EFFECTS OF MODELLING CLAY AND DEMONSTRATION KIT ON SENIOR SCHOOL STUDENTS' PERFORMANCE IN CELL DIVISION IN OMU-ARAN, NIGERIA

Ph.D. ORAL DEFENCE

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CERTIFICATION

This is to certify that this study entitled "Effects of Modelling Clay and Demonstration Kit on Senior School Students' Performance in Cell Division in Omu-Aran, Nigeria" was carried out by ADEOYE, Gabriel Ademakinwa (04/25OC068). The thesis has been read and approved as meeting part of the requirements for the award of Doctor of Philosophy in Science Education, in the Department of Science Education, Faculty of Education, University of Ilorin, Ilorin, Nigeria.

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DEDICATION

This thesis is dedicated to my mother Deaconess M. A. Adeoye.

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ABSTRACT

Cell division, the most important life process for the perpetuation of species, has been identified in literature as a hard-to-teach and hard-to-learn Biology concept. Study technology principles such as modelling clay and demonstration kit has been documented to be effective in enhancing students' performances. Therefore, this study investigated the effects of modelling clay and demonstration kit on Senior School students' performance in cell division. The objectives were to: (i) determine the difference in the performance of students that learnt cell division with modelling clay, demonstration kit, and conventional method; (ii) examine the effects of modelling clay and demonstration kit on the performance of students based on gender; (iii) investigate the effects of modelling clay on the performance of students based on cognitive styles and score levels; (iv) explore the effects of demonstration kit on the performance of students based on cognitive styles and score levels; and (v) establish the interaction effects among treatment, gender, cognitive styles and score levels.

The quasi-experimental, non-randomized, pre-test, post-test control group design was adopted. The population was all Senior School students offering Biology in Omu-Aran, Nigeria while the sample comprised 213 Senior School II students from three purposively selected government schools in Omu-Aran, Nigeria. The stimulus instruments used were Cell Division Course Guide and Research Assistant Training Guide while the test instruments were Cell Division Performance Test (CDPT) and Group Embedded Figure Test (GEFT). The reliability coefficients of the CDPT and GEFT were 0.83 and 0.87 respectively, using Pearson Product Moment Correlation statistics. Data were analysed using *t*-test and Analysis of Covariance at 0.05 level of significance.

The findings of the study were that:

i. a significant difference existed in the performance of students that learnt cell division with modelling clay, demonstration kit and the conventional teaching method ($F_{(2, 209)} = 90.59$, $p < 0.05$);
ii. there was no significant difference in the effects of modelling clay and demonstration kit on the performance of students based on gender;
iii. there was no significant difference in the effects of modelling clay on the performance of students based on cognitive styles and score levels;
iv. a significant difference existed in the performance of students that learnt cell division using demonstration kit based on cognitive styles ($F_{(2, 62)} = 3.55$, $p = 0.03$) and score levels ($F_{(2, 62)} = 9.58$, $p < 0.05$), respectively; and
v. there was no significant interaction of treatment and gender, treatment and cognitive styles. However, interaction existed between treatment and students score levels ($F_{(4, 203)} = 6.18$, $p < 0.05$).

The study concluded that modelling clay and demonstration kit improved students' performance in cell division. This implies that the use of modelling clay and demonstration kit can significantly enhance students' understanding of the life processes taking place in the cell and by extension other biological processes. The study recommended that biology teachers and students should embrace the use of modelling clay and demonstration kit for effective teaching and learning of cell division.

Word Count: 489

CHAPTER ONE

INTRODUCTION

Background to the Problem

Science is the strategic medium for ensuring the economic and technological development of every nation. Consequently, both developed and developing nations place high premium on the acquisition of requisite scientific knowledge and technological skills by all school aged citizens. Science, according to Abimbola and Omosewo (2013), is a body of knowledge, a way or method of investigating phenomena for a better understanding of nature. Olorundare (2014) posited that science is a planned systematic investigation of the world, nature and the universe. Science is, therefore, the logical and systematic process of applying a planned series of methods to acquiring knowledge about human and the environment.

Science, as a field of study, has two main divisions which are the pure and applied sciences. The pure science is composed of biology, chemistry, and physics while the applied science includes subjects such as agriculture, geography, engineering, and other related subjects where the knowledge of science is applied. Biology, as a pure science subject, deals with the study of living organisms, in relation to their evolution, taxonomy, distribution, structures, growth, and functions. The study of biology is important to national development and serves as foundation subject for professional courses in the fields of medicine, microbiology, pharmacy, nursing, and other allied courses (Nnorom & Erhabor, 2019).

Despite the importance of biology to humankind, research reports by science educators have revealed that students' performances in the subject is unimpressive (Bello et al., 2016; Bichi, Ibrahim, & Ibrahim, 2019; Okwara, Anyagh, & Ikyaan,

2017). The performances of senior secondary school students in biology, in the May/June West African Senior School Certificate Examinations (WASSCE) for ten consecutive years (2010 to 2019), also corroborate the submissions of science education researchers.

Table 1 revealed that the total number of students that sat for biology was higher than chemistry and physics, despite the provision of the National Policy on Education (Federal Republic of Nigeria, 2013), which made biology a core requirement for only science students. Table 1 and Figure 2, however, indicated inconsistency in students' performances in biology due to the drop in percentage credit pass in 2012 and 2018 respectively, which contrast the gradual improvement witnessed in the other years under review.

Table 1

Students' Enrolment and Performance in May/June West African Senior School Certificate Examinations in Biology, Chemistry, and Physics in Nigeria 2010 to 2019

Year	Biology			Chemistry			Physics		
	Total Sat	Credit Pass	%	Total Sat	Credit Pass	%	Total Sat	Credit Pass	%
2010	1,300,418	427,644	33.90	465,643	236,059	50.70	463,755	237,756	51.30
2011	1,505,199	579,432	38.50	565,692	280,250	49.54	563,161	360,096	63.94
2012	1,646,150	587,044	35.66	627,302	270,570	43.13	624,658	429,415	68.74
2013	1,648,363	852,717	51.73	639,296	462,517	72.34	637,023	297,988	46.77
2014	1,365,384	766,971	56.17	636,268	397,649	62.49	635,729	386,270	60.76
2015	1,390,234	798,246	57.42	680,357	412,323	60.60	684,124	410,543	60.01
2016	1,200,367	740,345	61.68	706,873	408,122	57.74	705,125	415,655	58.95
2017	580,449	394,898	68.03	377,970	320,635	84.83	377,851	205,757	54.45
2018	1,087,063	679,299	62.48	728,551	424,231	58.22	728,354	571,687	78.49
2019	1,033,304	775,103	75.01	726,132	566,156	77.96	725,853	565,746	77.94

Source: Adapted from "Theory into practice: Beyond surface curriculum in science education," by A. S. Olorundare, 2014, *the one hundred and forty-seventh (147th) inaugural lecture*. Ilorin: Unilorin Press, pp. 26-27 and West African Examinations Council Lagos, Nigeria

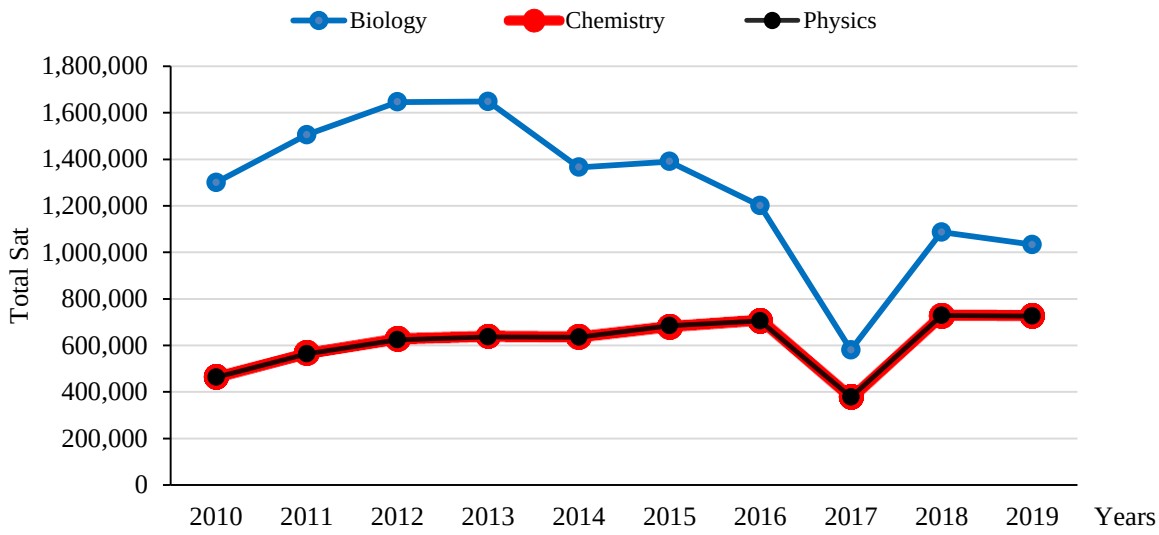


Figure 1. Graph showing the total number of students that sat for biology, chemistry, and physics in May/June West African Senior School Certificate Examination from 2010 to 2019 in Nigeria

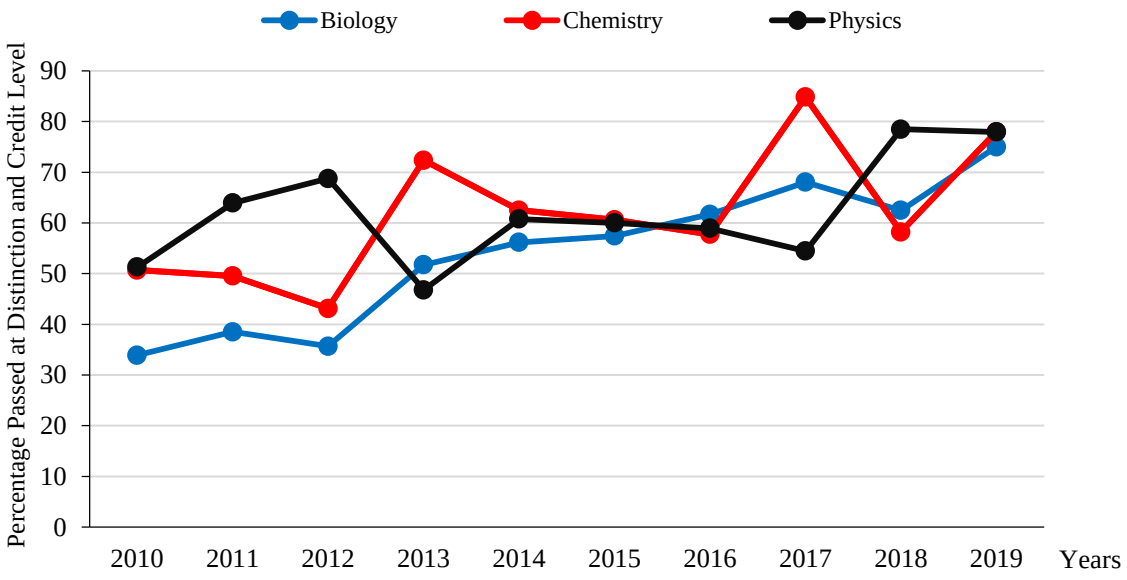


Figure 2. Graph showing the performances of students in May/June West African Senior School Certificate Examinations in biology, chemistry, and physics from 2010 to 2019 in Nigeria.

The inconsistency of students' performance in biology has been attributed to several factors and causal variables such as study barriers (Abe, Bello, & Hamzat, 2019), misconceptions of abstract concepts (Danmole & Lameed, 2014), teaching

styles and students' learning habits (Audu, 2018; Çimer, 2012), poor or inadequate instructional materials (Awolaju, 2016; Daworiye, Alagoa, Enaregha, & Eremasi, 2015; Uche, 2018), and the difficulty of some biology topics such as micro-organisms around us, genetics and cell division (Chukwuemeka & Dorgu, 2019; Elangovan, 2018; Etobro & Fabinu, 2017).

The life processes taking place in the cell that is, cell division, has been specifically identified as a hard-to-teach and hard-to-learn topic for senior secondary school biology teachers and students, respectively (Badmus, Bello, Hamzat, & Sulaiman, 2019; Musonda, 2014; Oztas, Ozay, & Oztap, 2003). Moreover, the West African Examinations Council (WAEC) Chief Examiners' Report observed that students were unable to either state the site of meiosis in animal or differentiate between mitotic and meiotic cell divisions (WAEC e-Learning, 2010, 2018).

Cell division is the process by which the cells of living organisms undergo nuclear and cytoplasmic divisions during growth, development and reproduction (Taylor, Green, & Stout, 2004). The process of cell division is of two forms, namely, mitosis and meiosis. Mitosis is the process by which a cell divides to produce two genetically identical daughter cells (diploid) containing similar set of chromosomes as the original parent cell (Yanagida, 2015). It occurs during asexual reproduction and in the body cells leading to an increase in cell number. Meiosis, on the other hand, is a reduction division by which the original cell of the parent is reduced to haploid numbers (four cells) which are genetically dissimilar to the parent cell during the formation of gametes and haploid spores (Alberts et al., 2014).

A typical cell division process has four major phases viz: prophase, metaphase, anaphase and telophase. These phases lead to the production of diploid (two) and haploid (four) number of cells in mitosis and meiosis, respectively (Ndu,

Asun, & Aina, 1999). Locke and McDermid (2005) assert that "learning the biological process of *mitosis and meiosis* [emphasis added] is fundamental to the understanding of molecular biology and transmission genetics" (p. 5). Kreiser and Hairston (2007) also believed that the acumen of learners, in mitosis and meiosis, is rudimentary to their understanding of Mendelian inheritance.

Cossa, Holtman, Ogunniyi, and Mikalsen (2008) remarked that students' poor knowledge of basic cell structure was responsible for their poor performance in cell division. Tanja and Harald (2008) posited that the lack of experiences of cells in everyday life and the construction of conceptions of cell division processes make the understanding of the topic difficult for students. Williams, Debarger, Montgomery, Zhou, and Tate (2012) observed that the inability of students to delineate connections between mitosis and meiosis was responsible for their poor performance in cell division, while Kamp and Deaton (2013) identified the microscopic nature of cell as the main factor causing the poor grasp of the processes of cell division by students.

Spronken-Smith (2008), therefore, advocated learning stimulated by inquiry, a learner-centred approach in which the role of the teacher is to act as a facilitator of learning. Hence, the teacher must adopt, or adapt, teaching strategies that can effectively facilitate students' learning. The principles of learning how to learn, based on study technology strategies, may assist in this regard because the teacher only facilitate the learning processes while the learners take up the responsibility of constructing their individual knowledge.

Study technology refers to the process of equipping learners with strategies that enable them take responsibility for, and control their own learning, thus, increasing learners' ability to apply knowledge to life (Applied Scholastics International, 2018). The main purpose of study technology, according to Adeosun-

Familoni (2015), is to expose learners to the basic principle of how to study using practicable principles and methods, so that learners can fully understand the content of each subject. The term technology, based on study technology principle, refers to a research-based system that can be used to assist people in studying or learning any subject. It does not have any bearing on educational technology nor the use of digital technologies or Information and Communication Technology in schools (Association for Better Living Education International, 2013).

Study technology was introduced into Nigeria in the year 2004 through a basic training programme sponsored by the defunct Education Trust Fund which is now Tertiary Education Trust Fund. Oladipo, Olowoye, and Adenaike (2012) reported that the teachers who took part in the training were selected from all the 36 states of the country. The training programme stimulated several educators in Nigeria to conduct empirical studies on the use of study technology strategies among students; such studies include those of Adeosun-Familoni (2015), Olowoye and Odumade (2016), Ahmed (2018), Luwoye (2019), and Onanuga, Saka, Adebanjo, and Olanrewaju (2019), among others.

Study technology identifies three barriers to learning, viz: (a) lack of mass, (b) too steep (skipped) a gradient, and (c) the misunderstood words (Abimbola, 2015; Hubbard, 1972). The misunderstood words constitute the third barrier to learners' study and it refers to a word that is not understood at all or wrongly understood which results in the non-comprehension of concepts, symbols, or situations and makes it difficult for students to apply the content of the materials being studied (Hubbard, 2001). The second barrier to study is based on gradient, which is the process of doing something step-by-step in a logical sequence. When any of the steps is too steep or skipped by learners, learning becomes difficult.

Mass, the lack of which constitutes the first barrier to learners' study, refers to the measure of mental tangibility that students ascribe to a subject so that the students have a picture in their minds of what they are learning about (Wikipedia, 2018). An individual needs mass in order to learn or understand anything because, without it, a learner only has thoughts or mental concepts (Hubbard, 2001). The mass being referred to, is the actual physical object used in classroom teaching and learning, and not the same as the mass in science which describes the property of matter in relation to its resistance to acceleration or the measure of the number of atoms in an object (Burton, 2019; The American Heritage Science Dictionary, 2011).

The abstract nature of some scientific concepts seems to compel teachers to frequently use the lecture method, while students embark on rote-learning as observed by Adeoye and Abimbola (2016) and Cetin, Ertepinar, and Geban (2015). Although, lecture method is a basic formal instructional strategy, it does not enhance perfect understanding. Hence, educators, such as Kılıç and Sağlam (2014) and Chapman (n.d.), among others, advocated the provision of mass during classroom teaching and learning processes.

Learning, in the absence of mass, sometimes makes students experience uncomfortable and distracting physical reactions such as feeling squashed, face squashed, bent, sort of spinning, sort of dead, dizzy, bored, angry, stomach feeling funny, headache, and eyes hurting frequently as posited by Awoyemi (2018) and Hubbard (2004) (see Appendix A). The use of specimens and hands-on demonstration is one of the ways through which teachers can provide mass for students during class instructions (Abimbola, 2015; Adeoye, Sulaiman, & Olawepo, 2018). Hands-on demonstrations are carried out in study technology using sketching, modelling clay, and demonstration kit (Hubbard, 1984).

The use of demonstration strategy constitutes an integral part of science teaching, especially for expressing scientific concepts in simplified forms which learners can easily comprehend. For instance, the use of the hands and eyes during demonstrations may stimulate more than one parts of the brain to bring about meaningful learning (Güneş & Çelikler, 2010; Rapp & Sengupta, 2011). Demonstrations are used in study technology to represent facts, ideas, procedures, and add reality to the significance of concepts by making learners demonstrate concepts with the use of modelling clay and demonstration kit, which may help to provide the required mass of the concepts (Hubbard, 2007).

Modelling clay is a flexible and colourful material that can be used for modelling different things. It is generally pliable; thus, it can be manipulated and reused for learning in order to turn both concrete and imaginary objects into colourful models (Herur, Kolagi, Chinagudi, Manjula, & Patil 2011). Modelling clay is used, in teaching and learning processes, for demonstrating words, actions, situations, concepts, or processes. This is because working with clay characters or models allows students to explore abstract concepts in a tangible way (Martinez-Aguilar, Obaya, Giammatteo, Montaño- Osorio, & Vargas-Rodríguez, 2018).

Mackinnon (2014) observed that the use of modelling clay provides the medium for demonstrating how things work, move or change. The use of modelling clay has been reported to improve science students' vocabulary development (House, 2007), the learning of pelvic anatomy (Patel, Rosentsveyg, Gabbur, & Marquez, 2014), the exploration of predator-prey interaction in vertebrates (Bateman, Fleming, & Wolfe, 2016), teaching of the periventricular structure of the brain (Akle, Peña-Silva, Valencia, & Rincón-Perez, 2017), and veterinary anatomy (Onuk, Çolak, Arslan, Sizer, & Kabak, 2019).

Another important tool to overcome the incidence of lack of mass is the demonstration kit. A demonstration kit is a collection of ‘odds and ends’ such as paperclips, corks, used phone recharge cards, pen tops, thumbtacks, erasers, crown corks, and threads (Awoyemi, 2018; Hubbard, 2001). These objects are kept in a box or container which is called demonstration kit. The demonstration kit can be used to teach or learn concepts, processes, situations, and actions or used while reading, watching films, and listening to tapes. This contrasts with the content specific demonstration kits which are used to teach specific contents as they only contain items which are related to the contents to being studied (Adeoye & Abimbola, 2016; Yetri, Koderi, Amirudin, Latifah, & Apriliana, 2019).

The use of demonstration kit requires students to pick objects from the kit and assign them significance as symbolic representations of ideas, objects, interrelationships, processes or principles. The objects which learners select from the demonstration kit can be used to describe the mechanics of concepts (Hubbard, 2001). For instance, learners can demonstrate a concept by choosing several objects from the demonstration kit, assigning them significance and verbalizing or physically demonstrating the relationships between them so as to make the topic being studied more real. Thus, providing a way to using manipulative to assess understanding (Chapman, n.d.; Touretzky, 2003).

Awoyemi (2018), Onanuga, Saka, Adebanjo, and Olanrewaju (2019), and Luwoye (2019) used the demonstration kit for teaching and learning, and found out that it improved the performance of senior school students in mathematics, computer, and biology, respectively. Other related studies, like those of Abdulkadri (2011), Gbigbadua, Abimbola and Ahmed (2014), and Ahmed (2018) revealed that the use of study technology strategies significantly enhanced the performance of senior school

students in biology. Edukugbo (2009) also reported improvement in students' reading levels in Mexico City and England after exposure to study technology strategy.

The instructional strategy adopted, or adapted, by teachers for classroom teaching and learning is usually influenced by students related factors such as gender, cognitive styles and score levels. Gender is the distinction between male and female individuals, based on their physical and behavioural features (Idaa & Ugbede, 2019). The performance of students' in cell division has been observed to be influenced by gender as reported by Meltem (2007) because the males outperformed females in mitotic and meiotic cell division processes. However, Badmus, Bello, Hamzat, and Sulaiman (2019), and Jiyah (2016) reported in their separate studies that there was no significant difference in the performance of male and female students taught cell division using WebQuest instructional package and hands-on with minds-on instructional strategy, respectively.

