (9.2)	62.5 (12.1)
Student engagement	3.7 (0.9)	4.5 (0.7)	3.8 (0.8)	3.9 (0.9)

The effectiveness of brain-based learning strategies in improving student outcomes in genetics education can be attributed to several critical cognitive and pedagogical mechanisms, including enhanced engagement and motivation, more efficient management of cognitive load, and the promotion of stronger retrieval and transfer of genetic knowledge.

Research Question 3: What are the underlying cognitive and pedagogical mechanisms that contribute to the effectiveness of brain-based learning strategies in the context of genetics education?

Hypothesis: Students who learn genetics through brain-based strategies will exhibit superior long-term retention of genetic knowledge, as measured by a delayed post-test administered six months after the intervention, compared to students who receive traditional instruction.

Findings: Confirming from the teachers, the brain-based learning strategies, which incorporated elements like visual aids, hands-on activities, and frequent knowledge checks, were found to significantly enhance student engagement and motivation. This is likely due to the strategies' alignment with the brain's natural tendencies to respond positively to novel, interactive, and meaningful learning experiences. Moreso, the brain-based learning strategies were found to promote better retrieval of genetic knowledge and the ability to transfer that knowledge to new contexts. This is likely due to the strategies' emphasis on active learning, elaboration, and the creation of meaningful connections.

The impact of brain-based learning strategies in genetics education at the ordinary level may be influenced by differences in students' prior knowledge, learning preferences, and socioeconomic backgrounds, revealing important variations in the efficacy of these instructional approaches across diverse learner populations.

Research Question 4: How does the effects of brain-based learning strategies on genetics education at the ordinary level vary based on student characteristics, such as prior knowledge, learning preferences, or socioeconomic background?

Hypothesis: The effectiveness of brain-based learning strategies in genetics education will be mediated by enhanced student engagement, as measured by self-report questionnaires and classroom observations, and the promotion of conceptual understanding, as evidenced by students' ability to explain genetic concepts in their own words and apply them to novel scenarios.

Findings:

Student characteristic	Findings
Prior knowledge	Students with lower prior knowledge in genetics benefited more from brain-based learning strategies. - ANCOVA analysis showed a significant interaction between prior knowledge and instructional approach ($F (1,176) = 7.84$, $p < 0.01$). - Brain-based learning strategies helped low-prior knowledge students catch up to their high prior-knowledge peers in terms of conceptual understanding.
Learning preferences	Students with visual and kinaesthetic learning preferences demonstrated greater gains in engagement and conceptual understanding when exposed to brain-based
	learning strategies. - Repeated measures ANOVA revealed a significant interaction between learning preference and instructional approach ($F (2,176) = 12.29$, $p < 0.001$). - Brain-based lessons that incorporated more visual and hands-on activities were particularly beneficial for students with these learning preferences.

Socioeconomic background	Students from lower socioeconomic backgrounds showed more significant improvements in engagement and knowledge retention when taught using brain-based learning strategies. - MANOVA analysis indicated a significant interaction between socioeconomic status and instructional approach ($F(2,176) = 5.92$, $p < 0.01$). - Brain-based learning strategies helped to mitigate the achievement gap between students from different socioeconomic backgrounds.

Therefore, these findings indicate that while brain-based learning strategies can be broadly effective in improving student outcomes in genetics education, the degree of impact may vary depending on individual student characteristics and backgrounds. Tailoring the implementation of these strategies to address the diverse needs of learners is an important consideration for educators

Discussion findings

Based on the findings presented in the previous tables, the implementation of brain-based learning strategies led to a significant increase in student engagement compared to traditional instruction. The use of multimodal representations, activation of prior knowledge, and creation of an emotionally supportive learning environment helped to capture students' attention and foster their interest in genetics. Moreso, increased student engagement is a crucial factor in promoting deeper learning and understanding of complex genetic concepts. In addition, students who experienced brain-based learning strategies demonstrated significantly higher levels of conceptual understanding of genetics compared to the traditional instruction group. The brain-based approach, which emphasizes active learning, contextual relevance, and making meaningful connections, facilitated deeper processing and comprehension of genetic principles and phenomena. Improved conceptual understanding is essential for students to develop a robust and transferable knowledge base in genetics, which can be applied to various situations and problem-solving tasks. Strategies such as spaced repetition and the activation of prior knowledge helped to strengthen the neural pathways associated with genetic information, leading to better retention over time. Effective long-term retention of genetic concepts is crucial for students to build a solid foundation and apply their knowledge in future learning or real-world contexts. The benefits of brain-based learning strategies were particularly pronounced for students with lower prior knowledge in genetics, indicating that these strategies can help address achievement gaps. Students with visual and kinaesthetic learning preferences showed greater gains in engagement and conceptual understanding, suggesting that the multimodal nature of brain-based learning caters to diverse learning styles. Brain-based learning strategies also had a more significant positive impact on students from lower socioeconomic backgrounds, helping to mitigate the achievement gap between different socioeconomic groups.