Other research findings in relation to students' gender and performances in biology have shown mixed results. For instance, Olutola (2017) concluded that gender was a significant factor for students' performance in biology because the average score of female students was higher than that of the male. Bilesanmi-Awoderu, Afuwape, and Jolaosho (2017) observed that the use of individualized and demonstration strategies favoured female biology students more than their male counterparts. However, Dike, Anyanwu, Zachariah, Dalhatu, and Samuel (2018); Kingdom-Aaron, Etokeren, and Okwelle (2019); and Ibrahim (2020) found out in their separate studies that there was no significant difference in the performance of male and female students in biology.

In addition to the influence of gender, researchers have equally examined the influence of cognitive styles on students' learning of several concepts in biology.

Cognitive styles refer to the way each learner processes information in their cognitive structures. Meanwhile, the most extensively studied dimensions of cognitive styles in education are the field-dependent and field-independent cognitive styles (Onyekuru, 2015). The field-dependent learners are non-analytic individuals that process information using external references, trial-and-error approaches and show low preference for abstract learning while the field-independent learners are analytic individuals who rely on internal references in solving problems because they view objects as a whole thereby finding out the underlying causal relationships of problem situations (Idika, 2017).

Studies have revealed that researchers held contradictory views on students' cognitive styles in relation to their performances in biology and other related science subjects. For instance, Sara, Maruta, and Olarinoye (2016) found out that the cognitive styles of field-dependent, field-independent, and field-neutral senior school biology students were significantly related to their performances in science process skills. However, Okoye (2016) argued that the performance of students in biology was not influenced by cognitive styles. The study of Ashiru and Sadiq (2016) on the impact of cognitive style on secondary school students' attitude and performance in biology practical revealed that there was a significant difference in the attitude and academic performance of field-dependent and field-independent students taught biology practical using discovery strategy.

Furthermore, Bassey, Umoren, and Udida (2010), and Idika (2017) reported a significant main influence of cognitive style on students' performance in chemistry. Okoronka and Wada (2014) noted that there was a significant interaction effect between cognitive style and gender on physics students' performance. Akanmu and Fajemidagba (2013) also observed a significant difference in the performance of field-

dependent and field-independent senior school students exposed to guided-discovery learning.

Studies have also revealed that students operate at different score levels which is reflected in their academic skills and variability of performance in specific tasks (Lamidi, Oyelekan, & Olorundare, 2015; Lukitasari, Hasan, & Sukri, 2020). Score level contrasts with intelligent level because it is the rating of students' performances in levels unlike intelligent level which is dependent on students' problem-solving skills. Meanwhile, researchers are yet to agree, in their conclusions, on students' performances in relation to their score levels.

Jiyah (2016) observed that there was no significant difference in the achievement of low, medium, and high scoring students that learnt cell division using hands-on with minds-on strategy. Yaduvanshi and Singh (2019) also observed that there was no significant difference in the performance of high, medium, and low scoring students in biology. However, Jegede and Olu-Ajayi (2017) discovered that mentoring enhanced the performance of low scoring students in biology. Olaniyan and Omosewo (2015) observed a significant difference in the score levels of the low, medium, and high scoring students taught current electricity using target-task problem-solving model.

The interaction effect of independent variables such as gender, cognitive styles, and score levels with treatment have received research attention in science education. For instance, Ibe and Abamuche (2019) discovered that there was no interaction between treatment and gender on students' achievement in biology. Onyekuru (2015), however, observed a significant interaction between students' cognitive styles and gender. In addition, Adeoye (2018) reported a significant interaction between treatment and score levels in relation to students' attitude and

achievement in biology. Kauts and Kaur (2019) also observed a significant interaction between students' cognitive style and treatment in concept attainment in science.

As important as cell division is to the growth, development, and regeneration of living organisms, the microscopic nature of the cell makes the provision of mass arduous. Therefore, in order to enhance the meaningful assimilation, retention, performance, and application of the acquired cell division knowledge by senior school biology students, there is the need to explore study technology strategies like the use of modelling clay and demonstration kit for the concretization and conceptualization of cell division processes.

Statement of the Problem

Biology, as a science subject, has remained an important requirement for science students, meant to equip learners with adequate laboratory and field skills, application of scientific knowledge to everyday life and functional scientific attitudes (Federal Ministry of Education, 2009). The attainment of the aforementioned objectives hinge on the pedagogical strategies adopted by teachers for the teaching and learning of biological –- facts, concepts, laws, principles, theories and life processes. Among the numerous life processes taking place in organisms, is cell division. It is the most fundamental life process that ensures the perpetuation of each species of organism. Therefore, cell division is the basic pre-requisite for the meaningful learning of related biology topics.

However, the West African Examinations Council (WAEC) Chief Examiners' Reports (2010, 2018) clearly indicated that students had difficulties answering questions on cell division and related biology concepts. Kamp and Deaton (2013) attributed the learning difficulties experienced by students in understanding cell

division to the microscopic nature of the cell which makes the supply of mass an uphill task for many biology teachers. Thus, it behoves the schools and teachers to provide instructional materials and models which students can easily manipulate as symbolic representations of cell division processes.

For instance, the use of modelling clay had been found to be effective for the teaching and learning of veterinary anatomy courses, as well as the sensory and motor tracts (Onuk, Çolak, Arslan, Sizer, & Kabak, 2019; Herur, Kolagi, Chinagudi, Manjula, & Patil, 2011), while the demonstration kit has been found to significantly improve the learning of mathematics and computer studies by senior school three and one students, respectively (Awoyemi, 2018; Onanuga, Saka, Adebanjo, & Olanrewaju, 2019). Furthermore, Luwoye (2019) reported that the use of the demonstration kit remediated most of senior school students' misconceptions in mitosis and meiosis.

The cited studies indicate a dearth of researches on the use of modelling clay and demonstration kit for the teaching and learning of cell division. This is because most of the previous studies were conducted in the field of medicine, anatomy, computer studies, and mathematics with just a few in biology. In addition, Senior Secondary School two (SSS II) biology students were not involved in most of the cited researches which were also conducted outside the locale of the present study. Moreover, students' cognitive style was not considered as a moderator variable in the cited studies. Thus, SSS II biology students and independent variables such as gender, cognitive styles and score levels were considered in the present study which investigated the effects of modelling clay and demonstration kit on senior school students' performance in cell division in Omu-Aran, Nigeria.

Purpose of the Study

The main purpose of this study was to investigate the effects of modelling clay and demonstration kit on senior school students' performance in cell division. Specifically, the study:

1. determined the effect of modelling clay, demonstration kit, and conventional method on the performance of senior school students in cell division;
2. examined the difference in the performance of male and female senior school students when they learnt cell division using modelling clay;
3. investigated the difference in the performance of male and female senior school students when they learnt cell division using demonstration kit;
4. explored the difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using modelling clay;
5. identified the difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using demonstration kit;
6. established the difference in the performance of high, medium, and low scoring students that learnt cell division using modelling clay;
7. considered the difference in the performance of high, medium, and low scoring students that learnt cell division using demonstration kit;
8. investigated the interaction effect of treatment and gender on senior school students performance in cell division;
9. ascertained the interaction effect of treatment and cognitive styles on senior school students performance in cell division;

10. examined the interaction effect of treatment and score levels on senior school students performance in cell division;

Research Questions

In this study, answers were provided to the following research questions:

1. What is the effect of modelling clay, demonstration kit, and conventional method on the performance of senior school students in cell division?
2. How do male and female students performance differ when they learnt cell division using modelling clay?
3. How do male and female students performance differ when they learnt cell division using demonstration kit?
4. What is the difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using modelling clay?
5. What is the difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using demonstration kit?
6. What is the difference in the performance of high, medium, and low scoring students that learnt cell division using modelling clay?
7. What is the difference in the performance of high, medium, and low scoring students that learnt cell division using demonstration kit?
8. What is the interaction effect of treatment and gender on senior school students performance in cell division?
9. What is the interaction effect of treatment and cognitive styles on senior school students performance in cell division?

10. What is the interaction effect of treatment and score levels on senior school students performance in cell division?

Research Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

H_{01}: There is no statistically significant difference in the effect of modelling clay, demonstration kit, and conventional method on the performance of senior school students in cell division.

H_{02}: There is no statistically significant difference in the performance of male and female senior school students when they learnt cell division using modelling clay.

H_{03}: There is no statistically significant difference in the performance of male and female senior school students when they learnt cell division using demonstration kit.

H_{04}: There is no statistically significant difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using modelling clay.

H_{05}: There is no statistically significant difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using demonstration kit.

H_{06}: There is no statistically significant difference in the performance of high, medium, and low scoring students that learnt cell division using modelling clay.

H_{07}: There is no statistically significant difference in the performance of high, medium, and low scoring students that learnt cell division using demonstration kit.

H_{08}: There is no statistically significant interaction effect of treatment and gender on senior school students performance in cell division.

H_{09}: There is no statistically significant interaction effect of treatment and cognitive styles on senior school students performance in cell division.

H_{010}: There is no statistically significant interaction effect of treatment and score levels on senior school students performance in cell division.

Scope of the Study

This study was conducted in Omu-Aran, Kwara State, Nigeria among Senior Secondary School (SSS) students in their penultimate year, that is, students in SSS II classes. The biology content coverage was limited to mitosis and meiosis that is, cell division processes while the moderator variables covered were; gender, cognitive styles and score levels. The effects of the use of two instructional tools namely, modelling clay and demonstration kit were also under focus in the study. The *t*-test and Analysis of Covariance were the statistical tools used for data analysis.

Significance of the Study

The findings of this study would be of immense benefits to biology students, biology teachers, teacher education programme, curriculum developers in the field of biology education, biology textbook authors, researchers in the field of biology education, and science teacher professional associations such as Science Teachers Association of Nigeria (STAN) and Science Association of Nigeria (SAN).

The findings of this study could stimulate students to learn and employ study technology principles to recognize and overcome the barriers to learning. Consequently, the students may use the modelling clay and demonstration kit for learning, thereby, improving their performances in biology since learners are actively, cooperatively and independently involved in the classroom teaching-learning processes.

The results from this study could make teachers more sensitive, motivated, creative, and keep abreast of innovative tools for teaching and learning such as the use of modelling clay and demonstration kit whilst guiding learners to generate their individual knowledge of concepts. This would help teachers make appropriate choices of the strategies to be adopted for their classroom instruction delivery so as to ensure an improved students' performance even when the conventional method is being utilized.

The findings of this study may also be useful to teacher education programme by revealing the need for educational institutions or teacher-training colleges to equip pre-service teachers with the knowledge of the importance of modelling clay and demonstration kit in assisting learners to effectively learn any subject. It is also hoped that the findings of this study would make teacher education agencies and institutions to regularly organize seminars, workshops, training programmes, and conferences to help practising teachers keep abreast of innovative strategies of teaching and learning, which may invariably improve the performances students.

The findings of this study would also be of immense benefits in the area of curriculum development by revealing the need to include demonstration activities that can stimulate students' critical thinking and problem-solving skills in the instructional curricular. It is similarly hoped that this study may give curriculum-planners an

insight into examples, illustrations and demonstration activities to be included in the teacher-student activity section of the biology curriculum and other related science subjects.

Textbook authors might also find the result of this study useful as they would see the need to include the use of modelling clay and demonstration kit in the exercise section of textbooks thereby serving as a check for readers during the process of evaluating the knowledge acquired on a topic read in such texts. The findings of this study may also be helpful in the area of educational policies by revealing the need for policies targeted at the constant review of teachers' compliance with the full implementation of the general objectives of biology as provided for in the senior secondary school biology curriculum.

The findings of this study might also serve as a springboard for researchers who may be interested in carrying out further studies on other related issues with respect to the use of modelling clay and demonstration kit. It may also reveal the need for researchers to direct more concerted efforts towards the investigation of student-centred strategies of teaching and learning which may be useful in the concretization of cell division processes owing to the microscopic nature of the cell. In addition, the findings of this study could make professional association to continually organise special sessions to update members on innovative teaching and learning strategies.

Clarification of Major Terms and Variables

The following terms were defined as used in this study:

Modelling Clay: this refers to coloured play dough made from flour which was used by students to model and learn cell division processes.

Demonstration Kit: a plastic box containing assorted small objects such as corks, coins, used phone recharge cards, paper clips, pen tops used by students to demonstrate and learn cell division processes.

Cell Division: a life process occurring in young and matured cells, resulting into two or four new daughter cells in mitosis and meiosis respectively.

Performance: students' scores in Cell Division Performance Test after exposure to the modelling clay and demonstration kit.

Strategies: the adaptation of modelling clay and demonstration kit for the teaching and learning of cell division.

Mass: the actual physical objects used as instructional materials to facilitate students learning.

CDPT: Cell Division Performance Test

GEFT: Group Embedded Figure Test

Cognitive Styles: students' preferred information processing styles classified as field-dependent (students with weak information processing skills and 35th percentile score in GEFT); field-neutral (students with fair information processing skills and 70th percentile score in GEFT); and field-independent learners (students with good information processing skills and 100th percentile score in GEFT).

Score Levels: Senior Secondary School two (SSS II) Students' cumulative performance in biology after the first session (SSS I). Students with a score range of 65% and above were classified as high scoring students, those with scores ranging from 50% to 64% were grouped as medium scoring students while those with scores ranging from 0% to 49% were classified as low scoring students.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter presents the review of literature that were related to this study. The review was carried out under the following sub-headings:

- Theoretical Framework for the Study
- Objectives and Contents of the Nigerian Senior Secondary School Biology Curriculum
- Empirical Studies on the Teaching and Learning of Cell Division
- Studies on the use of Modelling Clay for Teaching and Learning
- Studies on the use of Demonstration Kit for Teaching and Learning
- Influence of Gender on Students' Performance in Biology
- Influence of Cognitive Styles on Students' Performance in Biology
- Influence of Score Levels on Students' Performance in Biology
- Studies on the Interaction Effect of Treatment and Moderating Variables on Students' Performance in Biology
- Appraisal of the Reviewed Literature

Theoretical Framework for the Study

Learning theories are framework that describes how an individual acquire, process and retrieve information. It includes connectionism, constructivism, cognitivism, and behaviorism. The theoretical bases for this study stemmed from

constructivism and the theory of learning how to learn, both of which encourage experiential learning that is, learning by doing. Constructivism as an educational theory took its roots from cognitive psychology and biology with a focus on how the cognitive organism construct knowledge, interprets experiences and shape it into a structured world (Piaget, 1968; von Glasersfeld, 1982).

Derry (1996) observed that there are many psychological views of constructivism "ranging from general cognitive architecture to specific theories about how people reason with mental models to theories about how learning occurs with specific problem types in specific kind of instructional environment" (p. 164). The theory of constructivism is based on the principle of equilibrium brought about by adaption through the process of assimilation and accommodation of new information into existing cognitive structures which leads to the formation of new schema (Blake & Pope, 2008). This is because assimilation causes an individual to incorporate new experiences into pre-existing mental capacity while accommodation involves the fusion of these experiences to restructure the world (Piaget, 1977).

The development of children according to Piaget can be classified into four main stages which are the sensorimotor, preoperational, concrete operational, and formal operational stages (Gunduz, Aslanova, Kiraz, & Antip, 2019). The formal operational stage of Piaget's cognitive development as shown in Table 2 coincides with the average age of the target population in this study. Also, learners study independently in pairs through a hypothetical-deductive strategy and this tally with cognitive and social constructivism because learners are made to explore the materials been studied and construct their own knowledge individually and collectively (Lunenburg, 2011).

Table 2

Piaget's Cognitive Development Stages

Stage	Age Range	Description
Sensorimotor	0-2 years	Coordinating of senses with motor response, sensory curiosity of the world and development of object permanence.
Preoperational	2-7 years	Symbolic reasoning, appropriate use of syntax and grammar to explain concepts. High intuitive and imaginative thinking, with difficulty in abstract thought.
Concrete Operational	7-11 years	Concepts are related to concrete situations. Adequate knowledge about time, quantity, and space, but not as independent concepts
Formal Operations	11+	Theoretical and hypothetical thinking. Abstract logic and reasoning. Strategy and planning are possible. Concepts learnt in one context can be applied to another.

Source: Adapted from "Kohlberg's Theory of Moral Development," by Psychology Notes HQ, 2012, retrieved from https://www.psychologynoteshq.com/kohlbergs theory/

In addition, the constructivists perceived teachers as facilitators of knowledge whose main role is to aid the student when it comes to their own understanding thereby helping the learners develop effective study and learning strategies (Adeoye & Ayanda, 2019; Razia, 2015). The facilitator, in this case, guides the students to come to conclusions on their own instead of being told. Thus, there is a shift in focus from the teachers to the students and their learning. Akanbi (2013) submitted that student-directed learning is based on the belief that active students' involvement in

the learning process increases learners' motivation while the teacher provides appropriate guidance targeted towards making learners become self-regulated in the planning and organization of their own learning.

Abida and Muhammad (2012) observed that "the task of the instructor is to translate information to be learnt into a format appropriate to the learner's current state of understanding" (p. 171). The constructivist appreciates the essence of building constructs and internalizing the knowledge given, rather than accepting information as presented through rote-memory. This view of learning is based on the perception that knowledge cannot be mechanically ingested from the teacher or the textbook but rather it is constructed by the learner through an active mental process of development (Olorundare, 2014).

Learning, based on constructivism involves the modification of pre-existing knowledge to generate new cognitive structures. Piaget (1968) noted that learning is a dynamic process comprising of successive stages of adaption to reality during which learners actively construct knowledge by generating and testing different hypotheses. Thus, students are not just a passive receiver of knowledge but active learners who construct knowledge through experience, observation, analysis, documentation, and reflection (Singh & Yaduvanshi, 2015). This is because the unique factor in teaching is that each teacher learns to use strategies that suits each learner so that the objectives of the lesson can be achieved (Gengle, Abel, & Mohammed, 2016; Sam, Owusu, & Anthony-Krueger, 2018).

The principles of study technology developed by Hubbard (1972) coincides with the theory of constructivism because students versed in study technology principles understands the symptoms of the barriers to study, thus, apply appropriate strategies to proffer solutions to the difficulties they encounter while studying (Kyhl,

2003). Teachers can also use the same strategies to improve the learning rates of students because the end results of the application of study technology are students who know how to learn, how to study and are motivated independent lifelong learners (Abimbola, 2013).

Study technology principle is based on the use of strategies specifically designed to overcome the three basic barriers to study that is lack of Mass, too steep a study gradient and a bypassed definition or misunderstood words (Onojah, 2016). The present study is based on the first principle of study technology which recognized the use of pictures, diagrams, sketches, modelling clay and demonstration kit for providing mass when introducing new concepts, processes, and idea. This is because the use of concrete objects in teaching and learning could enhance learners problem-solving and conceptual learning skills (Krontiris-Litowitz, 2003, p. 109).

The use of modelling clay and demonstration kit for teaching and learning processes may help learners in the construction of their own idiosyncratic knowledge by physically conceptualizing concepts and processes to display perfect understanding. Learners may also be actively involved in the construction and internalization of new knowledge during the use of modelling clay and demonstration kit because learners take greater responsibility for their own learning as they seek, find, synthesize and share their knowledge with others (Adama, 2014).

The Edgar Dale's cone of experiences in Figure 3 also reveals that learners exposed to strategies requiring them to actively construct, organize and internalize their own knowledge produced the best of results because learners are allowed to coordinate their own learning.

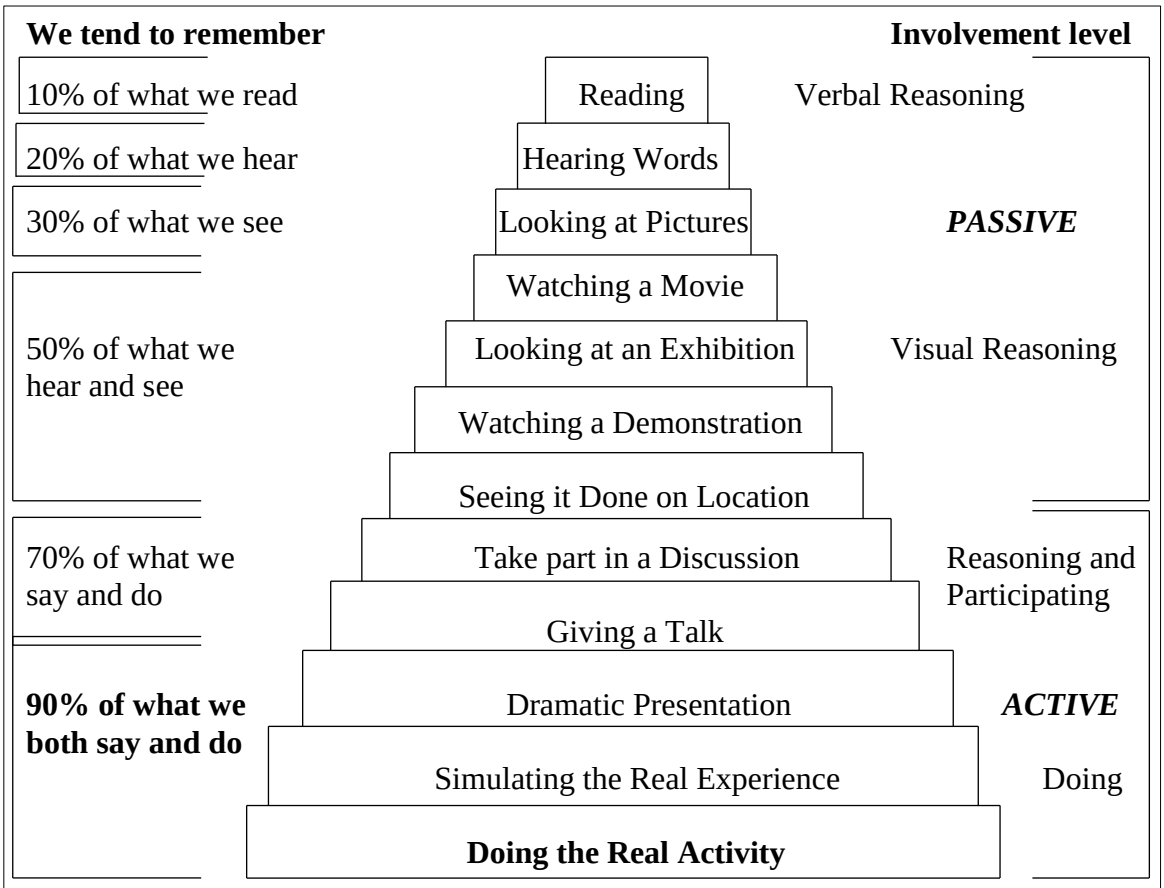


Figure 3. Edgar Dale's Cone of Experience. Adapted from "Teaching with Contrived Experiences," by O. Miyerkules, 2015, retrieved from http://www.capulongglaiza .blogspot .com.ng/

The strategies used in this study fits into the last segment of the cone because learners are able to touch, feel and manipulate the modelling clay and demonstration kit by themselves, thereby, aiding the concretization of knowledge. This is in line with

Atomatofa (2014) who posited that students understanding of scientific knowledge are improved when they are actively involved or engaged in scientific investigations.

One of the key features of constructivism as a learning theory is based on the explanation of how people learn through scientific observations and research. Just as teachers have to learn how to teach from a constructivist point of view, so also students must learn how to learn (Garbett, 2011). This tallies with the submission of Waeytens, Lens, and Vandenberghe (2002) that "learning to learn should include more than merely giving some techniques and strategies to process subject material" (p. 308).

The constructivist theory has implication on the present study because learners are guided by the instructors to construct their own individual knowledge through a group work approach with other learners. Thus, the instructors (trained research assistants) base on study technology principles used the modelling clay and demonstration kit to facilitate the integration of the content (cell division) into learners existing biological knowledge.

Objectives and Contents of the Nigerian Senior Secondary School Biology Curriculum

Curriculum forms an integral part of the educational system of every nation and has been defined in many different ways. Alade (2005) defined curriculum as an educational programme for specified group of learners aimed at achieving a predetermined objective. Olorundare (2014) described it as a structured, series of intended learning outcomes. Abidoye and Ogunlowo (2019) perceived curriculum as an educational experience specifically designed for learners within a particular period of time. Curriculum, therefore, is the broad and comprehensive statement of all the

learning outcomes which learners are expected to achieve within a specified period of teaching and learning.

The current senior secondary school biology curriculum published by the Nigerian Educational Research and Development Council (NERDC) is an outgrowth of the one previously developed by the Comparative Education Study and Adaptation Centre (CESAC). The contents and context of the Nigerian senior secondary school biology curriculum is organized around four themes which are the organization of life, organisms at work, the organisms and its environment, and continuity of life. These themes are expanded and organized into six sections comprising of topics, performance objectives, content, teacher and students' activities, instructional materials, and evaluation guide (Federal Ministry of Education, 2009).

Biology as a natural science subject deals with the study of life that is, living and non-living things (Ramalingam, 2013). The study of biology at the senior secondary school level of education in Nigeria is restricted to only science students and commences at senior secondary school one and terminated at senior secondary school three. Topics in the biology curriculum are diversify to cover both the biotic (living) and few abiotic (non-living) aspects of life. Such topics include: recognition and classification of living things, properties and functions of the cell, tissues and supporting systems, animal nutrition, microorganisms in action, habitats, biology of heredity, ecological management, pest and diseases of crops, regulation of internal environment, digestive, transport, respiratory, reproductive, nervous, and excretory systems (Federal Ministry of Education, 2009).

A cursory look at the senior secondary school biology curriculum indicates that mitosis and meiosis is part of the properties and functions of the cell which is subsumed under organization of life. The senior secondary school biology curriculum

only specified the evaluation guide for mitosis and meiosis without stating the performance objective, teacher and students' activities, teaching and learning materials like other contents. Thus, biology teachers must be creative and use strategies or tools which makes students' active during the teaching-learning processes rather than encourage students' to be a passive receiver of knowledge who are totally dependent on the teacher.

This made the curriculum statement to include the adoption of field studies, guided discovery, laboratory techniques and skill along with conceptual thinking by biology teachers (Federal Ministry of Education, 2009). All the aforementioned strategies encourage explorative learning with emphasis on the learner and the learning processes. This is also tally with study technology principles of teaching and learning which involves the use of modelling clay and demonstration kit.

Empirical Studies on the Teaching and Learning of Cell Division

The regeneration and continuity of life in every living organism is hinged on the viability and division potentialities of the organism's cells. This is because cell act as the building block for all the tissues, organs, systems, and invariably the organism as a whole. Ellinger and Ellinger (2014) defined the cell has as the smallest, structural, and functional unit of all living organisms, which can exist alone. Eigsti (2017) described the cell as the tiny unicellular or muticellular unit which forms the building blocks of living things and carry out the basic functions of life.

The cell is fundamentally important to the continued existence of life on earth, this is because all living organisms arise from pre-existing cells. This submission was well captured in the cell theory which states that: (a) all living things are made up of a cell or cells, (b) the cell is the structural and functional unit of all living things, and (c)

new cells arise from pre-existing cells by cell division (Idodo-Umeh, 2010). Three forms of cell division processes are identifiable; amitosis, mitosis and meiosis but the fact that amitosis occurs in unicellular organisms make it an asexual reproduction and a form of mitotic division (Elangovan & Ismail, 2014). Therefore, cell division is the process by which cell divides by mitosis and meiosis.

Mitosis, as a cell division process occurs in living organisms during growth and development yielding diploid number of cells. It is a vital life process for the regeneration of unicellular organisms and plants. In higher animals, mitosis takes place in the somatic or body cells (Okeke, et al., 2006; Ramalingam, 2013). Meiosis, in contrast is a reduction division in which a diploid cell from mitosis undergo two successive divisions to produce four haploid cells (Idodo-Umeh, 2010). Figure 4 shows mitosis and meiosis cell division processes resulting in the production of two (diploid) or four (haploid) daughter cells respectively.

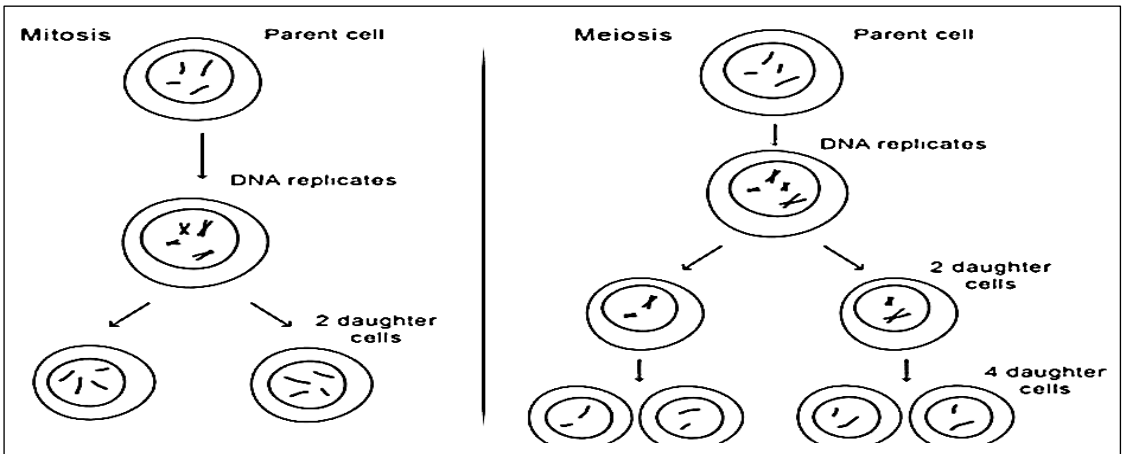


Figure 4. Mitotic and meiotic cell division processes. Adapted from "The Cell Cycle, Mitosis, and Meiosis," by Virtual Genetics Education Centre, n.d., retrieved from http://www2.le.ac.uk/departments/genetics/vgec/highereducation/topics/cellcycle-mitosis-meiosis

Learning about microscopic structures, such as cells, can often be mundane for learners because they may not be able to visualize or manipulate living structure like

the cell. Kamp and Deaton (2013) admitted that cell division has remained a difficult topic for students because most learners often times adopt the use of memorization for learning it. In addition, empirical investigations on students' conceptions of cell biology by Dikmenli, (2010), Strgar (2013) and Luwoye (2019) revealed that students have difficulty learning about cell division concepts and processes. To this end, several innovative strategies and materials have been investigated by different researchers to help students in the concretization and visualization of cell division processes.

Güneş and Çelikler (2010) investigated the effects of modelling and computer-assisted instruction (CAI) on students' academic performance in cell division. The study was carried out with one control and two experimental groups to whom cell division was taught. One hundred and thirty-two students participated in the study. CAI was used to teach one of the experimental groups while students in the second experimental group developed models related to cell division using plasticine, buttons, beads, wire and yarns. The *t*-test was used for data analysis and the result indicated a significant difference in the performance of the experimental and control groups, respectively.

Mohapatra and Mohapatra (2011) conducted a study on the effect of animations in constructing and reconstructing students' knowledge of cell division. The sample comprised 124 students while a twenty-item multiple-choice questionnaire, ten open-ended questionnaire and five item personal interviews questions constituted the instruments used for data collection. The results presented using charts, pictures and percentages revealed that the integration of animations into cell division instruction resulted in better understanding as against the conventional method of teaching.

Ertugrul and Yilmaz (2012) investigated students' performance in cell division and reproduction using two-tier multiple-choice diagnostic test. The sample consisted of 403 high school students. Structured interview and two-tier diagnostic test on cell division and reproduction were the instruments used for data collection. The results from the study indicated that there is the lack of perfect understanding of cell division and reproduction concepts among high school students.

Wekesa, Wekesa, and Amadalo (2013) examined the teaching of cell division by biology teachers using computer-mediated simulation module. The researchers utilized quasi-experimental approach of Solomon-Three group design and a total of 102 students (59 males and 43 females) participated in the study. Biology Achievement Test consisting of 30 items and Students' Attitude Questionnaire (SAQ) was used for data collection while Analysis of Variance (ANOVA) was used for data analysis. Findings from the study showed that computer-mediated simulations positively influenced students' understanding, achievement, and attitude towards cell division topic in school biology.

The effectiveness and problems of utilizing diagrams for secondary school students' learning of cell division was investigated by Cheung (2014). Convenience sampling technique was used to select 22 secondary school students from an intact biology class in a local girl school. Data were collected using a set of task sheet consisting of six pages' illustrations of mitotic and meiotic cell division, and interview protocol. Results from the study revealed that students generally perceived diagrams useful for learning cell division.

Baharom (2015) examined the use of learning cycle in understanding of cell division. The study adopted the quasi-experimental, post-test only control group design. A total of 51 students offering biology from two different colleges were

involved in the study while an achievement test consisting of 40 multiple choice question and four-word problems on cell division and growth, cell cycle, mitosis and meiosis were used for data collection. The *t*-test statistics was used for data analysis. The findings revealed that the performance of students exposed to learning cycle was better than those exposed to the conventional method of teaching.

Jiyah (2016) conducted a study on the effects of hands-on with minds-on instructional strategy on senior school students' achievement in cell division. The quasi-experimental, pre-test, post-test control group design was used in the study. The 226 senior secondary schools two students that participated in the study used cowpea, cardboard, threads, and adhesive gum to learn cell division. The data collected using the researcher-designed Cell division Achievement Test (CAT) were analyzed using Analysis of Covariance. Findings from the study showed a significant difference in the achievement of students taught cell division using hands-on with minds-on strategy and those taught with the conventional method.

Olasehinde (2018) explored the effects of video media on senior school students' achievement in cell division concepts. The quasi-experimental design was used for the study. The sample was composed of 87 senior secondary school one students offering biology. The instruments used were instructional guide on cell division and lecture method, and an achievement test on cell division. The *t*-test statistical tool was used to analyze the data collected. One of the finding showed that there was a significant difference in the achievement of students' taught cell division with video media strategy and those taught with the lecture method.

Badmus, Bello, Hamzat, and Sulaiman (2019) investigated the use of WebQuest strategy on the achievement of senior school students' in cell division. The quasi-experimental design was adopted for the study while the sample comprised 53

students from two purposively selected senior schools in Ilorin, Kwara State, Nigeria. A researcher designed Cell Division Achievement Test (CAT) was used for data collection. The *t*-test and ANCOVA were used for data analysis. The finding from the study indicated that the use of WebQuest improved students achievement in cell division.

On the basis of the reviewed literature, it has been established that cell division is an important process for the growth, reproduction and development of organisms but mitosis and meiosis have remained a difficult biology topic owing to the abstract nature of the topic. Sequel to this, several innovative strategies have been explored in order to enhance student achievement in cell division and other adjoining biology concepts. It is, however, clear that the cited studies did not investigate the use of modelling clay and demonstration kit for the learning of cell division.

Studies on the use of Modelling Clay for Teaching and Learning

Models are physical, computational, or mental representations of real objects which can be directly manipulated, allowing for the description, prediction, and explanation of concepts, or phenomena (Porntrai, 2014; Rapp & Sengupta, 2011). Pop-Pacurar and Tirla (2009) remarked that the use of models is an active strategy that can help biology teachers improve students' critical thinking abilities, especially in the intuitive, abstract, and more difficult topics, such as cellular structure and microscopic processes because models can be used to represent biological objects and phenomena.

The use of modelling clay has been explored in several studies for teaching and learning. For instance, Myers, Arya, Verma, Polseno, and Buchanan (2001) investigated the use of clay models for teaching pelvic anatomy to obstetrics and

gynaecology residents. Postgraduate obstetrics and gynaecology students constituted the target population for the study. The experimental group participated in clay modelling session. The data collected were analysed using parametric, nonparametric, and repeated measures analyses. Results from the study showed that the combination of modelling clay with lecture was more effective than lecture alone for teaching pelvic anatomy.

Oh, Kim, and Choe (2009) explored the use of modelling clay for learning about cross-sectional anatomy. The sample was composed of 70 medical students. The participants in the study used polymer clay (a synthetic form of modelling clay) to create models of organs based on the pictures and figures in their respective textbooks and atlases. Data collected using examination test were analysed using *t*-test statistics. The finding revealed that the group that used modelling clay had a higher performance than the group taught with the lecture method.

DeHoff, Clark, and Meganathan (2011) investigated the effects of modelling clay and cat dissection on undergraduate learning outcomes in human anatomy and physiology. One hundred and ten students participated in the study. During the administration of treatment, students first examined human plastic models of the muscular system and diagrams in their textbook. Examination consisting of identical set of low and high order questions was used for data collection. The independent sample *t*-test was used for data analysis. Findings from the study indicated that the modelling clay group performed better in the low order questions.

Active learning by playdough modelling in the medical profession was investigated by Herur, Kolagi, Chinagudi, Manjula, and Patil (2011). The 100 students selected for the study were randomly assigned into experimental and control groups, respectively. Coloured playdough was the modelling clay used for the study.

After the modelling process, students were asked to demonstrate and explain the course of the different tracts they had modelled and were thereafter assessed with a questionnaire. Wilcoxon's signed rank test and *t*-test were used for data analysis. The findings revealed that the experimental group performed better than the control group.

Antonishen (2014) examined the effects of the use of clay for sculpting muscles in a human anatomy course. The sample comprised 129 undergraduate students. Participants in the treatment group were provided with clay which they used to modelled muscles, while the control group did not use clay modelling. Students' performance on lab examination was evaluated by comparing mean examination scores between the control and experimental groups via independent sample *t*-test. Findings from the study indicated that the mean score of the treatment and the control group were significantly different.

Kooloos, Schepens-Franke, Bergman, Donders, and Vorstenbosch (2014) compared the anatomical knowledge acquired through clay modelling with video observations. The pre-test and post-test experimental procedure was adopted while the sample consisted of 399 medical students. The data collected was analyzed using Analysis of Covariance with the pre-test as covariates. The findings from the study showed that students engaged in clay modeling exercise acquired more anatomical knowledge than students exposed to live video observations.

Patel, Rosentsveyg, Gabbur, and Marquez (2014) investigated the influence of clay modelling on the teaching of pelvic anatomy. Twenty-three third-year medical and four physician assistant students participated in the study. Peer tutoring strategy was adopted for the clay modelling sessions. Data was collected using examination questions while the *t*-test was used for data analysis. A significant difference was observed in the posttest and pretest scores of the participants. Thus, it was concluded

that clay modelling with concurrent lecture is an effective method for teaching pelvic anatomy.

Chumark and Puncreobutr (2016) studied the development of basic mathematical skills of pre-school children using plasticized clay. The study adopted the quasi-experimental design. The experimental group were taught the basic mathematical skills using plasticized clay art activities for 6 weeks. The data collected were analyzed using the paired sample *t*-test. One of the findings showed that the use of plasticized clay for pre-school children art activities was effective for the development of their mathematical skills.

In sum, the reviewed literature has revealed that different forms of modelling clay had been employed in different subject areas or field of study such as anatomy, physiology, and mathematics for learning about muscles, pelvic anatomy, evolution, ion channels, nerve cell, passive membrane, sensory and motor tracts. It is evidently clear from the literature available to the researcher that there is a dearth of empirical studies on the use of modelling clay for the teaching and learning of cell division. Also, unlike some of the reviewed literature, the participants in the present study did not used already made clay models but created their own models from the modelling clay.

Studies on the use of Demonstration Kit for Teaching and Learning

Demonstration is the act of showing or explaining how something works or how it is done (Hornby, 2015). This meaning coincides perfectly with that of study technology in which demonstration is viewed as the process of describing a principle, idea or datum using physical objects to demonstrate it or by making a sketch of such

principle, idea or datum (Clearbird Study Manual, 2004). Demonstrations are carried out in study technology using tools such as the demonstration kit.

A demonstration kit is a box containing materials which can be used as symbolic representation of concepts and processes in any subject. This is because "the lack of the physical object associated with a word can inhibit all understanding" (The Business Community, 2015, p. 8). The learners are stimulated to touch, feel and use the objects in the demonstration kit to create significance for intangible concepts, processes, and actions in order to boost what the learner read in a text or through class discussions. Thus, learners are able to take the full responsibilities for their own learning.

Evidence from empirical studies has revealed that students' performance may be enhanced through the use of kits (National Council of Educational Research and Training, 2013). For instance, the effects of using loci-kit for teaching the topic "loci" in mathematics was investigated by Githua and Mwangi (2013). The Solomon four, non-equivalent control group design was adopted for the study. A total of 195 students were involved in the study. The instrument was loci-kit demonstration box consisting of loci-kit models. The *t*-test, Analysis of Variance and ANCOVA were used for data analysis. Results from the study revealed that students exposed to loci-kit achieved significantly higher than those who were taught through the conventional method.

Adeoye and Abimbola (2016) conducted a study on the effects of senior school students' use of demo kit on their achievement in biology. The quasi-experimental design was adopted for the study. A total of 173 senior school three biology students participated in the study and ANCOVA was used for data analysis. The result from the study indicated that there was a significant difference in the

achievement of students that learnt biology using demo kits and those that learnt it without the use of demo kits in favour of students in the experimental group who were exposed to the use of demo kits.

Awoyemi (2018) investigated the use of demonstration kit on senior school students' performance in mathematics in Igbara Odo, Nigeria. The study adopted the quasi-experimental design. One hundred and forty-five SSS 1 students participated in the study while the *t*-test and ANCOVA were used to analyse the data collected from the Mathematics Performance Test. The result from the study revealed that there was a significant difference in the performance of SSS 1 students that learnt mathematics using demonstration kit and those that learnt it without the demonstration kit in favour of those exposed to the use of demonstration kit.

Ahmed (2018) carried out a research on the effects of study technology learning strategies on senior school students' achievement in ecology in Ilorin, Nigeria. The quasi-experimental design was adopted for the study while the sample consisted of three hundred and ninety-nine SSS 1 students purposively selected from two co-educational schools. Ecology Achievement Test constituted the response instrument and Analysis of Covariance was used for data analysis. The findings revealed that learning ecology with the demonstration kit combined with either the gradient or word clearing had a significant effect on students' achievement.

Luwoye (2019) conducted a study on effects of demonstration kit on remediating senior school students' misconceptions in mitosis and meiosis in Ilorin, Nigeria. Quasi-experimental design was adopted for the study. A sample of 60 students were purposively selected for the study. Mitosis and Meiosis Achievement Test (MMAT) was used for data collection while the hypotheses formulated were tested using Chi-square. Findings from the study revealed that there was no

significant difference in the number of misconceptions held by students that learnt mitosis and meiosis using demonstration kit and those that learnt it using the conventional method of teaching.

Onanuga, Saka, Adebanjo, and Olanrewaju (2019) conducted a study on the use of demonstration kit on students' achievement in computer studies in Ogun State, Nigeria. The researchers adopted the quasi-experimental design. The samples for the study were 72 senior school two students randomly selected from two secondary schools. The data collected through the use of computer studies achievement test were analysed using Analysis of Covariance statistics. Findings of the study revealed that students exposed to demonstration kit achieved significantly better than their counterpart that were taught using the conventional teaching method.

The reviewed literature indicated that the demonstration kit has been used in previous studies for the teaching and learning of biology related topics. However, few studies had been conducted in literature in relation to the use of demonstration kit for the teaching and learning of cell division. Therefore, the present study investigated the effect of demonstration kit on students' performance in cell division.

Influence of Gender on Students' Performance in Biology

Gender is one of the important variables to consider when investigating students' achievement in cell division and biology because gender disparities have remained an issue in introductory biology classrooms (Eddy, Brownell, & Wenderoth, 2014). Researchers like Okoye (2016) have acknowledged that the difference in the biology achievement of students due to gender has remained an issue of concern to a lot of educationists. In addition, results from existing studies have also revealed that

researchers hold conflicting views with regards to students' gender and their achievement in cell division and biology.

Casmir (2011) examined the influence of gender on students' attitude towards biology in Enugu State, Nigeria. The research design adopted for the study was the survey research design. Multistage sampling techniques was used to select 414 students that participated in the study from nine senior secondary schools. The instrument used for data collection was questionnaires on Students' Attitude Towards Biology while the data collected were analysed using the mean, standard deviation and ANCOVA. The finding indicated that gender did not exert any significant influence on the attitudes of students towards biology.