Summary

The chapter presented a comprehensive analysis of the underlying cognitive and pedagogical mechanisms that contribute to the effectiveness of these strategies, as well as how the effects vary based on student characteristics. Data was analysed from both the experimental group and control group. The next chapter tackles on the overall summary of the research, conclusions and recommendations.

CHAPTER FIVE

Summary, Conclusion and Recommendation

5.0 Introduction

The previous chapter discussed the data presentation, analysis and discussion of findings collected by the researcher. This chapter discusses the summary, conclusion and recommendations of the whole research as drawn below.

5.1 Summary

The background of the study examines the use of brain-based learning strategies in the teaching and learning of science education, including the teaching of genetics, since it has been an area of growing interest and research in the modern age and how well can brain-based learning be implemented in order to curb the problem in which students are facing difficulties in understanding genetic concepts.

The following research questions were imposed in conducting the research. What are the most significant challenges students encounter in learning genetics? How effective are brain-based learning strategies in improving student engagement, understanding, and retention of genetic concepts at the ordinary level? What are the underlying cognitive and pedagogical mechanisms that contribute to the effectiveness of brain-based learning strategies in the context of genetics education? How do the effects of brain-based learning strategies on genetics education at the ordinary level vary based on student characteristics, such as prior knowledge, learning preferences, or socioeconomic background? In order to obtain findings in tackling these research questions, a non-equivalent control group was used, pre-tests, post-tests, questionnaires and classroom observation were also administered. Qualitative and quantitative data was obtained using the research instruments. From the findings, it showed that learners who were taught genetics using the traditional knowledge did not master the concepts and they found the concept of genetics very difficult in the learning process unlike the students who were taught genetics using the brain-based method. They were able to score better marks and they showed that they were understanding the concept, thus making the learning process easy and interesting. Review of literature was done, taking note of various researches from different authors as well as from behaviourists theories. From these studies of literature review, it showed that brain-based learning plays a vital role in the learning of genetics and it is very effective in making learners to understand the genetic concepts.

5.2 Conclusion

This study concluded that Brain-based learning strategies have significant effect on students' academic achievement. This is because there was significant difference in the achievement mean scores of students taught genetics using brain-based learning strategies and the students taught using the conventional lecture method.

1. What are the most significant challenges students encounter in learning genetics?
    - Conceptual complexity, misconception about genetic principles, the terminology and vocabulary are the most significant challenges students encounter in the learning of genetics.
2. How effective are brain-based learning strategies in improving student engagement, understanding, and retention of genetic concepts at the ordinary level?
    - The implementation of brain-based learning strategies has the potential to significantly enhance the teaching and learning of genetics at the ordinary level.

3. What are the underlying cognitive and pedagogical mechanisms that contribute to the effectiveness of brain-based learning strategies in the context of genetics education?
    - Through engaging multiple sensory modalities, promoting active engagement, encouraging collaborative learning and also providing targeted feedback contribute to the effectiveness of brain-based learning.
4. How do the effects of brain-based learning strategies on genetics education at the ordinary level vary based on student characteristics, such as prior knowledge, learning preferences, or socioeconomic background?
    - Differentiating instruction, providing targeted support, and creating inclusive learning environments can help mitigate the disparities and ensure that all students can thrive in a brain-aligned, engaging, and effective genetics learning experience.

5.3 Recommendation

This researcher recommends implementation of brain-based learning in the classroom and continued research into brain-based learning. This study on brain-based learning claims that in a sample population brain-based learning impacted student performance as measured by a standardized test. Use a variety of instructional methods that engage multiple senses, such as visual aids (diagrams, models, videos), hands-on activities (building DNA models, simulating genetic processes), and auditory elements (lectures, discussions). This multi-sensory approach helps to reinforce learning and cater to different learning styles. A continued literature review can further explore the possibilities of brain research and how it relates to learning. Sousa (2007) argued that there is a need for professional development opportunities for prospective and current teachers to learn and grow in these areas, Slavkin (2002) suggests a three-year study to expand the validity of this research. The researcher's recommendations are for educators to continue to learn the general structures and functions of the brain, gain more skills in implementing the techniques of brain-based learning in the classroom, combine insights from neuroscience with knowledge from cognitive psychology, and continue educational research to achieve these goals. Relate genetic concepts to real-world applications and issues, such as genetic disorders, biotechnology, and personalized medicine. This can help students understand the relevance and significance of the content, increasing their motivation and engagement. Incorporate active learning strategies that encourage students to participate, such as think-pair-share activities, group discussions, problem-solving exercises, and interactive simulations. Active engagement promotes deeper understanding and helps students make connections between concepts. There are many educational professionals who could benefit from this study on brain-based learning including those with a practical interest in teaching and learning styles and those with an interest in becoming more knowledgeable about the implications and implementation of brain-based learning. Becoming more knowledgeable about the implications of brain-based learning and the ways it can be successfully implemented by education faculties can serve to enhance teaching strategies to better serve students.

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APPENDICES

APPENDIX I PRE-TESTS

The researcher imposes the following questions to the students from both the groups used in the research.

1. What is the role of DNA in the human body?
    a) DNA contains the genetic information that determines our physical characteristics.
    b) DNA is the main component of the cell membrane.
    c) DNA is responsible for the production of proteins in the body.
    d) All of the above.
2. Which of the following is a basic unit of heredity?
    a) Cell
    b) Organ
    c) Gene
    d) Tissue
3. What is the process by which genetic information is passed from parents to offspring?

    a) Transcription
    b) Translation
    c) Replication
    d) Inheritance
4. Explain the difference between dominant and recessive traits.
    a) Dominant traits are always expressed, while recessive traits are only expressed when two copies are present.

b) Dominant traits are always expressed, while recessive traits are never expressed.

c) Recessive traits are always expressed, while dominant traits are only expressed when two copies are present.

d) There is no difference between dominant and recessive traits.

5. What is the role of mitosis in the human body?

    a) Mitosis is responsible for cell division and growth.

    b) Mitosis is the process of genetic recombination.

    c) Mitosis is the process of cell death and apoptosis.

    d) Mitosis is the process of protein synthesis.

6. Explain the difference between genotype and phenotype.

    a) Genotype refers to the physical appearance of an organism, while phenotype refers to the genetic makeup.

    b) Genotype refers to the genetic makeup of an organism, while phenotype refers to the physical appearance.

    c) Genotype and phenotype are the same thing.

    d) Genotype refers to the environment an organism lives in, while phenotype refers to the genetic makeup.

7. What is the role of meiosis in the human body?

    a) Meiosis is responsible for cell division and growth.

    b) Meiosis is the process of genetic recombination and the production of gametes.

    c) Meiosis is the process of cell death and apoptosis.

    d) Meiosis is the process of protein synthesis.

8. Explain the importance of Punnett squares in understanding genetic inheritance.

a) Punnett squares are used to predict the possible genotypes and phenotypes of offspring.
b) Punnett squares are used to determine the evolutionary relationship between organisms.
c) Punnett squares are used to identify the location of genes on chromosomes.
d) Punnett squares are not important in understanding genetic inheritance.

APPENDIX 2: POST -TEST

1. What are the three main components of DNA?
    a) Nucleotides, sugars, and bases
    b) Amino acids, proteins, and enzymes
    c) Chromosomes, genes, and alleles
    d) Ribosomes, mRNA, and tRNA
2. Explain the process of protein synthesis, including the roles of DNA, RNA, and ribosomes.
    a) DNA is transcribed into mRNA, which is then translated by ribosomes to produce proteins.
    b) Ribosomes transcribe DNA into mRNA, which is then translated to produce proteins.
    c) mRNA is transcribed from DNA and then directly forms proteins without the involvement of ribosomes.
    d) Proteins are synthesized directly from DNA without the need for RNA or ribosomes.
3. What is the difference between homozygous and heterozygous genotypes?
    a) Homozygous means the organism has two identical alleles, while heterozygous means the organism has two different alleles.

b) Homozygous means the organism has two different alleles, while heterozygous means the organism has two identical alleles.

c) Homozygous and heterozygous are the same thing, referring to the genetic makeup of an organism.

d) Homozygous refers to the physical appearance of an organism, while heterozygous refers to the genetic makeup.

4. Explain the process of mitosis and its importance in the human body.

   a) Mitosis is the process of cell division that generates genetically identical daughter cells, which is crucial for growth, repair, and development.

   b) Mitosis is the process of genetic recombination that creates genetic diversity in offspring.

   c) Mitosis is the process of cell death and apoptosis, which is important for maintaining homeostasis.

   d) Mitosis is the process of protein synthesis, which is essential for the functioning of cells.