Jibrin, Abba, and Zayum (2012) conducted a study on the comparative analysis of students' achievement in genetics based on gender using concept map instructional strategy. The quasi-experimental design was adopted for the study while the sample consisted of 96 senior secondary school two students. Genetics Achievement Test was the response instrument used for data collection. The data collected were analysed using the *t*-test statistics. Findings from the study revealed that there was a significant difference in the performance of students exposed to concept mapping instructional strategy based on gender.

In another related study, Ezenwosu and Nworgu (2013) examined the influence of peer tutoring and gender on senior secondary school students' achievement in biology. The study adopted the quasi-experimental design. A total of 228 Senior Secondary School two (SSS 2) students participated in the study. A researcher-designed Biology Achievement Test constituted the response instrument while the mean, standard deviation and Analysis of Covariance were used for data

analysis. It was observed from the findings of the study that there was a significant difference in the performance of biology students based on gender.

Olumide (2013) conducted a study on computer simulation package and gender as predictors of students' achievement in biology. The study adopted the quasi-experimental design of 2 x 2 x 3 factorial design while the sample comprised 240 biology students randomly selected from four schools. Five instruments were used for data collection while Analysis of Covariance was used to test the null hypothesis on interaction effect. The finding indicated that the interaction effect of treatment and gender in relation to the achievement of students' in biology was not significant.

Nabwire, Toili, Ong'unya, and Songok (2014) explored the influence of teacher's gender on students' performance in biology in secondary schools in Kenya. The study adopted the descriptive survey design while 414 respondents were involved in the study. Interview schedules and questionnaires constituted the instruments. Descriptive statistics such as percentages, frequencies and mean were used for data analysis. Findings from the study showed that students' performance was influenced by their attitude towards their teacher's gender and manner of interaction.

Amedu (2015) explored the effects of jigsaw on students' achievement in biology based on gender. Intact class of 39 male and 49 female senior secondary school one students were involved in the study. Biology Achievement Test was the instrument used to gather data after students were taught topics on microorganisms for 12 weeks. The *t*-test statistics was used for the analysis of the data collected. The finding indicated that the boys achieved significantly higher than the girls when both sexes were taught topics on microorganisms using the Jigsaw method.

Yadav, Singh, and Singh (2015) investigated the effects of gender on the development of conjunctive concepts by biology students. The descriptive Survey method was used for the study while Conjunctive Concept Test in Biology was the instrument used for data collection. Three hundred students from six different higher secondary schools from Varanasi city were involved in the study. Descriptive and inferential statistics were used for data analysis. The findings from the study showed that the conjunctive concepts formed by male students were not significantly different from that of the females.

Ibrahim, Sabitu, and Magaji (2016) conducted a study on differences in the performance of male and female pre-degree students' in chemistry, physics, and biology. The ex-post facto research design was adopted for the study while 56 male and 27 female students participated in the study. Descriptive statistics and independent sample *t*-test were used for data analysis. It was observed from the findings of the study that the performance of male students was not significantly different from that of the female students in chemistry, physics, and biology.

Njue and Magana (2016) investigated the effects of Vee heuristic teaching method on the biology achievement of male and female students in Kenya public secondary schools. The Solomon four non-equivalent control group design was adopted for the study. The sample was composed of 396 male and female students. The instrument used for data collection was a researcher-design Biology Achievement Test and the data collected were analysed using ANOVA, ANCOVA and *t*-test statistics. Findings from the study indicated that gender is not a significant factor when the Vee Heuristics method is used for the teaching and learning of biology.

Jiyah (2016) conducted a study on the effects of hands-on with minds-on strategy on senior school students' achievement in cell division. The study adopted

the quasi-experimental design of the pre-test, post-test control group design. The two hundred and twenty-six SSS 2 biology students that participated in the study used cowpea, cardboard, threads, and adhesive gum to learn cell division. Cell division Achievement Test (CAT) was used for data collection while descriptive statistics and ANCOVA was used to analyse the data collected. The finding revealed that there was no significant difference in the achievement of students taught cell division using hands-on with minds-on strategy based on gender.

Owoeye and Agbaje (2016) conducted a study on attitude and gender as correlates of students' academic performance in biology in senior secondary school. The sample consisted of 180 Senior Secondary School two biology students. Biology Attitudinal Scale (BAS), Gender and Academic Performance in Biology (GAPB), and terminal continuous assessment results were the instruments used to gather data which were analysed using Pearson's product-moment correlation statistic. The findings showed that there was no relationship between gender and students' performance in biology.

Sakiyo, Musa, and Waziri (2018) carried out a study on multimedia instructional strategy and secondary school students' academic achievement in biology. The study adopted the quasi-experimental design. A sample of 286 students purposively selected from two senior secondary schools in Adamawa state, Nigeria were involved in the study. Biology Achievement Test (BAT) adapted from West African Senior School Certificate Examinations (WASSCE) was used for data collection while ANCOVA was used for data analysis. Findings from the study indicated that gender was a significant factor in relation to students' achievement in biology.

Godpower-Echiei and Owo (2019) investigated the influence of gender differences on achievement of basic science students in private secondary schools in Rivers State. Stratified random sampling technique was used to select the 800 Junior Secondary School three students that participated in the study. Proforma was used to gather data on students' performance in the Junior School Certificate Examinations (JSCE). Findings from the study revealed that the performance of students in basic science was not influenced by their gender.

Kingdom-Aaron, Etokeren, and Okwelle (2019) examined the effect of cooperative learning strategy on the performance of Senior Secondary Schools students' in biology. The sample comprised 120 Senior Secondary School three student. The instrument used for data collection was Biology Performance Test (BPT) adopted from WASSCE. The resultant data gathered from the administration of the BPT was analysed using mean, standard deviation, and *t*-test at 0.05 level of significance. Findings from the study indicated that the performance of students in biology was not affected by gender.

It can be concluded from the previous studies that gender is a main variable to consider in researches involving individual from co-educational settings. Thus, the present study also investigated the influence of gender on the performance of senior school students in cell division.

Influence of Cognitive Styles on Students' Performance in Biology

Cognitive style is an important variable to consider when investigating the rate of perception, processing, and remembering of information by any individual. This is because cognitive style has remained a legitimate factor for judging the academic

choices, academic development and vocational preferences of students based on their chosen career, learning capabilities and students-teacher relationship (Witkin, 1973).

Empirical studies have revealed that learners' cognitive styles play a significant role in their performance, awareness of their own learning styles, retention and transfer of knowledge from one situation to another (Nabwire, Toili, Ong'unya, & Songok, 2014). For instance, Mutlu and Temiz (2013) investigated the science process skills and cognitive styles of field dependent and field independent students. The sample comprised 496 students. Group Embedded Figures Test (GEFT) was used for data collection while *t*-test was used for data analysis. Findings revealed that the field independent students had a better science processing skill than the field dependent students.

Ella (2014) conducted a correlational survey research to determine the cognitive styles and attitude towards science of senior secondary school science students of high and low cognitive abilities. The population for the study consisted of 1330 students that were selected through proportionate stratified random sampling technique. The research instruments were GEFT, science students' attitude scale and science cognitive ability levels. Data gathered were analysed using mean and standard deviation while all hypotheses were tested using *t*-test and regression analysis. Findings from the study revealed that high cognitive ability students showed positive attitude to science and belonged to field independent category than the low cognitive ability students.

In another related study, Okoye (2014) investigated the influence of cognitive styles on students' achievements in biology in senior secondary schools in Anambra State. The sample was composed of 265 senior school two students. The GEFT was used to group students into their respective cognitive styles while Biology

Achievement Test was the instrument used for data collection. The mean, standard deviation and ANOVA were used for data analysis. The results revealed that the influence of cognitive styles on the achievement of biology students was significant.

Ashiru and Sadiq (2016) explored the impact of cognitive style on the attitude and performance of secondary school students' in biology practical. The quasi-experimental design without control group was adopted for the study while the sample comprised 134 SSS 2 biology students. Three instruments; Biology Practical Attitude Questionnaire, Practical Performance Tests, and Field-dependent/Field-independent Figure Sorting Test were used for data collection while Kruskal Wallis test and Analysis of Variance were used for data analysis. Findings indicated that the performance and attitude of field-dependent and field-independent students to biology practical was significantly different.

Kuldeep and Meera (2016) conducted a study on the cognitive styles of science teachers in India to determine the differences between male and female secondary school teachers based on five cognitive styles (systematic, intuitive, integrated, undifferentiated and split cognitive styles). The research adopted a survey method and utilized cognitive style inventory developed by Praveen (2001) as research instrument. Data was analysed using descriptive statistics (mean and standard deviation) while *t*-test was used to test the hypotheses raised in the study. Findings revealed a significant difference in male and female teachers' in systematic and intuitive cognitive styles. There was no significant difference in integrated, undifferentiated and spilt cognitive style between male and female teachers.

Sara, Maruta, and Olarinoye (2016) examined the effects of cognitive styles on the science process skills and performance of senior school students in biology. The quasi-experimental design was adopted for the study while the sample comprised

216 students selected by proportionate random sampling and balloting technique. Biology Science Process Skills Achievement Test and GEFT were used for data collection. Descriptive statistics and the *t*-test were used for data analysis. The findings revealed that gender was positively related to the cognitive styles of field-dependent and field-independent students.

Nworgu, Ellah, and Oparah (2019) examined the cognitive styles and attitude of senior school low ability level students to science. The study adopted the correlational survey design while the sample was composed of 777 low ability senior school two students selected from 35 public schools in Benue State. The instruments used were science students attitude scale and group embedded figure test. The data collected were analyzed using mean, standard deviation, correlation and *t*-test statistical tools. One of the findings indicated that there was a significant difference in the attitude and cognitive styles of low ability level students in science.

The reviewed literature has revealed that researchers have utilized different forms of instruments to categorize students into their respective cognitive styles. However, the Group Embedded Figure Test (GEFT) was adapted in the present study to classify participants into the field-dependent, field neutral, and field-independent cognitive styles. The GEFT is preferred over other cognitive style instruments because it is a non-verbal, paper-based test which is not related to any subject area in the senior school curriculum.

Influence of Score Levels on Students' Performance in Biology

Research studies on students' score levels have revealed an indifferent situation whereby researcher holds contrasting views on students' score levels in relation to their achievement in cell division and biology. For instance, Abdulkadri

(2011) carried out a study on the effects of teachers' use of checksheet on senior secondary school student' performance in biology. The researcher adopted the use of 2x2x3 quasi-experimental design. 272 students participated in the study while ANCOVA was used for the analysis of data collected. Results from the study showed that there was no significant difference in the achievement of high, medium and low scoring students.

The effects of teachers' use of analogies on the achievement of senior school biology students in Oro, Kwara state, Nigeria was investigated by Ayanda, Abimbola, and Ahmed (2012). Quasi-experimental design, of the pre-test, post-test, non-randomized control group design was adopted for the study. The sample composed of 199 SSS 2 biology students. Biology Achievement Test was used for data collection while ANCOVA, *t*-test and descriptive statistics were used for data analysis. Results from the study indicated that the achievement of the low, medium, and high scoring students were not significantly different.

Gbigbadua, Abimbola, and Ahmed (2014) conducted a study on the effects of pre-instructional word-clearing strategy on the achievement of senior school students' in biology in Ilorin, Nigeria. The study adopted the quasi-experimental design. One hundred and fifty-eight students were involved in the study while Biology Achievement Test was the main instrument used for data collection. Analysis of Co-variance was the main statistical tool for data analysis. The findings revealed that students' score levels had a significant effect on their biology achievement.

Saidu and Suleiman (2014) investigated the effects of outdoor laboratory strategy on the performance of pre-service teachers in North-west zone Nigeria. A total of sixty biology students were randomly sampled for the study in two Colleges of Education. The researchers developed an Outdoor Laboratory Teaching Procedure

(OLTP) and multiple-choice test items on ecological concepts as the treatment and instruments, respectively. Analysis of Variance was used for data analysis. It was observed from the findings of the study that the performances of the participants were not significantly different after their exposure to outdoor laboratory teaching strategy.

Salami (2015), in another related study, examined the influence of modified laboratory learning environment on students' biology process skills. The quasi-experimental design was used for the study while the sample consisted of 274 SSS 1 students from six intact classes of six randomly selected secondary schools. Observation Checklist/Rating Scale (OCRS) and Students' Biology Achievement Test (SBAT) were the two-instrument used and the data collected was analysed using *t*-test statistics. The findings revealed that the biology process skills of low achieving students improved significantly than the high achievers with modified laboratory learning environment

Alabi (2016) conducted a research on comparative effects of text structures on achievement in genetics of senior secondary school biology students. Two hundred and thirty- nine senior school students were involved in the study while data was collected using Achievement Test on Genetics (ATG). The statistical tool used for data analysis was *t*-test and ANCOVA statistics. Findings from the study revealed that the achievement of the low, medium and high scoring students were not significantly different.

Jiyah (2016) investigated the effects of Hands-on with Minds-on instructional strategy on senior school students' achievement in cell division in Lafiagi, Nigeria. The pre-test, post-test quasi-experimental design of 2x2x3 factorial matrix was adopted for the study. Two hundred and twenty-six SSS 2 biology students from two senior secondary schools in Lafiagi were involved in the study. Cell division

Achievement Test (CAT) was used for data collection while ANCOVA and descriptive statistics were used to analyse the data collected. Results from the study indicated that there was no significant difference in the achievement of the low, medium, and high scoring students.

Awoyemi (2018) carried out a study on the effects of use of demonstration kit on senior secondary school students' performance in mathematics in Igbara Odo, Nigeria. The quasi-experimental design was used for the study. The sample was composed of 145 Senior Secondary School one students. Mathematics Performance Test on Sets was used for data collection while the hypotheses formulated were tested using *t*-test and ANCOVA. The findings indicated a significant difference in the score levels of students taught set theory using the demonstration kit.

Ibrahim (2018) investigated the effects of concept map on the learning outcomes of low achieving senior school students' in biology in Jigawa state, Nigeria. The study adopted a quasi-experimental design. A sample of 71 low achieving of senior school two students participated in the study. Data for the study were collected using Biology Achievement Test and analysed with *t*-test statistics. Result from the study revealed that there was a significant difference in the achievement scores of low achieving students and those taught with the conventional teaching method.

It can be deduced from the literature reviewed on score levels that researchers differ in their conclusions on students' performances in relation to score levels. Hence, the present study investigated the differences in the performance of students in cell division based on score levels.

Studies on the Interaction Effect of Treatment and Moderating Variables on Students' Performance in Biology

Neboh (2009) investigated the effect of learning activity package on the biology achievement and retention of senior school students. Quasi-experimental design was adopted for the research while the sample was 317 SSS 2 students offering biology. A researcher-designed Biology Achievement Test constituted the instrument while ANCOVA was used for data analysis. The findings revealed that there was no significant interaction between gender and teaching strategies but a significant interaction was observed for ability levels and teaching strategies.

Nnodi (2012) explored the effects of cognitive style and problem-based learning on students' self-efficacy belief and achievement in selected science concepts. The quasi-experimental design was adopted while the sample comprised 184 students. Group Embedded Figures Test, Science Concepts Achievement Test, and Students' self-efficacy Questionnaire in Science Concepts constituted the instruments while ANCOVA was used for data analysis. Findings form the study showed that the interaction between treatment and cognitive style based on achievement was significant whereas that of treatment and cognitive style based on self-efficacy was not significant.

The influence of experiential learning strategy on biology students' achievement was explored by Okoli and Abonyi (2014). The quasi-experimental design was used for the study while the sample comprised 74 SSS 1 students from two intact classes. Biology Achievement Test (BAT) was used for data collection. The mean, standard deviation, and ANCOVA were the statistical tools used for data analysis. The result from the study indicated that the interaction between treatment and gender was not significant.

Adesina, Adegoke, and Ogundiwin (2015) conducted a study on puzzle-based critical thinking motivation strategies, cognitive style and gender on biology students' exploration of environment-related concepts. The quasi-experimental design was adopted for the study. The sample was composed of 451 SSS 2 biology students from six purposively selected senior secondary schools. Five instruments were used to gather data. The ANCOVA test of the hypothesis on interaction effect of cognitive style and gender was found to be significant.

Goff, et al (2017) investigated the effects of virtual cell animation collection on meiosis learning module. The sample consisted of 534 participants enrolled in introductory biology course while the test instrument consisted of 25 questions on basic biological concepts, and 10 questions on meiosis. ANOVA was used for data analysis and the result revealed that the interaction between the treatment, multimedia learning preference and gender was not significant.

Okwara, Anyagh, and Ikyaan (2017) investigated the effects of projected instructional media on students' achievement in biology. The study adopted the quasi-experimental design while the sample was composed of 165 Senior Secondary School one students. Biology Achievement Test was the instrument used for data collection. The Analysis of Covariance test of the null hypothesis revealed that the interaction effect of gender and projected instructional media on students' achievement was not significant.

Adeoye (2018) conducted a study on the effects of blended learning on biology students' attitude and achievement in colleges of education. Quasi-experimental design of 2 x 2 x 3 factorial design was adopted for the study. The sample comprised 115 students. A researcher designed Biology Achievement Test, Attitude Questionnaire, and Biology Blended Learning Package were used to gather

data. The mean, *t*-test and ANCOVA statistics were used for data analysis. Findings revealed that the interaction effect of treatment and score levels was significant while that of treatment and gender was not significant.

Ayanda, Adeoye, and Olayinka (2019) conducted a study on the interaction effect of gender, score levels, analogies, and concept maps on senior school students' achievement in ecological concepts. The study was a quasi-experimental research. The sample consisted of 183 Senior School two biology students drawn from six purposely selected co-educational schools in Kwara South, Nigeria. The instrument used for data collection was Ecological Concepts Achievement Test (ECAT) while the null hypotheses formulated were tested using Analysis of Covariance. Findings from the study revealed that the interaction between treatment and gender was significant while that of treatment and score levels, and the joint effect of treatments, gender and score levels on students' achievement in ecological concepts were not significant.

Appraisal of the Reviewed Literature

The review of literature has been carried out on studies related to this research. The review showed that the learning of cell division processes can be mundane to students due to the microscopic nature of the cell. Meanwhile, no particular strategy has been adjudged the best for the teaching and learning of cell division processes, but students centred strategies that facilitates active knowledge construction and participation of learners in classroom lessons are usually preferred over others.

Studies reviewed on the use of modelling clay (Oh, Kim, & Choe, 2009; Herur, Kolagi, Chinagudi, Manjula, & Patil, 2011; Chumark & Puncreobutr, 2016) and demonstration kit (Ahmed, 2018; Awoyemi, 2018; Onanuga, Saka, Adebanjo, &

Olanrewaju, 2019) have established the effectiveness of these tools for the teaching and learning of different concepts at different levels of education. Based on the reviewed literature, Luwoye (2019) had earlier conducted a study on the use of demonstration kit for remediating students' misconceptions in mitosis and meiosis. However, the study of Luwoye is at variance with the present study based on the locale, statistical tool, and the independent variables such as modelling clay and cognitive style which were considered in the present study.

Furthermore, the studies reviewed on students' gender, cognitive styles, score levels, and the interaction effect of these variables revealed that researchers are unresolved in their conclusions concerning these variables in relation to students' performances in cell division and biology. Therefore, the present study investigated the effects of modelling clay and demonstration kit on senior school students' performance in cell division based on students' score levels, cognitive styles, and gender.

CHAPTER THREE

RESEARCH METHOD

This chapter presents the methodology that was used for conducting this study under the following sub-headings: research design, population, sample and sampling techniques, research instrument, validation of research instrument, procedure for data collection and data analysis techniques.

Research Design

The quasi experimental, non-randomized, pre-test, post-test control group design of the 3 x 2 x 3 x 3 factorial design was adopted for this study. The first, third, and fourth number 3 of the factorial design represents levels of the groups (experimental group 1, experimental group 2, and control group), cognitive styles (field dependent, field neutral, and field independent), and score levels (high, medium, and low) while the number 2 represents students' gender which occurs at two levels as male and female (see Appendix B). The dependent variable was the performance of participants in the pre-test and post-test. The schematic layout of the research design is presented below:

EG₁	O_1	X_1	O_2
EG₂	O_1	X_2	O_2
	– –		
CG	O_1		O_2

Where;

EG_1 = Experimental Group 1

EG_2 = Experimental Group 2

CG = Control Group

O_1 = Pre-test administered to all the groups

O_2 = Post-test (reshuffled CDPT) administered to all the groups

X_1 = Treatment (modelling clay) administered to EG_1

X_2 = Treatment (demonstration kit) administered to EG_2

Population, Sample, and Sampling Techniques

The population for this study consisted of all Senior Secondary Schools students offering biology in Omu-Aran, Kwara State, Nigeria while the target population was composed of Senior Secondary School two (SSS II) students. The sample comprised 213 (97 male and 116 female) SSS II students offering biology in their penultimate year in Omu-Aran, Kwara State, Nigeria. The choice of SSS II students was considered appropriate because it was assumed that students at this level would have been exposed to introductory topics related to the study of cell in SSS I but would not have learnt cell division since it is usually scheduled for SSS II by most secondary school biology teachers.

Purposive sampling technique was used to select three senior secondary schools in Omu-Aran, Kwara State. This sampling technique was considered appropriate for the selection of the schools based on the following criteria: the schools must be co-educational, not situated close to one another, have been presenting students for external examinations, have at least one biology teacher teaching SSS II students, and the willingness of the relevant members of staff and students to participate in the study.

The assignment of the three purposively selected senior secondary schools into experimental group 1, experimental group 2, and control group was done using simple random sampling technique. Modelling clay and demonstration kit were the treatment for experimental group 1 and 2 respectively, while students in the control group learnt cell division using the conventional method.

Research Instrument

The instruments that were used for data collection were Cell Division Performance Test (CDPT) and Group Embedded Figure Test (GEFT) while modelling clay and demonstration kit were used as stimulus instruments. Other stimulus instruments used in the study were Cell Division Course Guide (CDCG) and Research Assistant Training Guide (RATG).

The instruments were classified as stimulus or response instruments as shown in Figure 5.

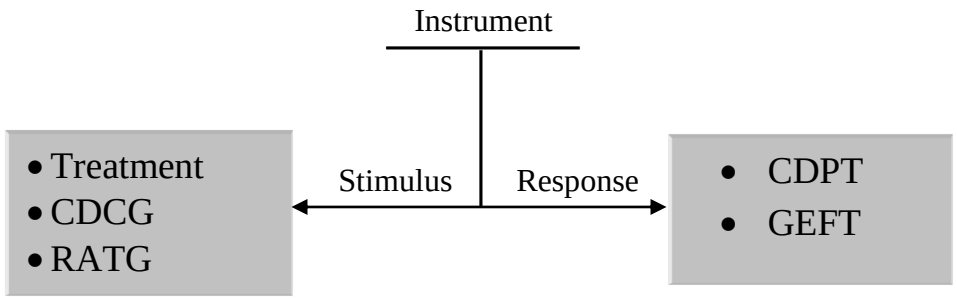


Figure 5. Classification of the research instruments as response or stimulus instruments

The treatment were modelling clay and demonstration kit, which were used by the biology teachers of the selected senior secondary schools to teach cell division. Playdough, was used as modelling clay for modelling cell division processes. This is because it is cost-effective, recipes are readily available, non-toxicity, colours were added for differentiation and any error in the creation of the models can be easily corrected. Playdough, after its preparation, can also be preserved and reused a number of times for the same purpose as long as it is stored in an airtight container (see Appendix C). The demonstration kit, consisted of the following items; crown corks, thumbtack, used pen, used phone recharge cards, corks, small pieces of papers, and

erasers. These items were carefully selected by the researcher in line with the practices and conventions in study technology (see Appendix D).

The CDCG contained the contents of cell division processes to be learnt by the students organized in a logical sequence. There was a place for each student to append their signatures and date as each item on the course guide are studied. The two sets of course guides that were used in this study were Cell Division Course Guide on Modelling Clay (CDCGMC) and Cell Division Course Guide on Demonstration Kit (CDCGDK) (see Appendix E). The CDCG consisted of explanatory notes on cell division and practical activities designed to enable the students to associate and coordinate the explanatory note on cell division with the objects and actions to which the data applies.

The RATG was used as a guide to train the Research Assistants, that is, biology teachers from the two experimental schools on learning how to learn, barriers to learning, strategies to overcome each of the barriers to study, difficulties in the teaching and learning of cell division, and the use of modelling clay and demonstration kit for the teaching and learning of cell division (see Appendix F).

The CDPT was a researcher-designed test instrument which consisted of fifty-seven multiple choice test items on cell division. Each of the questions had four options A-D and was used to assess students' performance in cell division (see Appendices G and H). The revised edition of Bloom's taxonomy of educational objectives by Krathwohl (2002) was used to prepare the CDPT table of specifications as shown in Table 3.

Table 3

Table of Specifications for the Cell Division Performance Test

Contents	Cognitive domain						Total No. of items	Percentage
	Remember	Understand	Apply	Analyse	Evaluate	Create		
Introduction to cell division	5	3		1			9	15.79
Mitotic division	6	6	5	5	2	2	26	45.61
Meiotic division	6	5	5	2	3	1	22	38.60
Total	17	14	10	8	5	3	57	100
Percentage	29.83	24.56	17.54	14.04	8.77	5.26	100	

The GEFT was a non-verbal paper base test adapted from Witkin, Oltman, Raskin, and Karp (1971). It consisted of 21 items organized into three sections. The first section consisted of the biodata of respondents while the second and third sections comprise of an example and 20 embedded figures which was used to test students' ability to locate a simple shape hidden within a complex pattern (see Appendix I). The GEFT was considered appropriate because it requires minimal use of language and has been used in recent studies by Okoye and Onwuachu (2018), and Sara, Maruta, and Olarinoye (2016) to group students as Field Dependent (FD), Field Neutral (FN), and Field Independent (FI) learners.

Validation of Research Instrument

The face and content validity of the CDPT and GEFT were established by three biology lecturers from the Department of Science Education, one lecturer from the Department of Life Science, University of Ilorin, Ilorin, Nigeria and three experienced senior secondary school biology teachers from Omu-Aran, Kwara State

Nigeria. The modelling clay (playdough), demonstration kit, CDCG, and RATG were given to the validators to assess their validity. The validators among others recommended that the embedded figures to be located by students in the GEFT be moved to the first page. In addition, they suggested the removal of thumbtacks from the demonstration kit items for it not to injure students due to its sharpness.

Item analysis was carried out on the CDPT to ensure that each of the items were appropriate by computing the difficulty index, discrimination index, and distractor analyses. Item statistic was employed to evaluate each of the CDPT test items by utilizing the responses of SSS 2 biology students in a senior secondary school in Omu-Aran, Kwara State, Nigeria. These students were not involved in the main study. Results of the item analysis led to the restructuring of seven CDPT questions (1, 5, 8, 18, 22, 48, and 56) which were either too easy, difficult or do not discriminate among students in the upper and lower third (see Appendix J). The distractor analysis of the CDPT (being a multiple-choice test) revealed that distractors D, A, and B of questions 4, 18, and 56 respectively were confusing, hence, they were restructured (see Appendix K).

The test-retest method was employed to determine the reliability coefficient of the CDPT and GEFT. The two instruments were administered to all SSS II biology students in a school that was not selected for the main study. There was a space of three weeks between the first and second administration of the instrument to the same set of students. Pearson product-moment correlation statistic was used to analyse the resultant data and a reliability coefficient value of 0.83 was obtained for the CDPT while the GEFT had a reliability coefficient of 0.87.

Procedure for Data Collection

A letter of introduction was obtained from the Head of Department of Science Education, University of Ilorin to seek the permission and assistance of the school Principals and biology teachers of the selected schools. Informed consent forms indicating detail information about the research such as; the purpose, procedure, anonymity, confidentiality, risks, benefits and rights of volunteers were given to research assistants and students to indicate their willingness to participate in the study (see Appendices L and M).

The experiment lasted for five weeks in each of the selected schools. The first week was used to classify students into their respective cognitive style and score levels using the GEFT and SSS 1 end of session results of participants in biology. In addition, the three Research Assistants from the two experimental groups were trained using the RATG. The training took place during the weekend of the first week (so has not to disturb teachers' lessons) in one of the experimental schools. The session lasted for two and half hours while the researcher provided projection equipment, feeding and a token for the transportation of the teachers during the period of the training. The CDPT was administered as a pre-test in the second week and the data gathered were used as covariates during the analysis of data.

The administration of treatments took place during the third and fourth week in the experimental and control groups using two double periods of 80 minutes and a single period of 40 minutes. The lesson plan was used as a guide by Research Assistant in experimental group 1 and 2 respectively (see Appendix N). At the commencement of treatment administration, the principles of study technology, the use of modelling clay and demonstration kit were explained to students in each of experimental group 1 and 2 to remove grey areas in its implementation.

Also, students were allowed to pair up voluntarily and directed to interact with each other during the use of modelling clay and demonstration kit for learning the cell division processes. Each student in experimental group 1 and 2 were given CDCGMC and CDCGDK respectively which served as a guide for each student in relation to the content of the topic and the application of the modelling clay and demonstration kit for learning it.

The research assistant in the control group used the conventional method for the teaching and learning of cell division processes. This was done without any form of interference from the researcher. In the fifth week, the post-test was administered using the same CDPT administered as pre-test but with reshuffled items to eliminate the effect of remembering. Table 4 shows the summary of the weekly schedule of activities for data collection.

Table 4

Weekly Schedule of Activities for Data Collection

Scheduled Activity	Period
Administration of GEFT, Score level grouping, and Training of Research Assistants	Week 1
Pre-test administration	Week 2
Treatment	Week 3-4
Post-test administration	Week 5

The identity of the participating schools and students were not disclosed at any point in this study. Also, all related data were handled with utmost confidentiality and used exclusively for the purpose of the research only. The health risks of using the modelling clay and demonstration kit, such as, gastrointestinal offset due to the ingestion of small parts was avoided by using non-toxic play dough made from flour, not allowing students to share the items of the demonstration kit, washing of hands

after each lesson and proper guidance of the students. All reviewed studies were paraphrased and summarized to reflect the authors' ideas and referenced appropriately.

Data Analysis Techniques

Data collected were collated and analysed using descriptive and inferential statistics. Research questions one to ten were answered using descriptive statistics. Research hypotheses two and three were tested using *t*-test statistic while hypotheses one, four, five, six, and seven were tested using One-way Analysis of Covariance (ANCOVA). Research hypotheses eight, nine, and ten were tested using Two-way ANCOVA because these hypotheses contained two independent variables occurring at two or more levels. Summary of the statistical tools used to test each hypothesis is presented in Table 5. Bonferroni post-hoc analysis was used to locate the direction of significant differences. All statistical analyses were carried out using Statistical Package for Social Science (IBM SPSS Statistics) 20.0 software.

Table 5

Summary of the Statistical Tools used for Hypotheses Testing

Hypotheses	Independent Variables		Statistical Tool
H_{01}	Treatment	Modelling clay Demonstration kit Conventional method	One-way ANCOVA
H_{02} & H_{03}	Gender	Male Female	*t*-test
H_{04} & H_{05}	Cognitive styles	Field Dependent Field Neutral Field Independent	One-way ANCOVA
H_{06} & H_{07}	Score levels	Low Medium High	One-way ANCOVA
H_{08}	Treatment & Gender		Two-way ANCOVA
H_{09}	Treatment & Cognitive styles		
H_{010}	Treatment & Score levels		

CHAPTER FOUR

DATA ANALYSIS AND RESULTS

This chapter deals with the collation, analysis, and interpretation of the data collected using the Cell Division Performance Test (CDPT) administered to all the students that participated in the study.

The demographic characteristics of participants in Figure 6 revealed that 69, 66 and 78 students participated in experimental group one (modelling clay), experimental group two (demonstration kit) and control groups, respectively.

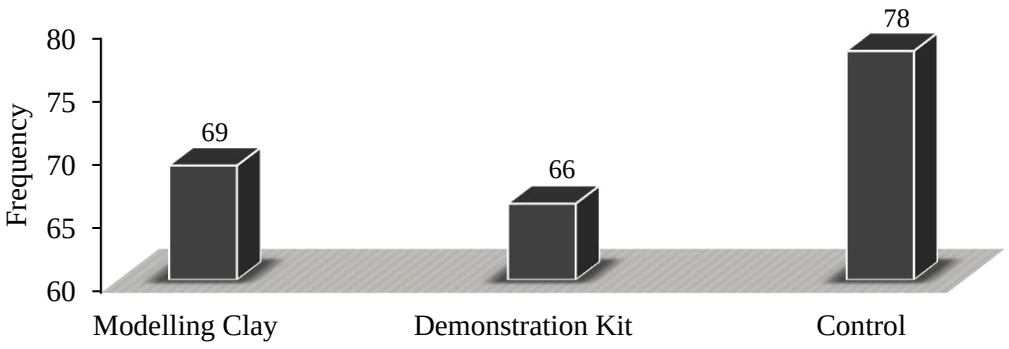


Figure 6: Demographic representation of participants based on groups

The demographic characteristics of participants based on gender in Figure 7 showed that experimental group one (modelling clay) was constituted by 33 male and 36 female students, experimental group two (demonstration kit) was composed of 29 male and 37 female students while 35 male and 43 female students participated in the control group.

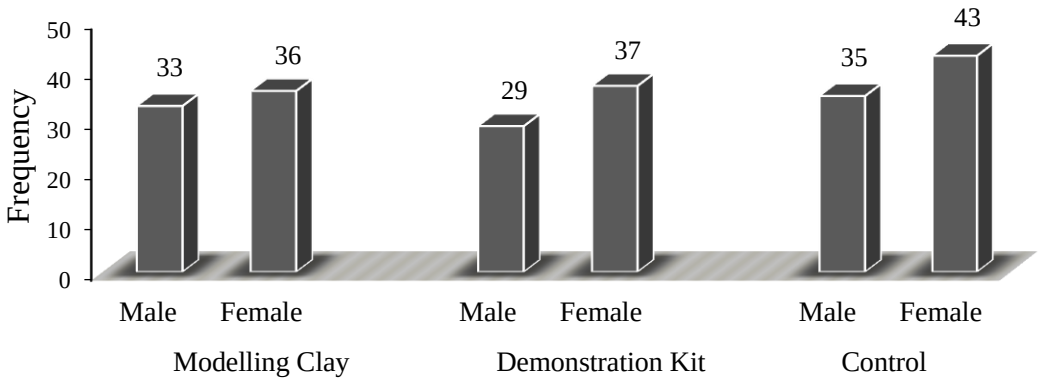


Figure 7: Distribution of participants by gender

The demographic characteristics of participants based on cognitive styles in Figure 8 showed that experimental group one (modelling clay) was constituted by 27 field dependent, 18 field neutral and 24 field independent students, experimental group two (demonstration kit) was composed of 22 field dependent, 26 field neutral and 18 field independent students while 25 field dependent, 32 field neutral and 21 field independent students participated in the control group, respectively.

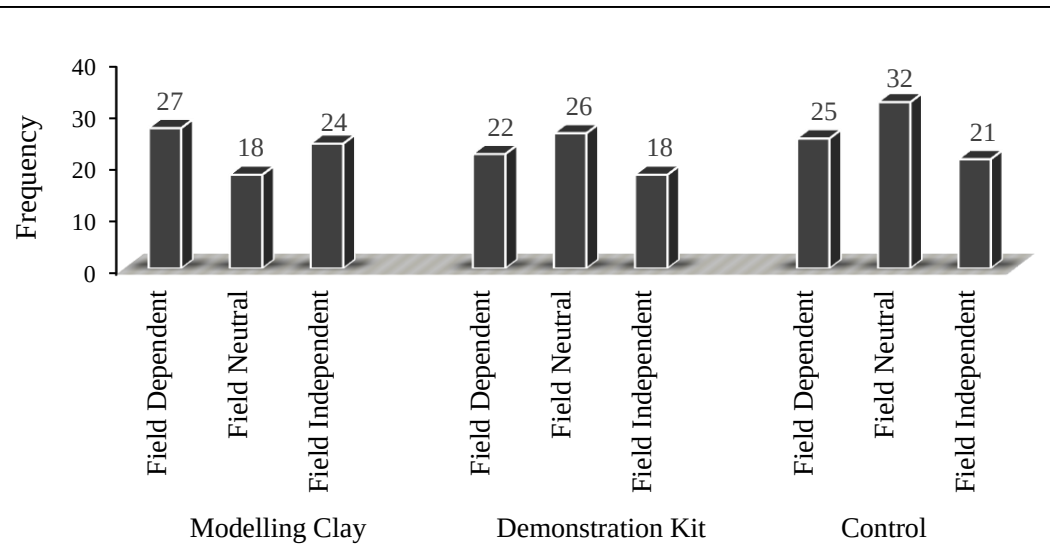


Figure 8: Demographic representation of participants based on cognitive styles

The demographic characteristics of participants based on score levels in Figure 9 showed that experimental group one (modelling clay) was constituted by 11 high,

32 medium and 26 low scoring students, experimental group two (demonstration kit) was composed of 13 high, 30 medium and 23 low scoring students while 17 high, 28 medium and 33 low scoring students participated in the control group, respectively.

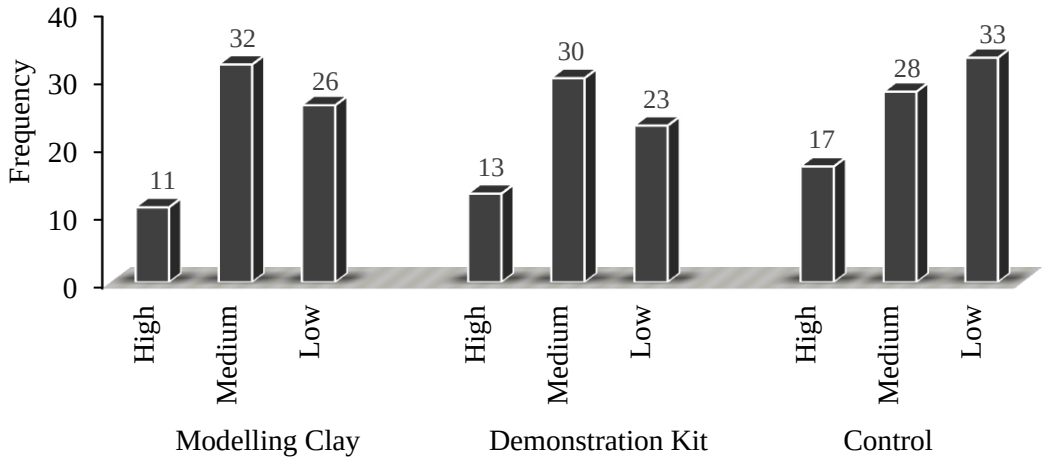


Figure 9: Demographic representation of participants based on score levels

Research Question 1: What is the effect of modelling clay, demonstration kit, and conventional method on the performance of senior school students in cell division?

Table 6 revealed that the mean score of students that learnt cell division using modelling clay (M = 29.39) was higher than those exposed to demonstration kit (M = 24.18), and the conventional method (M = 22.23). These results suggest that the modelling clay improved students' performance more than the demonstration kit while the later, improved students' performance more than the conventional method of teaching.

Table 6

Descriptive Statistics of Students' Performance in Cell Division

Treatment	N	Mean	Standard Deviation
Modelling clay	69	29.39	4.77
Demonstration kit	66	24.18	4.87
Conventional method	78	22.23	4.62
Total	213	25.16	5.62

Hypothesis 1: There is no statistically significant difference in the effect of modelling clay, demonstration kit, and conventional method on the performance of senior school students in cell division.

Table 7 revealed that there was a statistically significant difference in the performance of students in Experimental Group 1 (students exposed to modelling clay), Experimental Group 2 (students exposed to demonstration kit) and the Control Group (students exposed to conventional method), $F_{(2, 209)} = 90.59$, $p < .05$, $\eta_p^2 = .46$. Hence, hypothesis 1 was rejected since $p < .05$. This implies that there was a statistically significant difference in the effects of modelling clay, demonstration kit, and conventional method on the performance of senior school students in cell division.

Table 7

Summary of Analysis of Covariance (ANCOVA) for Experimental Groups 1, Experimental Groups 2, and the Control Group

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	η_p^2
Corrected Model	3730.46[a]	3	1243.49	87.76	.00	.56
Intercept	1552.22	1	1552.22	109.55	.00	.34
Pretest	1762.67	1	1762.67	124.40	.00	.37
Group	2567.34	2	1283.67	90.59	.00	.46
Error	2961.43	209	14.17			
Total	141472.00	213				
Corrected Total	6691.89	212				

a. R Squared = .56 (Adjusted R Squared = .55)

Note. df = Degrees of freedom; *F* = Fisher's *F* ratio; η_p^2 = Partial Eta Square

Bonferroni post hoc analysis was carried out to determine where the significant differences occurred between Experimental Group 1, Experimental Group 2 and the Control Group. The result of the analysis presented in Table 8 indicated that the Experimental Group 1 (Students exposed to modelling clay) with the highest mean score (8.41) accounted for the significant difference. This result showed that the use of modelling clay improved students' performance in cell division more than either of demonstration kit and the conventional method.

Table 8

Bonferroni Post Hoc Analysis showing the Source of the Significant Difference in the Performance of Students in the Experimental Group 1, Experimental Group 2, and the Control Group

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Modelling clay	Demonstration kit	5.55*	.65	.00	3.98	7.11
	Control	8.41*	.63	.00	6.88	9.93
Demonstration kit	Modelling clay	-5.55*	.65	.00	-7.11	-3.98
	Control	2.86*	.64	.00	1.33	4.39
Conventional method	Modelling clay	-8.41*	.63	.00	-9.93	-6.88
	Demonstration kit	-2.86*	.64	.00	-4.39	-1.33

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

Research Question 2: How do male and female students performance differ when they learnt cell division using modelling clay?

Table 9 indicated that there was a marginal difference in the mean score of male (M = 29.73) and female (M = 29.08) students that learnt cell division using modelling clay. This suggest that male and female students benefitted equally when they learnt cell division using modelling clay.

Table 9

Descriptive Statistics of Students' Performance in Experimental Group 1 based on Gender

Treatment	Gender	N	Mean	Mean Difference	Standard Deviation
Modelling Clay	Male	33	29.73	0.65	4.61
	Female	36	29.08		4.95
	Total	69	29.39		4.77

Hypothesis 2: There is no statistically significant difference in the performance of male and female senior school students when they learnt cell division using modelling clay.

The independent sample *t*-test in Table 10 indicated that when $t_{(67)} = .56$, $p = .58$. Hence, hypothesis 2 was not rejected since $p > .05$. This implies that there was no statistically significant difference in the performance of male and female senior school students when they learnt cell division using modelling clay.

Table 10

t-test *Result of the Performance of Male and Female Senior School Students that Learnt Cell Division using Modelling Clay*

Treatment	Gender	*M*	*t*	*df*	Sig.
Modelling clay	Male	29.73	.56	67	.58
	Female	29.08			

Note. *M* = mean; *t* = value of *t*-test statistic.

Research Question 3: How do male and female students performance differ when they learnt cell division using demonstration kit?

Table 11 indicated that the mean score of male (*M* = 23.93) and female (*M* = 24.38) students that learnt cell division using demonstration kit is homogeneous. This suggest that there was no disparity in gender when students learnt cell division using demonstration kit.

Table 11

Descriptive Statistics of Students' Performance in Experimental Group 2 based on Gender

Treatment	Gender	N	Mean	Mean Difference	Standard Deviation
Demonstration Kit	Male	29	23.93	0.45	4.44
	Female	37	24.38		5.23

Total	66	24.18		4.87

Hypothesis 3: There is no statistically significant difference in the performance of male and female senior school students when they learnt cell division using demonstration kit.

The result of the independent sample *t*-test in Table 12 showed that when $t_{(64)}$ = -.37, p = .71. Hence, hypothesis 3 was not rejected since $p > .05$. This implies that there was no statistically significant difference in the performance of male and female senior school students when they learnt cell division using demonstration kit.

Table 12

t-test Result of the Performance of Male and Female Senior School Students that Learnt Cell Division using Demonstration Kit

Treatment	Gender	*M*	*t*	*df*	Sig.
Demonstration Kit	Male	23.93	-.37	64	.71
	Female	24.38			

Note. *M* = mean; *t* = value of *t*-test statistic.

Research Question 4: What is the difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using modelling clay?

Table 13 revealed that the mean score of field-dependent (*M* = 28.96), field-neutral (*M* = 29.33), and field-independent (*M* = 29.92) students that learnt cell division using modelling clay were nearly similar. These results suggest that the field-dependent, field-neutral, and field-independent students benefitted almost equally when they learnt cell division using the modelling clay.

Table 13

Descriptive Statistics of Students' Performance in Experimental Group 1 based on Cognitive Styles

Treatment	Cognitive Styles	N	Mean	Standard Deviation
Modelling Clay	Field Dependent	27	28.96	4.97
	Field Neutral	18	29.33	4.07
	Field Independent	24	29.92	5.15
	Total	69	29.39	4.77

Hypothesis 4: There is no statistically significant difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using modelling clay.

The one-way Analysis of Covariance (ANCOVA) test output in Table 14 showed that when $F_{(2, 65)} = .18$, $p = .84$. Hence, hypothesis 4 was not rejected, since $p > .05$. This implies that there was no statistically significant difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using modelling clay.

Table 14

Summary of the ANCOVA of Field-Dependent, Field-Neutral and Field-Independent Senior School Students that Learnt Cell Division using Modelling Clay

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	η_p^2
Corrected Model	302.83[a]	3	100.94	5.29	.00	.20
Intercept	1477.81	1	1477.81	77.37	.00	.54
Pretest	291.19	1	291.19	15.24	.00	.19
Cognitive Styles	6.81	2	3.41	.18	.84	.01
Error	1241.61	65	19.10			
Total	61150.00	69				
Corrected Total	1544.44	68				

a. R Squared = .20 (Adjusted R Squared = .16)

Note. df = Degrees of freedom; *F* = Fisher's *F* ratio; η_p^2 = Partial Eta Square

Research Question 5: What is the difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using demonstration kit?

Table 15 illustrated the mean scores of field-dependent, field-neutral, and field-independent students that learnt cell division using demonstration kit. It is evident from Table 15 that the mean scores of the field-independent students (*M* = 26.94) was higher than that of the field-neutral (*M* = 23.54) and field-dependent students (*M* = 22.68). This result suggests that the use of demonstration kit favoured the field-independent students than the field-neutral and field-dependent students.

Table 15

Descriptive Statistics of Students' Performance in Experimental Group 2 based on Cognitive Styles

Treatment	Cognitive Styles	N	Mean	Standard Deviation
Demonstration Kit	Field Dependent	22	22.68	4.85
	Field Neutral	26	23.54	4.62
	Field Independent	18	26.94	4.30
	Total	69	24.18	4.87

Hypothesis 5: There is no statistically significant difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using demonstration kit.

The one-way within group ANCOVA test output in Table 16 revealed that when $F_{(2, 62)} = 3.55$, $p = .03$, $\eta_p^2 = .11$. Hence, hypothesis 5 was rejected, since $p < .05$. This implies that there was a statistically significant difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using demonstration kit.

Table 16

Summary of the ANCOVA of Field-Dependent, Field-Neutral and Field-Independent Senior School Students that Learnt Cell Division using Demonstration Kit

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	η_p^2
Corrected Model	677.71[a]	3	255.90	16.25	.00	.44
Intercept	314.49	1	314.49	22.62	.00	.27
Pretest	480.07	1	480.07	34.53	.00	.36
Cognitive Styles	104.15	2	52.07	3.75	.03	.11
Error	862.11	62	13.91			
Total	40134.00	66				
Corrected Total	1539.82	65				

a. R Squared = .44 (Adjusted R Squared = .41)

Note. df = Degrees of freedom; *F* = Fisher's *F* ratio; η_p^2 = Partial Eta Square

The post hoc comparison using Bonferroni test in Table 17 showed that there was no statistically significant difference in the performance of field-dependent and field-neutral students (p = 1.00) as well as field-dependent and field-independent students (p = .07). However, students performance differ significantly between the field-neutral and field-independent students (p = .04). This result suggests that cognitive styles had an effect on students use of demonstration kit for learning cell division in favour of the field-independent students.

Table 17

Bonferroni Post Hoc Analysis showing the Source of the Significant Difference in the Performance of Field-Dependent, Field-Neutral and Field-Independent Senior School Students that Learnt Cell Division using Demonstration Kit

(I) Cognitive Styles	(J) Cognitive Styles	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Field Dependent	Field Neutral	.08	1.09	1.00	-2.61	2.77
	Field Independent	-2.81	1.21	.07	-5.79	.17
Field Neutral	Field Dependent	-.08	1.09	1.00	-2.77	2.61
	Field Independent	-2.89*	1.15	.04	-5.71	-.07
Field Independent	Field Dependent	2.81	1.21	.07	-.17	5.79
	Field Neutral	2.89*	1.15	.04	.07	5.71

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

Research Question 6: What is the difference in the performance of high, medium, and low scoring students that learnt cell division using modelling clay?

Table 18 indicated a marginal difference in the mean score of the low scoring (M = 29.00), Medium scoring (M = 29.47), and high scoring (M = 30.09) students that learnt cell division using modelling clay. These results suggest that score levels did not affect students performance when they learnt cell division using modelling clay.

Table 18

Descriptive Statistics of Students' Performance in Experimental Group 1 based on Score Levels

Treatment	Score Levels	N	Mean	Standard Deviation
Modelling Clay	Low	26	29.00	5.10
	Medium	32	29.47	4.50
	High	11	30.09	5.07
	Total	69	29.39	4.77

Hypothesis 6: There is no statistically significant difference in the performance of high, medium, and low scoring students that learnt cell division using modelling clay.

Table 19 showed that when $F_{(2, 65)} = .63$, $p = .54$. This result indicated that the *p*-value is greater than .05 significant level. Therefore, hypothesis 6 was not rejected. This implies that there was no statistically significant difference in the performance of high, medium, and low scoring students that learnt cell division using modelling clay.

Table 19

Summary of the ANCOVA of High, Medium, and Low Scoring Students that Learnt Cell Division using Modelling Clay

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	η_p^2
Corrected Model	319.62[a]	3	106.54	5.65	.00	.21
Intercept	982.49	1	982.49	52.14	.00	.45
Pretest	310.06	1	310.06	16.46	.00	.20
Score Levels	23.60	2	11.80	.63	.54	.02
Error	1224.82	65	18.84			
Total	61150.00	69				
Corrected Total	1544.44	68				

a. R Squared = .21 (Adjusted R Squared = .17)

Note. df = Degrees of freedom; *F* = Fisher's *F* ratio; η_p^2 = Partial Eta Square

Research Question 7: What is the difference in the performance of high, medium, and low scoring students that learnt cell division using demonstration kit?

Table 20 indicated that the mean score of the high scoring students (*M* = 27.77) was higher than that of the medium (*M* = 24.27) and low scoring students (*M* = 22.68). These results suggest that the use of demonstration kit enhanced the performance of the high scoring students more than the medium and low scoring students.

Table 20

Descriptive Statistics of Students' Performance in Experimental Group 2 based on Score Levels

Treatment	Score Levels	N	Mean	Standard Deviation
Demonstration Kit	Low	23	22.04	4.51
	Medium	30	24.27	4.94
	High	13	27.77	3.06
	Total	66	24.18	4.87

Hypothesis 7: There is no statistically significant difference in the performance of high, medium, and low scoring students that learnt cell division using demonstration kit.

The one-way within group ANCOVA test output in Table 21 indicated that when $F_{(2, 62)} = 9.58$, $p < .05$, with a small effect size ($\eta_p^2 = .24$). Hence, hypothesis 7 was rejected since the *p*-value of .00 was less than .05 significant level. This implies that there was a statistically significant difference in the performance of high, medium, and low scoring students that learnt cell division using demonstration kit.

Table 21

Summary of the ANCOVA of High, Medium, and Low Scoring Students that Learnt Cell Division using Demonstration Kit

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	η_p^2
Corrected Model	801.65[a]	3	267.22	22.44	.00	.52
Intercept	320.38	1	320.38	26.91	.00	.30
Pretest	528.96	1	528.96	44.43	.00	.42
Score Levels	228.08	2	114.04	9.58	.00	.24
Error	738.17	62	11.91			
Total	40134.00	66				

Corrected Total	1539.82	65

a. R Squared = .52 (Adjusted R Squared = .50)

Note. *df* = Degrees of freedom; *F* = Fisher's *F* ratio; η_p^2 = Partial Eta Square

The Bonferroni post hoc analysis in Table 22 showed that there was a statistically significant difference in the performance high and low scoring students (*p* = .00) as well as high and medium scoring students (*p* = .01). However, the performance of medium scoring students did not significantly differ from that of the low scoring students (*p* = .38). This result indicated that the use of demonstration kit improved the performance of high scoring students in cell division more than either of the medium and low scoring students.

Table 22

Bonferroni Post Hoc Analysis showing the Direction of the Significant Difference in the Performance of High, Medium, and Low Scoring Students that Learnt Cell Division using Demonstration Kit

		Mean Difference	Std.		95% Confidence Interval for Difference[b]	
(I) Score Levels	(J) Score Levels	(I-J)	Error	Sig.[b]	Lower Bound	Upper Bound
Low	Medium	-1.49	.96	.38	-3.86	.88
	High	-5.22*	1.20	.00	-8.17	-2.27
Medium	Low	1.49	.96	.38	-.88	3.86
	High	-3.73*	1.15	.01	-6.55	-.91
High	Low	5.22*	1.20	.00	2.27	8.17
	Medium	3.73*	1.15	.01	.91	6.55

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

Research Question 8: What is the interaction effect of treatment and gender on senior school students performance in cell division?

Table 23 showed that the total mean score of the male (*M* = 25.36) and female students (*M* = 24.98) were similar with a marginal difference. These results suggest that the performances of the male and female students were comparable in relation to the interventions.

Table 23

Descriptive Statistics of the Interaction Effect of Treatment and Gender

Gender	Treatment	N	Mean	Standard Deviation
	Modelling clay	33	29.73	4.65
Male	Demonstration kit	29	23.93	4.44
	Conventional method	35	22.43	4.48
	Total	**97**	**25.36**	**5.50**
	Modelling clay	36	29.08	4.95
Female	Demonstration kit	37	24.38	5.23
	Conventional method	43	22.07	4.77
	Total	**116**	**24.98**	**5.74**

Hypothesis 8: There is no statistically significant interaction effect of treatment and gender on senior school students performance in cell division.

The 3 x 2 ANCOVA test between treatment (modelling clay, demonstration kit, conventional method) and gender (male, female) in Table 24 indicated that the interaction effect of treatment and gender was not significant, $F_{(2, 206)} = .01$, $p = .99$. Thus, hypothesis 8 was not rejected since the *p*-value of .99 is greater than .05 significant level ($p > .05$). Hence, there was no statistically significant interaction effect of treatment and gender on senior school students performance in cell division.

Table 24

Summary of the ANCOVA of the Interaction Effect of Treatment and Gender

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	η_p^2
Corrected Model	3731.83[a]	6	621.97	43.29	.00	.56
Intercept	1545.36	1	1545.36	107.55	.00	.34
Pretest	1751.17	1	1751.17	121.87	.00	.37
Treatment	2553.44	2	1276.72	88.85	.00	.46
Gender	1.26	1	1.26	.09	.77	.00
Treatment * Gender	.16	2	0.81	.01	.99	.00
Error	2960.05	206	14.37			
Total	141472.00	213				
Corrected Total	6691.89	212				

a. R Squared = .56 (Adjusted R Squared = .55)

Note. df = Degrees of freedom; *F* = Fisher's *F* ratio; η_p^2 = Partial Eta Square

In addition, the profile plot of the interaction between treatment and gender in Figure 10 indicated an ordinal interaction (parallel lines) which suggest that the performance of male and female students was similar based on the interventions used in the study. Thus, no interaction existed between treatment and gender.

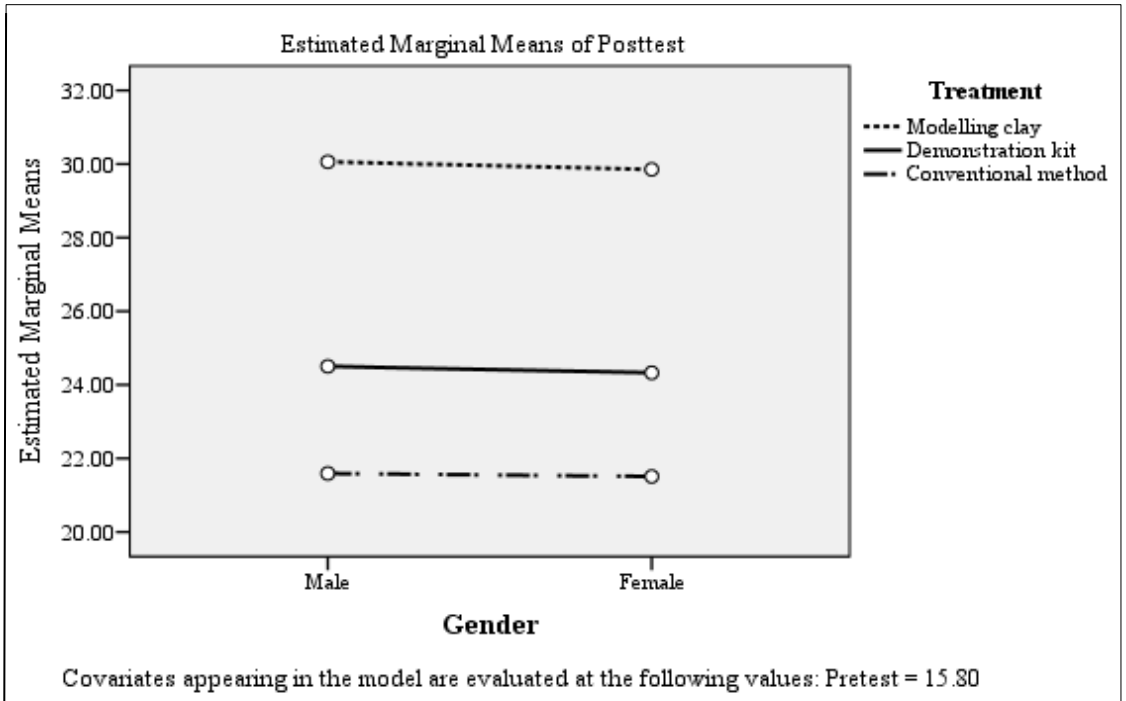


Figure 10. Profile plot of the interaction effect of treatment and gender on senior school students performance in cell division

Research Question 9: What is the interaction effect of treatment and cognitive styles on senior school students performance in cell division?

Table 25 revealed that the total mean score of the field-dependent (*M* = 24.19) and field-neutral (*M* = 24.25) students were homogeneous. Meanwhile, the field-independent students, appeared to benefit more from the interventions (*M* = 27.38). These results suggest that the field-dependent and field-neutral students in each of the groups applied similar cognitive processes to learn cell division processes.

Table 25

Descriptive Statistics of the Interaction Effect of Treatment and Cognitive Styles

Cognitive Style	Treatment	N	Mean	Standard Deviation
Field Dependent	Modelling clay	27	28.96	4.97
	Demonstration kit	22	22.68	4.85
	Conventional method	25	20.36	4.15
	Total	**74**	**24.19**	**5.95**
Field Neutral	Modelling clay	18	29.33	4.07
	Demonstration kit	26	23.54	4.62
	Conventional method	32	21.97	3.27
	Total	**76**	**24.25**	**4.89**
Field Independent	Modelling clay	24	29.92	5.15
	Demonstration kit	18	26.94	4.30
	Conventional method	21	24.86	5.75
	Total	**63**	**27.38**	**5.50**

Hypothesis 9: There is no statistically significant interaction effect of treatment and cognitive styles on senior school students performance in cell division.

The 3 x 3 ANCOVA between-subjects treatment (modelling clay, demonstration kit, conventional method) and cognitive styles (field dependent, field neutral, field independent) in Table 26 revealed that the interaction between treatment and cognitive styles was not statistically significant, $F_{(4,\ 203)} = 1.01$, $p = .40$. Thus, hypothesis 9 was not rejected since $p > .05$. This implies that there was no statistically significant interaction effect of treatment and cognitive styles on senior school students performance in cell division.

Table 26

Summary of the ANCOVA of the Interaction Effect of Treatment and Cognitive Styles

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	η_p^2
Corrected Model	3955.98[a]	9	439.55	32.61	.00	.59
Intercept	1672.62	1	1672.62	124.11	.00	.38
Pretest	1544.37	1	1544.37	114.59	.00	.36
Treatment	2353.69	2	1176.85	87.32	.00	.46
Cognitive styles	184.35	2	92.18	6.84	.00	.06
Treatment * Cognitive styles	54.49	4	13.62	1.01	.40	.02
Error	2735.90	203	13.48			
Total	141472.00	213				
Corrected Total	6691.89	212				

a. R Squared = .59 (Adjusted R Squared = .57)

Note. df = Degrees of freedom; *F* = Fisher's *F* ratio; η_p^2 = Partial Eta Square

Furthermore, the profile plot of the interaction between treatment and cognitive styles in Figure 11 indicated an ordinal interaction (parallel lines). This suggest that the performances of the field dependent, field neutral, and field independent students were enhanced by the different forms of treatments used in the study.

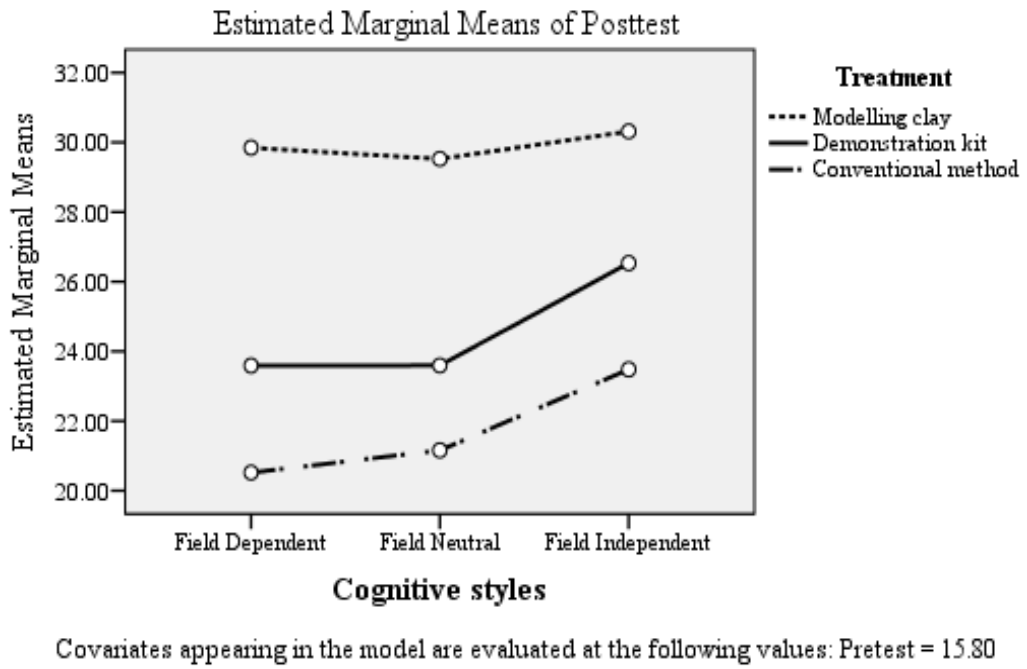


Figure 11. Profile plot of the interaction effect of treatment and cognitive styles on senior school students performance in cell division

Research Question 10: What is the interaction effect of treatment and score levels on senior school students performance in cell division?

Table 27 showed that the total mean scores of the low scoring (M = 23.54), medium scoring (M = 25.56), and high scoring (M = 27.51) students were different. These implies that score levels affected students use of treatments. In addition, the results suggested that the high scoring students benefited most from the interventions.

Table 27

Descriptive Statistics of the Interaction Effect of Treatment and Score Levels

Score Levels	Treatment	N	Mean	Standard Deviation
Low	Modelling clay	26	29.00	5.10
	Demonstration kit	23	22.04	4.51
	Conventional method	33	20.27	4.12
	Total	**82**	**23.54**	**5.90**
Medium	Modelling clay	32	29.47	4.50
	Demonstration kit	30	24.27	4.94
	Conventional method	28	22.46	3.72
	Total	**90**	**25.56**	**5.32**
High	Modelling clay	11	30.09	5.07
	Demonstration kit	13	27.77	3.06
	Conventional method	17	25.65	4.99
	Total	**41**	**27.51**	**4.74**

Hypothesis 10: There is no statistically significant interaction effect of treatment and score levels on senior school students performance in cell division.

The 3 x 3 ANCOVA between treatment (modelling clay, demonstration kit, conventional method) and score levels (low, medium, high) in Table 28 revealed that interaction existed between treatment and score levels, $F_{(4, 203)} = 6.18$, $p < .05$, with a small effect size ($\eta_p^2 = .11$). Hence, hypothesis 10 was rejected since $p < .05$. This implies that there was a statistically significant interaction effect of treatment and score levels on senior school students performance in cell division.

Table 28

Summary of the ANCOVA of the Interaction Effect of Treatment and Score Levels

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	η_p^2
Corrected Model	4232.42[a]	9	470.27	38.82	.00	.63
Intercept	1430.52	1	1430.52	118.07	.00	.37
Pretest	1655.93	1	1655.93	136.68	.00	.40
Treatment	1796.28	2	898.14	74.13	.00	.42
Score Levels	138.23	2	69.12	5.71	.00	.05
Treatment * Score Levels	299.36	4	74.84	6.18	.00	.11
Error	2459.47	203	12.12			
Total	141472.00	213				
Corrected Total	6691.89	212				

a. R Squared = .63 (Adjusted R Squared = .62)

Note. df = Degrees of freedom; *F* = Fisher's *F* ratio; η_p^2 = Partial Eta Square

Moreover, the profile plot of the interaction between treatment and score levels in Figure 12 showed a dis-ordinal interaction (non-parallel lines) which suggest that the low, medium, and high scoring students performed differently with respect to the interventions. Hence, interaction existed between treatment and students score levels.

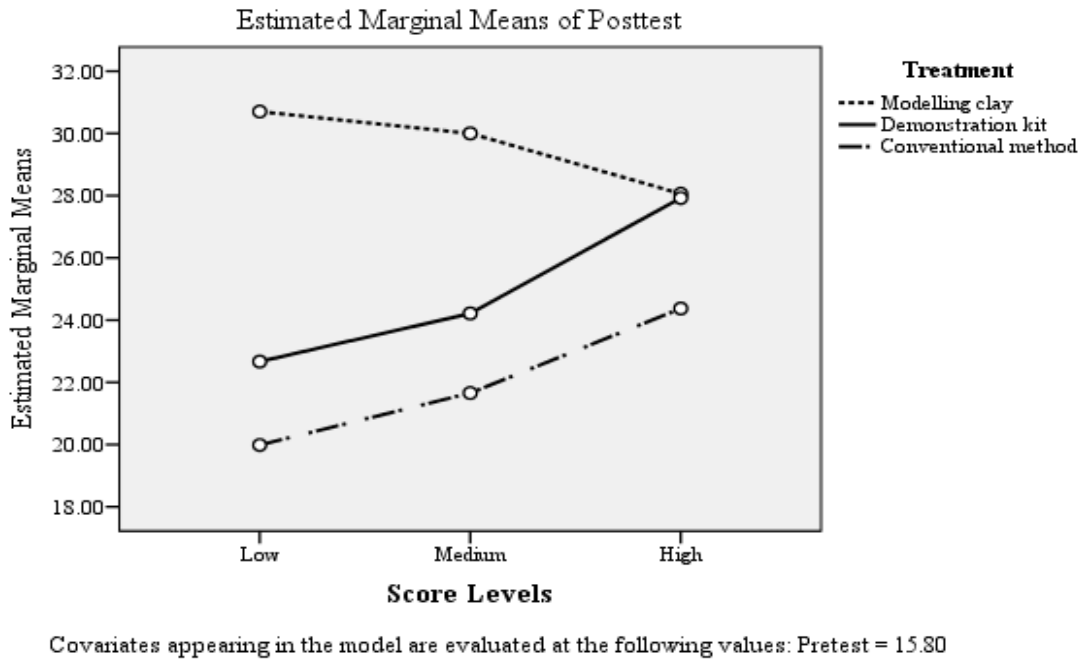


Figure 12. Profile plot of the interaction effect of treatment and score levels on senior school students performance in cell division

Summary of Findings

The following are the summary of the findings in this study.

i. There was a statistically significant difference in the performance of students that learnt cell division using modelling clay, demonstration kit and the conventional method of teaching in favour of those exposed to modelling clay.

ii. No statistically significant difference existed in the performance of male and female students when they learnt cell division using modelling clay.

iii. The performance of male and female students was not significantly different when they learnt cell division using demonstration kit.

iv. No statistically significant difference existed in the performance of field-dependent, field-neutral and field-independent students that learnt cell division using modelling clay.

v. Significant difference existed in the performance of field-dependent, field-neutral and field-independent students that learnt cell division using demonstration kit in favour of field-independent students.

vi. There was no statistically significant difference in the performance of high, medium, and low scoring students that learnt cell division using modelling clay.

vii. Significant difference existed in the performance of high, medium, and low scoring students that learnt cell division using demonstration kit in favour of the high scoring students.

viii. The interaction effect of treatment and gender on students performance in cell division was not statistically significant.

ix. There was no statistically significant interaction effect of treatment and cognitive styles on senior school students performance in cell division.

x. There was a statistically significant interaction effect of treatment and score levels on senior school students performance in cell division.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

This chapter deals with the discussion and conclusion drawn from the findings of this study on which recommendations and suggestions for further studies were advanced.

Discussion

This study investigated the effects of modelling clay and demonstration kit on senior school students' performance in cell division. The first finding of this study revealed that students exposed to the use of modelling clay had a better performance than their counterparts exposed to the use of demonstration kit and conventional method of teaching, respectively. This finding could be attributed to the moulding of the exact cell division processes by students exposed to the use of modelling clay as against the demonstration kit which cannot be moulded or manipulated.

However, the supply of mass through the use of modelling clay and demonstration kit could have enhanced students' performances over those that learnt cell division using the conventional method. The pedagogical implication of this finding is that the modelling clay and demonstration kit are more suitable for the teaching and learning of cell division processes than the conventional method of teaching.

This finding is in line with Abimbola (2015) who posited that study technology strategies help learners to take control of their own learning. It also tallies with the finding of Herur, Kolagi, Chinagudi, Manjula, and Patil (2011) that students engaged in making models of the sensory and motor tracts using modelling clay had a

better performance than the control group. Furthermore, it corroborates the finding of Luwoye (2019) and Awoyemi (2018) that the use of demonstration kit enhanced senior school students' performances in biology and mathematics, respectively.

The second finding revealed that there was no statistically significant difference in the performances of male and female senior school students that learnt cell division using modelling clay. This finding may be attributed to the paring of male and female students as study partners which facilitated the sharing of ideals. The finding implies that the modelling clay can be used in co-educational schools. This finding agrees with that of Jiyah (2016), and Badmus, Bello, Hamzat, and Sulaiman (2019) that gender had no significant effect on the performances of male and female senior school students in cell division. It is also in line with the findings of Sakiyo, Musa, and Waziri (2018), and Kingdom-Aaron, Etokeren, and Okwelle (2019) who observed no significant difference in the performances of male and female students in biology.

The third finding revealed that there was no statistically significant difference in the performances of male and female senior school students when they learnt cell division using demonstration kit. This finding may be as a result of the homogenous learning materials used by male and female students who were paired and exposed to the use of demonstration kit at the same time in the same learning environment. Thus, the demonstration kit is suitable for use in co-educational schools. This finding tallies with that of Onanuga, Saka, Adebanjo, and Olanrewaju (2019) who observed no significant difference in the performances of male and female senior school students exposed to the demonstration kit. However, it is at variance with the finding of Ahmed (2018) who observed a significant difference in the achievement of senior school students that learnt ecology with the demonstration kit.

The fourth finding from the study indicates that there was no statistically significant difference in the performance of field-dependent, field-neutral and field-independent senior school students that learnt cell division using modelling clay. This finding may be due to the concrete representation of cell division processes using the modelling clay, which might have aided the knowledge processing skills of each student. This finding implies that the use of modelling clay could enhance students' performance irrespective of the way individual student processes knowledge. This finding is contrary to that of Ashiru and Sadiq (2016), and Idika (2017) who, in their respective studies, observed a significant difference in the performances of students based on cognitive styles.

The fifth finding showed that there was a statistically significant difference in the performances of field-dependent, field-neutral and field-independent senior school students that learnt cell division using demonstration kit. This finding could be due to students' time management, analytic and critical thinking skills in assigning significance to the demonstration kit items which may have affected their construction of the mental picture of cell division processes. The pedagogical implication of this finding is that the demonstration kit might not be suitable without the instructor taking into cognisance that it might not benefit students belonging to the field dependent and field neutral cognitive styles. This finding corroborates Okoye (2014), and Akanmu and Fajemidagba (2013) who observed a significant difference in students' cognitive styles in favour of the field-independent learners.

The sixth finding revealed that there was no statistically significant difference in the performance of high, medium, and low scoring students that learnt cell division using modelling clay. This finding could be because each student had his or her own modelling clay and there was a high cognitive demand on each student to concretize

the cell division processes through an individualized group-work approach which could have facilitated the sharing of ideas among students of the different score levels. The finding implies that the modelling clay can be used in any classroom irrespective of students score levels. This finding conforms with Abdulkadri (2011); Alabi (2016); and Jiyah (2016) who observed no significant difference in the achievement of high, medium, and low scoring students.

The seventh finding indicates that there was a statistically significant difference in the performances of high, medium, and low scoring students that learnt cell division using demonstration kit. This finding may be as a result of the poor grasp of the technique of assigning significance and the inability of the low and medium scoring students to correctly represent the cell division processes using the demonstration kit. The pedagogical implication of this finding is that the demonstration kit may not effectively address students' individual differences in terms of score levels. This finding corroborates Adeoye and Abimbola (2016), and Awoyemi (2018) who observed a significant difference in the performances of the high, medium and low scoring students taught biology and mathematics with the demonstration kit.

A finding further revealed that there was no statistically significant interaction effect of treatment and gender on senior school students' performance in cell division. This finding may be as a result of the equivalent strategies used by male and female students in each group who learnt cell division at the same time under the same learning condition. It implies that each of the treatment is suitable for use in co-educational institutions. This finding contrast with that of Ayanda, Adeoye, and Olayinka (2019) who discovered that the interaction between treatment and students' gender was significant. It however, tallies with the findings of Olatoye (2017), and

Okoli and Abonyi (2014), who observed no significant interaction between treatment and gender on senior school students' achievement in biology.

Another finding from this study revealed that there was no interaction between treatment and cognitive styles based on senior school students' performance in cell division. This finding could be due to the fact that students in each of the groups displayed some levels of knowledge processing skills with reference to the treatment they used for learning cell division. The finding implies that each of the strategies has the potential to facilitate students' knowledge processing skills. This finding is not in conformity with that of Nnodi (2012) that there was a significant interaction effect of treatment and cognitive style on students' achievement in science concepts. Also, the finding is not in line with that of Agboghoroma (2015) who discovered that there was a significant interaction between cognitive style and teachers' mode of instruction.

In addition, a finding indicated that there was a statistically significant interaction effect of treatment and score levels on senior school students' performance in cell division. This finding may be attributed to the exposure of the students to different treatments which might have caused the differences in their performances, with respect to their score levels. The pedagogical implication of this finding is that not all strategies are suitable for learning among students with different score levels. This finding agrees with that of Neboh (2009), who observed an interaction between ability levels and teaching methods on students' mean achievement in biology, and Adeoye (2018), who discovered that interaction existed between treatment and score levels on students' attitude and achievement in biology. The finding is contrary to that of Ayanda, Adeoye, and Olayinka (2019) who observed no significant interaction between biology students score levels and treatments used for teaching ecological concepts

Conclusion

The study concluded that the modelling clay and demonstration kit are effective tools for enhancing students' performance in cell division over the conventional method of teaching. In addition, the performances of male and female students were homogenous, meaning that the modelling clay and demonstration kit can be used by both male and female students in co-educational schools. Also, the modelling clay is appropriate for the teaching and learning of cell division, irrespective of students' cognitive styles and score levels. However, the demonstration kit is not suitable for students belonging to the field-dependent and field-neutral cognitive styles as well as those of the low and medium score levels.

Recommendations

The following recommendations were advanced based on the findings of the study:

1. Biology teachers and students in Nigerian senior secondary schools should embrace the use of modelling clay and demonstration kit for effective teaching and meaningful learning of cell division processes.
2. Teachers should give equal considerations to male and female students when the modelling clay is used for teaching and learning.
3. Students should be allowed to pair up as study partners, irrespective of their gender, during the use of demonstration kit for classroom teaching and learning.
4. Students should be encouraged to develop positive social interaction among themselves during the use of modelling clay for teaching and learning since

pairing facilitated the sharing of ideas and concrete representation of learnt data among students with different cognitive styles.

5. Students belonging to the field dependent and field neutral cognitive styles should be adequately tutored on the placement of significance on selected demonstration kit items prior to classroom teaching and learning.
6. The modelling clay is suitable for classroom teaching and learning of cell division processes and other biology topics, irrespective of students' score levels.
7. The placement of students in classes should be based on their score levels so as to assist the medium and low scoring students learn at their own pace during the use of demonstration kit. Also, teachers should supplement the use of the demonstration kit with active teaching.
8. Government agencies and professional bodies saddled with the responsibility of designing and revising the curriculum should incorporate appropriate teaching and learning strategies that would facilitate students' learning, irrespective of gender.
9. The selection of instructional strategies for the teaching and learning of cell division and other topics should not be based on students' cognitive styles.
10. Teachers should consider students' individual differences in terms of score levels when selecting instructional strategy for classroom teaching and learning.

Suggestions for Further Studies

1. Qualitative research could be conducted using clinical interview and questionnaires to elucidate the views of learners on the use of modelling clay and demonstration kit.
2. Future researchers could carry out equivalent studies to include other variables such as students' retention and attitude towards the use of the demonstration kit and modelling clay.
3. Similar studies could be replicated on the use of modelling clay and demonstration kit for the teaching and learning of other biology topics at different geographical locations involving small and manageable sample sizes.
4. Meta-analysis studies could be conducted to appraise the different researches on study technology principles, so as to evaluate its efficacy to teaching and learning.
5. Studies could be carried out on the comparative effects of modelling clay and demonstration kit on students' performance in biology and other science subjects.

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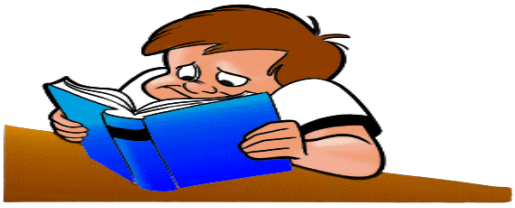
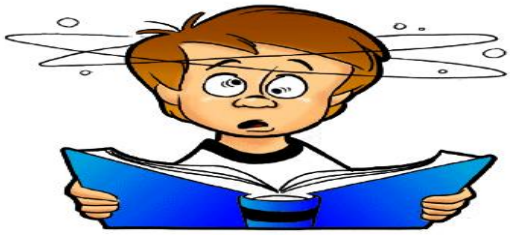
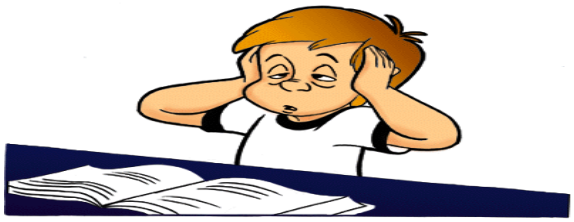
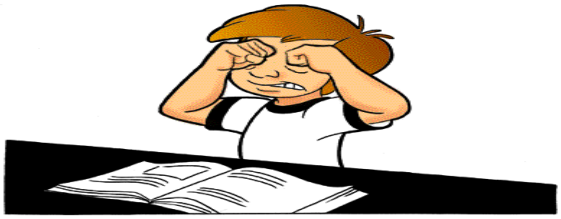
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Appendix A

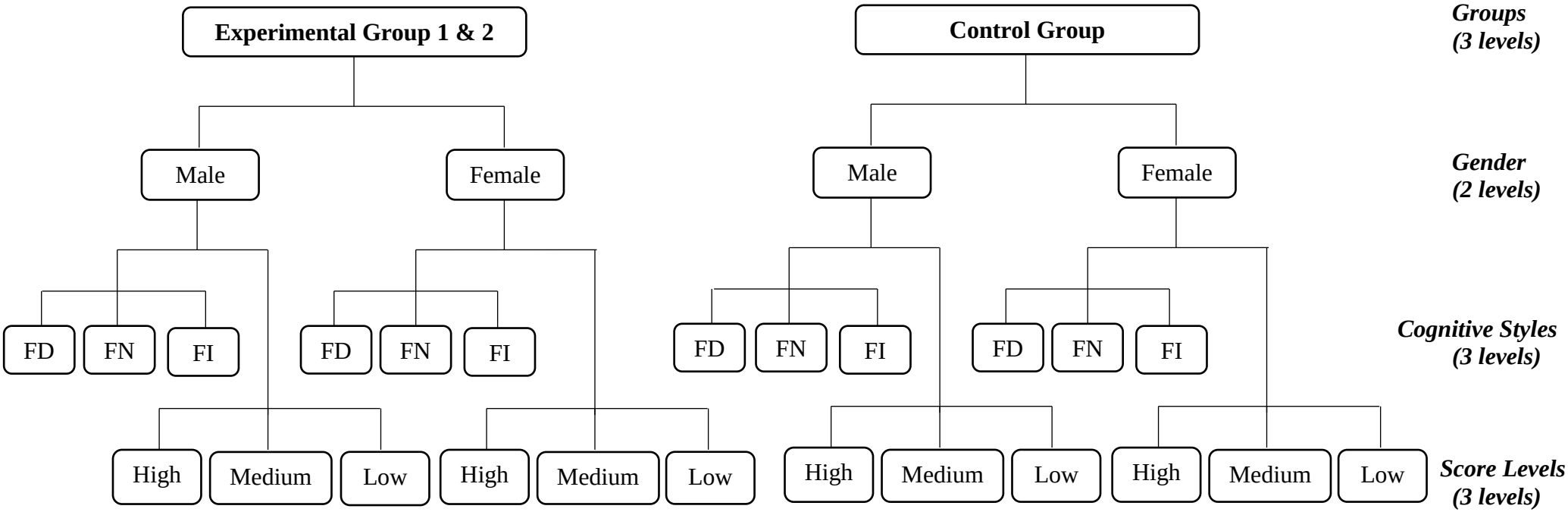
Animated Pictures of the Physical Reactions Exhibited by Learners' due to the Lack of Mass

Feel Squash	**Feel Bent**
	
Sort of Spinning	**Sort of Lifeless**
	
Feel Dizzy	**Bored**
	
Angry	**Stomach feeling funny**
	
Headaches	**Eyes Hurting**
	

Source: http://www.studytechnology.org/special/lackmass.html

Appendix B

Diagrammatic Representation of the Research Design



KEY: **FD =** Field Dependent **FN =** Field Neutral **FI** = Field Independent

Appendix C

Coloured Playdough for Modelling



Playdough Recipe

Ingredients:

- 2 cups of flour
- 1 tablespoon of baking powder
- 2 cups of water
- 1 tablespoon of vegetable oil
- 1 tablespoon of food preservative
- Food colouring (Red, Blue, Yellow, etc.)

Directions:

1. Pour and mix together the flour and food preservative in a pot.

2. Add water, vegetable oil and few drops of preferred food colouring.

3. Stir the mixture together and allow to cook for 3-5 minutes.

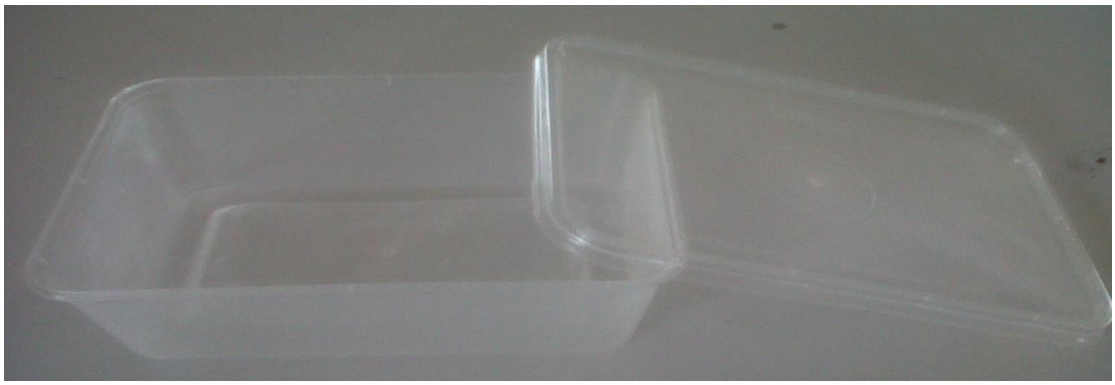
4. Place the dough on a kneading board and knead it properly.

5. Allow the dough to cool and store in an airtight container or cellophane bag

6. Repeat the procedure using other food colouring agents to obtain doughs of different colours.

Appendix D

Demonstration Kit and its Contents







Appendix E

Cell Division Course Guide

Cell Division Course Guide on Modelling Clay

Name: …….

Class: ……..…. Gender: *Male* ( ) *Female* ( )

Date: ……...

Dear Students,

This course guide is designed to present cell division concepts and processes in a logical sequence. The strategy used in this course guide is based on study technology principles which involve the use of modelling clay to overcome the first barrier to study, that is, the lack of mass. The lack mass in this context is the absence of the real physical object of a subject matter, which can make an individual exhibit some physical reactions such as feeling squashed, face squashed, bent, sort of spinning, somewhat dead, bored, angry, stomach feeling funny, headache, eyes hurting and dizzy. Watch out for any of these reactions as you use the modelling clay for learning cell division.

You are expected to adhere to the procedure provided in this course guide for learning cell division using the playdough provided on your table as the modelling clay. Each student together with the study partner is expected to append their signatures after demonstrating each of the cell division concepts and processes to indicate mastery.

Week One (Mitosis)

1. Open your textbooks to the appropriate pages on the topic mitosis (for instance, pages 55 – 60 in Essential Biology for Senior Secondary Schools by Michael, M. C.)

2. Read through and master the meaning of mitosis and demonstrate the meaning with the modelling clay taking note of where mitosis occurs in plants and animals, and the number of daughter cells produced

Mitosis is a cell or nuclear division which takes place during growth and development. It takes place in the body or somatic cells yielding two daughter cells only. This type of cell division may occur in connection with growth or in unicellular organisms e.g. Amoeba, Euglena, etc. In plants, mitosis occurs only in cells found at the tips of the roots and shoots, cambium, or in other specific parts. Mitosis leads to production of diploid number of cells (2n) in an organism.

- *Mitosis* _____ _____
  Partner Sign Student Sign

3. Identify all the stages of mitosis and master the events taking place at each stage. Also, study each of the diagrammatic representation of the mitotic cell division stages from your textbooks (for instance, page 57 in Essential Biology for Senior Secondary Schools by Michael, M. C.).

Stages of Mitosis

Prophase: this stage signifies the onset of cell division processes after the resting stage. It is of two forms that is, early and late prophase. At the early Prophase, the nucleolus dissolves, chromosomes become short and thick, spindles begin to form from the centrioles which are situated at opposite poles of the cell. Late prophase is characterised with the shortness and fatness of chromosomes which consist of a pair of chromatids connected by the centromere.

- *Prophase* _____ _____
  Partner Sign Student Sign

Metaphase: this is the second stage of mitotic cell division where the chromosome connected by the spindle fibres lies at the equator.

- *Metaphase* _____ _____
  Partner Sign Student Sign

Anaphase: third stage of mitotic cell division where the chromosome separates at the centromere into two chromatids and move to opposite poles.

- *Anaphase* _____ _____
  Partner Sign Student Sign

Telophase: this signifies the end of mitosis which is followed by division of the cytoplasm thereby leading to the formation of a diploid number of cells (**2n**). Spindle apparatus gradually disappears, nuclear membrane forms around each set of chromatids. The chromosomes become visible as threadlike structures.

- *Telophase* _____ _____
  Partner Sign Student Sign

Instructor's Assessment _____

Week Two (Meiosis)

1. Open your textbooks to the appropriate pages on the topic meiosis (for instance, pages 58 – 60 in Essential Biology for Senior Secondary Schools by Michael, M. C.)

2. Read through and master the meaning of mitosis and demonstrate the meaning with the modelling clay taking note of where mitosis occurs in plants and animals, and the number of daughter cells produced.

Meiosis is a cell division process that results in haploid number of cells. It is also called reduction division. Unlike mitosis, meiosis takes place in the reproductive cells of plants and animals. Meiosis is of two successive cell division: the first meiotic division also called reduction division and second meiotic division which is similar to mitosis.

- Meiosis _____ _____
  Partner Sign Student Sign

3. Identify all the stages of meiosis and master the events taking place at each stage. Also, study each of the diagrammatic representation of the meiotic cell division stages from your textbooks (for instance, page 59 in Essential Biology for Senior Secondary Schools by Michael, M. C.).

<u>Stages of Meiosis</u>

First Meiotic Division or Reduction Division

Interphase: this is the resting stage of the cell. The cell at this stage is not dividing and the chromosomes are visible in the form of chromatin granules.

First Meiotic Prophase: Chromosomes become visible, homologous chromosomes lie side by side forming a bivalent, the chromatids may become joined at a point called chiasmata and when they separate portions of chromatids may have been swapped (crossing over).

- *First Meiotic Prophase* _____ _____
  Partner Sign Student Sign

First Meiotic Metaphase: The nuclear membrane disappears and chromosomes connected by the spindle lies at the equatorial plane.

- *First Meiotic Metaphase* _____ _____
  Partner Sign Student Sign

First Meiotic Anaphase: Each member of the bivalent chromosomes moves apart towards the poles of the cell and the spindle also shortens

- *First Meiotic Anaphase* _____ _____
  Partner Sign Student Sign

First Meiotic Telophase: Chromatids arrive at the poles, spindle gradually disappears, nuclear membrane forms around each set of chromatids and the chromatids becomes visible as threadlike structures.

- *First Meiotic Telophase* _____ _____
  Partner Sign Student Sign

Second Meiotic Division or Reduction Division

Second Meiotic Prophase: Chromosomes become visible in the two nuclei, centrioles divide and moves to opposite poles and spindles begin to form from the centrioles.

- *Second Meiotic Prophase* _____ _____
  Partner Sign Student Sign

Second Meiotic Metaphase: The centromere starts to divide and the chromosomes joined by the spindle fibres lies along the equatorial plane

- *Second Meiotic Metaphase* _____ _____
  Partner Sign Student Sign

Second Meiotic Anaphase: The chromosomes splits into chromatids and begins movement in opposite directions of the cell

- *Second Meiotic Anaphase* _____ _____
  Partner Sign Student Sign

Second Meiotic Telophase: The two cells are divided into four which is tetrads. New nuclear membrane is formed around the four cells. Cleavage of the cytoplasm then occurs and each cell holds haploid number (n) of cells

- *Second Meiotic Telophase* _____ _____
  Partner Sign Student Sign

Instructor's Assessment _____

Cell Division Course Guide on Demonstration Kit

Name: …….

Class: ……. Gender: *Male* ( ) *Female* ( )

Date: ……...

Dear Students,

This course guide is designed to present cell division concepts and processes in a logical sequence. The strategy used in this course guide is based on study technology principles which involve the use of demonstration kit to overcome the first barrier to study, that is, the lack of mass. The lack mass in this context is the absence of the real physical object of a subject matter, which can make an individual exhibit some physical reactions such as feeling squashed, face squashed, bent, sort of spinning, somewhat dead, bored, angry, stomach feeling funny, headache, eyes hurting and dizzy. Watch out for any of these reactions as you use the demonstration kit for learning cell division.

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- *Mitosis* _____ _____
  Partner Sign Student Sign

3. Identify all the stages of mitotic cell division and master the events taking place at each of the stages. Also, study each of the diagrammatic representation of the

mitotic cell division stages from your textbooks (for instance, page 57 in Essential Biology for Senior Secondary Schools by Michael, M. C.).

Stages of Mitosis

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  Partner Sign Student Sign

Metaphase: this is the second stage of mitotic cell division where the chromosome connected by the spindle fibres lies at the equator.

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  Partner Sign Student Sign

Anaphase: third stage of mitotic cell division where the chromosome separates at the centromere into two chromatids and move to opposite poles.

- *Anaphase* _____ _____
  Partner Sign Student Sign

Telophase: this signifies the end of mitosis which is followed by division of the cytoplasm thereby leading to the formation of a diploid number of cells (**2n**). Spindle apparatus gradually disappears, nuclear membrane forms around each set of chromatids. The chromosomes become visible as threadlike structures.

- *Telophase* _____ _____
  Partner Sign Student Sign

Instructor's Assessment _____

Week Two (Meiosis)

1. Open your textbooks to the appropriate pages on the topic meiosis (for instance, pages 58 – 60 in Essential Biology for Senior Secondary Schools by Michael, M. C.)

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Meiosis is a cell division process that results in haploid number of cells. It is also called reduction division. Unlike mitosis, meiosis takes place in the reproductive cells of plants and animals. Meiosis is of two successive cell division: the first meiotic division also called reduction division and second meiotic division which is similar to mitosis.

- Meiosis _____ _____
  Partner Sign Student Sign

3. Identify all the stages of meiosis and master the events taking place at each stage. Also, study each of the diagrammatic representation of the meiotic cell division stages from your textbooks (for instance, page 59 in Essential Biology for Senior Secondary Schools by Michael, M. C.).

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  Partner Sign Student Sign

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  Partner Sign Student Sign

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  Partner Sign Student Sign

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  Partner Sign Student Sign

Second Meiotic Division or Reduction Division

Second Meiotic Prophase: Chromosomes become visible in the two nuclei, centrioles divide and moves to opposite poles and spindles begin to form from the centrioles.

- *Second Meiotic Prophase* _____ _____
  Partner Sign Student Sign

Second Meiotic Metaphase: The centromere starts to divide and the chromosomes joined by the spindle fibres lies along the equatorial plane

- *Second Meiotic Metaphase* _____ _____
  Partner Sign Student Sign

Second Meiotic Anaphase: The chromosomes splits into chromatids and begins movement in opposite directions of the cell

- *Second Meiotic Anaphase* _____ _____
  Partner Sign Student Sign

Second Meiotic Telophase: The two cells are divided into four which is tetrads. New nuclear membrane is formed around the four cells. Cleavage of the cytoplasm then occurs and each cell holds haploid number (n) of cells

- *Second Meiotic Telophase* _____ _____
  Partner Sign Student Sign

Instructor's Assessment _____

Appendix F

Research Assistant Training Guide

Aim: To guide Research Assistants through the use of modelling clay and demonstration kit for classroom teaching and learning of cell division.

Duration: 2½ hours

Objectives: At the end of the training, the Research Assistants should be able to:

1. State the barriers to study and how to overcome them.
2. Explain the meaning of the lack of mass and how to overcome it.
3. Describe the roles of teachers based on study technology principle.
4. Demonstrate how to use modelling clay and demonstration kit for the teaching and learning of cell division.
5. Describe the preparation of sample course guide and lesson plan on the use of modelling clay and demonstration kit for classroom teaching and learning.

S/N	Schedule of Activity	Duration
1.	Learning how to learn	12 minutes
2.	Barriers to study and how to overcome them	15 minutes
3.	Roles of teachers based on study technology principles	8 minutes
4.	Difficulties in the teaching and learning of cell division due to the lack of mass	10 minutes
5.	Use of modelling clay and demonstration kit for teaching and learning	20 minutes
6.	The use of prepared lesson plan and Cell Division Course Guide on modelling clay and demonstration kit for learning cell division	30 minutes
7.	Demonstration and practice session	55 minutes

Question and Answer Session:

Appendix G

Cell Division Performance Test

PART A

GENERAL INFORMATION

1. Name: …….

2. Class: ……

3. Gender: Male ( )
   Female ( )
   (***Please tick (√) as appropriate***)

PART B

Instruction: Answer all Questions **Duration:** 50 minutes

1. The carrier of genetic material in a cell is the

   A. Mitochondria
   B. Centriole
   C. Chromosome
   D. Nuclear membrane

2. The whole activity of the cell is controlled by the

   A. Chloroplast
   B. Nucleus
   C. Cytoplasm
   D. Mitochondria

3. The structure that house all other cell organelles is the

   A. Cytoplasm
   B. Nucleus
   C. Golgi body
   D. Ribosomes

4. Which of this organelle is present in both plant and animal cells

   A. Cell membrane

B. Chloroplast
C. Cellulose
D. Large cell vacuoles

5. The process of the multiplication of cell is called

A. Cell division
B. Cell differentiation
C. Cell enlargement
D. Cell multiplication

6. One of the following perfectly describes the structure of a chromosome

A. A pair of chromatids which a centromere joins together
B. A pair of chromatids connected by a spindle fibre
C. A pair of threads connected by asters
D. A pair of thread not joined together

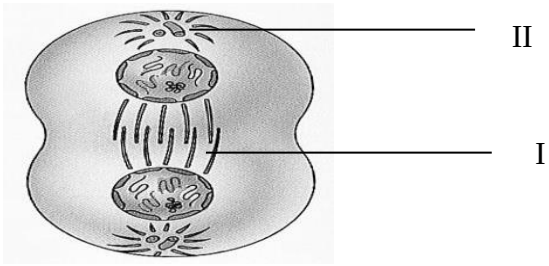
7. Which of the following processes occurs in the second phase of meiosis

A. Separation of chromosomes that are homologue
B. Diploid cells are produced
C. Fertilization occurs
D. Segregation of genes occurs

8. Mitotic division involves _____ and _____ organelles

A. Golgi apparatus and Centriole
B. Mitochondrion and Nucleus
C. Nucleus and Ribosome
D. Nucleus and Centriole

The drawing below represents the phenomenon of growth in meristematic cell of plant. Use it to answer questions 9 and 10



Source: Adapted from "Flashcards," by Studyblue, 2018, retrieved from https://www.studyblue.com/notes/note/n/lab-3/deck/3123085

9. The part labelled II in the drawing is the

A. Centriole
B. Tonoplast
C. Chromatid
D. Chloroplast

10. The part labelled I is called the

A. Nucleolus
B. Centromere
C. Centriole
D. Spindle

11. During binary fission in a lower organism, the nucleus is known to undergo

A. Mitosis
B. Meiosis
C. Fragmentation
D. Mutation

12. One of the following is not true mitotic division

A. mitosis is unique to young cells only
B. body cells replicates only by mitosis
C. there is constancy in cell numbers
D. the genetic composition of the parent cell is the same as that of the daughter cell

13. Which of the following occurrences is not a feature of meiosis

A. Formation of four daughter cells
B. Two successive nuclear cell divisions
C. Pairing of homologous chromosomes at prophase
D. Only two diploid cells are produced

14. Growth includes the following processes except

A. differentiation
B. enlargement
C. mitosis
D. meiosis

15. How many chromosomes are present in a gamete if the somatic cell has eight chromatids

A. 4
B. 2
C. 8
D. 16

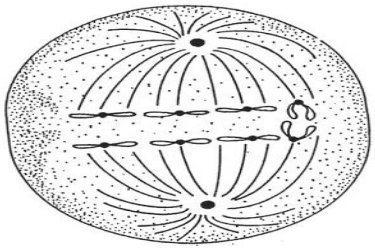
16. Crossing over is peculiar to _____ division

A. mitotic
B. meiotic
C. prophase
D. Spindle fibres

17. At the end of mitosis, _____ daughter cells are produced from a parent cell

A. four
B. two
C. eight
D. three

The drawing below represents a stage in mitosis. Use it to answer questions 18 and 19



Source: Adapted from "Anaphase," by Google Sites, 2010, retrieved from https://sites.google .com/a/asu.edu/the-almighty-cell/the-source/animal-cell/centriole

18. Which of the following processes is not evident from the drawing

A. Chromatids start to move to opposite poles
B. The absence of a nuclear membrane
C. Chromatids held by centromere
D. Centromere attaching a pair of chromatids to a spindle fibre

19. The mitotic stage in the drawing is known as

A. telophase
B. metaphase
C. anaphase
D. prophase

20. At resting stage, a cell is said to be at _____ stage

A. telophase
B. metaphase
C. anaphase
D. interphase

21. Which stage of cell division occurs directly after Metaphase in meiosis?

A. Prophase
B. Telophase
C. Anaphase
D. Interphase

22. The original cell that undergoes the process of Mitosis is referred to as the

A. Daughter cell
B. Parent cell
C. Mother cell
D. Sister cell

23. The point at which the two sister chromatids are held together is called the

A. Centromere
B. Spindle body
C. Chromatin body
D. Centriole

24. A cell that contains two chromosomes of the same number and type is said to be

A. Haploid
B. Chromoloid
C. Diploid
D. Monoloid

25. Meiosis as a cell division process leads to the formation of

A. Palisade and epidermal cell
B. Cheek cell and red blood cell
C. Root tip cell and guard cell
D. Sperm and ova

26. The mitotic cell division is divided into _____ phases

A. 2
B. 8
C. 6
D. 4

27. Meiosis occurs in one of the following parts in a plant

A. Petals
B. Ovule
C. Ovary
D. Sepal

28. The exchange of genetic materials during cell division occurs as a result of

A. Crossing over
B. Spindle fibre
C. Fibre form
D. Duplication

29. The repair of worn out tissues and binary fission occurs as a result of

A. Meiosis
B. Synthesis
C. Mitosis
D. Growth

30. Chromosomal reconstitution occurs at which stage of cell division

A. Metaphase
B. Interphase
C. Telophase
D. Anaphase

31. The point where the exchange of genetic materials occurs is called

A. Chiasmata
B. Chromatids
C. Centrioles
D. Chromosomes

32. Mitosis is important for the following process in living organism except

A. Cell replacement
B. Gamete formation
C. Growth and development
D. Tissue maintenance

33. One of the following is not peculiar to meiosis

A. Reduction division
B. Occurs in germ cell
C. Four non-identical cells are produced
D. Chromosomes with diploid numbers results

34. The following are correct about mitosis except

A. Body cells is the site for mitosis
B. Number of cells is constant
C. Number of cells is halved
D. It occurs during growth and development

35. The correct order of a typical cell division stages is

A. prophase, anaphase, metaphase, telophase
B. prophase, metaphase, telophase, anaphase
C. prophase, metaphase, anaphase, telophase
D. anaphase, prophase, metaphase, telophase

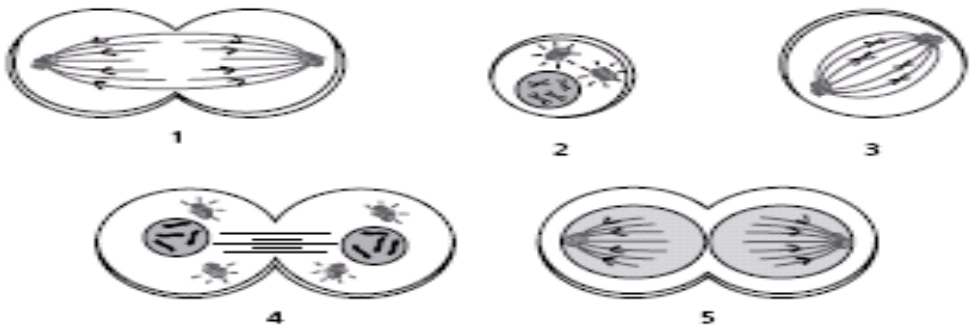
36. Which of the following description is not correct

A. telophase - spindle appears
B. metaphase - chromosomes aligned at the equator of the cell
C. anaphase - daughter chromosomes migrate to the poles
D. prophase - chromosomes appears

37. A pair of chromosome that is similar in genetic composition and size is referred to as

A. diploid
B. chromatin
C. chromatids
D. homologous chromosomes

Use the diagram below to answer questions 38 and 39



Source: Adapted from "Triand - Edit Test," by Triand, n.d., retrieved from http://emltrd .com/tests/75941

38. Put the cell division stages above in the right order.

A. 5,3,1,2,4
B. 3,1,4,2,5
C. 4,1,2,5,3
D. 2,3,1,5,4

39. The metaphase and anaphase stages in the diagram above are depicted by

A. 1 and 3
B. 1 and 5
C. 3 and 2
D. 3 and 4

40. Chromosomes in the reproductive cells are depicted with

A. 2^N
B. 23
C. 2n
D. n

41. The type of cell division that takes place during asexual reproduction is called

A. Mitosis
B. Meiosis
C. Miotosis
D. Mieosis

42. The stage of mitosis where the chromosomes become shorter and fatter is called

A. Anaphase
B. Telophase
C. Prophase
D. Metaphase

43. A form of reduction division is referred to as

A. Cell division
B. Meiosis
C. Mitosis
D. Cell enlargement

44. The second meiotic division is similar to

A. Meiosis
B. Mieosis
C. Mitosis
D. Miotsis

45. Chromosomes are visible as chromatin granules during which phase

A. Interphase
B. Prophase
C. Metaphase
D. Anaphase

46. At which stage of meiosis does nuclear membrane enclose each group of chromosomes

A. Interphase
B. Telophase

C. Metaphase
D. Anaphase

47. The growth of root tips and terminal buds of plants is by

A. Meiosis
B. Mitosis
C. Conjugation
D. Absorption

48. The stage of cell division that comes after anaphase in meiosis is the

A. Metaphase
B. Prophase
C. Interphase
D. Telophase

49. Meiosis ensures that a fertilized egg (zygote) has _____ number of chromosomes

A. diploid
B. haploid
C. triple
D. tetrad

50. During gametogenesis the 46 chromosomes in man become

A. 23
B. 128
C. 28
D. 46

51. Pairing of chromosome is not a feature of

A. Mitosis
B. Meiosis
C. Gametogenesis
D. Formation of ovules in plant

52. Two set of nuclear division occurs during

A. Mitosis
B. Growth
C. Meiosis
D. Death

53. In mitosis, the division of the nucleus is followed by that of the

A. Centriole
B. Spindle fibre

C. Nucleolus
D. Cytoplasm

54. The organelles which are broken down during mitosis reappear during

A. Interphase
B. Prophase
C. Metaphase
D. Anaphase

55. During mitosis, spindle fibre disappears gradually at

A. Telophase
B. Anaphase
C. Metaphase
D. Prophase

56. One of the following organelles is not significant to cell division

A. Nuclear membrane
B. Centriole
C. Chromosome
D. Mitochondria

57. Furrows are formed at _____ stage in meiosis

A. Prophase
B. Telophase
C. Metaphase
D. Anaphase

Appendix H

CDPT Marking Scheme

1.	C	26.	D	51.	A
2.	B	27.	B	52.	C
3.	A	28.	A	53.	D
4.	A	29.	C	54.	A
5.	A	30.	C	55.	A
6.	A	31.	A	56.	D
7.	A	32.	B	57.	B
8.	D	33.	D		
9.	A	34.	C		
10.	A	35.	C		
11.	A	36.	A		
12.	A	37.	D		
13.	D	38.	D		
14.	D	39.	A		
15.	A	40.	B		
16.	B	41.	A		
17.	B	42.	C		
18.	C	43.	B		
19.	C	44.	C		
20.	D	45.	A		
21.	C	46.	B		

22.	B	47.	B
23.	A	48.	D
24.	C	49.	A
25.	D	50.	A

Appendix I

Group Embedded Figure Test

Name: …….

Class: ……. Gender: *Male* ( ) *Female* ( )

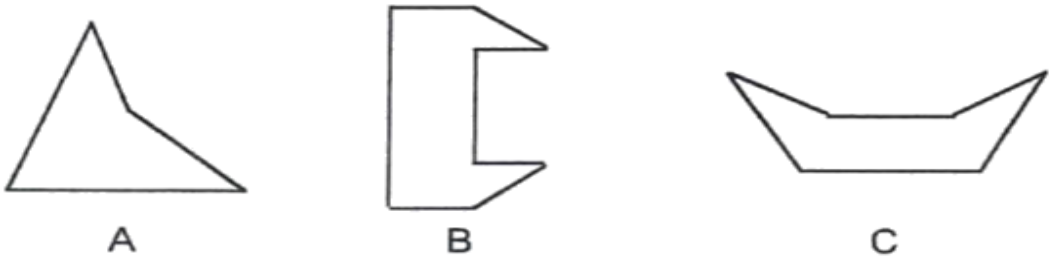
Date: ……...

Instruction: This test is meant to determine your ability to locate an embedded shape hidden within a complex shape.

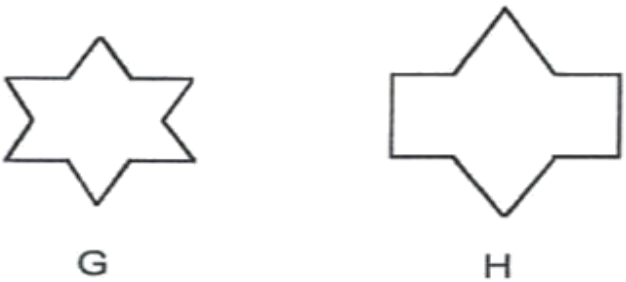
Time allowed: 20 minutes

Note: The results of this test will not affect your subject assessment in any way