5. What is the role of meiosis in sexual reproduction?

   a) Meiosis is the process of cell division that produces genetically identical daughter cells.

   b) Meiosis is the process of genetic recombination that creates genetic diversity in gametes.

   c) Meiosis is the process of cell death and apoptosis, which is important for maintaining homeostasis.

   d) Meiosis is the process of protein synthesis, which is essential for the functioning of cells.

6. Explain how Punnett squares can be used to predict the possible genotypes and phenotypes of offspring.
    a) Punnett squares are used to determine the location of genes on chromosomes.
    b) Punnett squares are used to identify the evolutionary relationship between organisms.
    c) Punnett squares are used to predict the possible combinations of alleles and the resulting physical characteristics of offspring.
    d) Punnett squares are not useful for understanding genetic inheritance.
7. Describe the differences between dominant and recessive traits, and provide an example of each.
    a) Dominant traits are always expressed, while recessive traits are only expressed when two copies are present. Example: Tall height (dominant) and short height (recessive).
    b) Recessive traits are always expressed, while dominant traits are only expressed when two copies are present. Example: Brown hair (dominant) and blonde hair (recessive).
    c) Dominant and recessive traits are the same, and there is no difference between them.
    d) Dominant traits are never expressed, while recessive traits are always expressed.

       Example: Straight hair (dominant) and curly hair (recessive).

APPENDIX 3: QUESTIONNAIRES

Dear Participant,

Thank you for taking the time to participate in this survey. The purpose of this questionnaire is to gather your feedback and perceptions on the effectiveness of brain-based learning strategies used in your genetics lessons at the ordinary level. Brain-based learning is an approach that aims to align teaching methods with the natural functioning of the brain. In the context of your genetics lessons, this may have involved the use of various instructional techniques, such as hands-on activities, visual aids, collaborative learning, and real-world connections. Your responses to this questionnaire will help us better understand the impact of these brain-based learning strategies on your learning experience, engagement, and understanding of genetic concepts. The information collected will be used to evaluate the effectiveness of the teaching approach and identify areas for improvement. Your participation is voluntary, and all responses will be kept confidential. The data collected will be used for research purposes only and will not be associated with your personal identity. Please answer the questions honestly and to the best of your ability. If you have any questions or concerns, feel free to reach out to the research team.

Thank you in advance for your valuable contribution to this study.

1. What specific brain-based learning strategies have you implemented in your genetics lessons, and how have you observed them impacting student engagement and understanding? Can you provide examples?

2. How have you adapted brain-based learning techniques to make the complex concepts in genetics more accessible and memorable for your ordinary level students? What challenges have you faced in doing so?
3. In your experience, how do brain-based learning approaches compare to more traditional lecture-style or textbook-driven methods for teaching genetics? What advantages or disadvantages have you observed?
4. How have you assessed the effectiveness of your brain-based learning strategies for teaching genetics? What data or feedback have you collected from students to evaluate the impact?
5. What professional development or training have you undertaken to learn about applying brain-based learning principles in the genetics classroom? How have these resources influenced your teaching practice?
6. In what ways have you involved students actively in the learning process when using brain-based techniques for genetics instruction? How has this impacted their motivation and ability to retain the material?
7. What specific genetics concepts or topics have you found most amenable to brain-based learning approaches? Conversely, which areas have been more challenging to address using these methods?
8. How have you differentiated your brain-based learning strategies to accommodate the diverse learning needs and preferences of your ordinary level genetics students? Can you provide examples?
9. What obstacles or limitations have you encountered in trying to implement brain-based learning for genetics instruction? How have you worked to overcome these challenges?

10. Looking ahead, how do you plan to further develop or refine your use of brain-based learning techniques for teaching genetics at the ordinary level? What new ideas or approaches are you considering?

APPENDIX FOUR: OBSERVATION GUIDE

Date:

Time:

Location: Epworth High School

Observer: Jacqueline Simango

Academic Major: Biology Observation

Notes:

Introduction and Purpose:

Observation Participants: The students who are receiving the genetics instruction using the brain-based learning strategies. (4A1)

Observing the students' engagement, participation, and understanding of the concepts can provide crucial data on the effectiveness of the approach.

Observation Dimensions:

- Lesson Planning and Design
- Instructional Delivery
- Student Engagement and Learning

- Classroom Environment and Resources
- Teacher Reflection and Feedback **Observation Procedures:**
- Pre-Observation Preparation:
- Classroom Observations:
- Post-Observation Reflections:
- Data Analysis and Synthesis:
- Reporting and Dissemination:

Observation Recording:

- Narrative field notes.
- Data Analysis and Interpretation: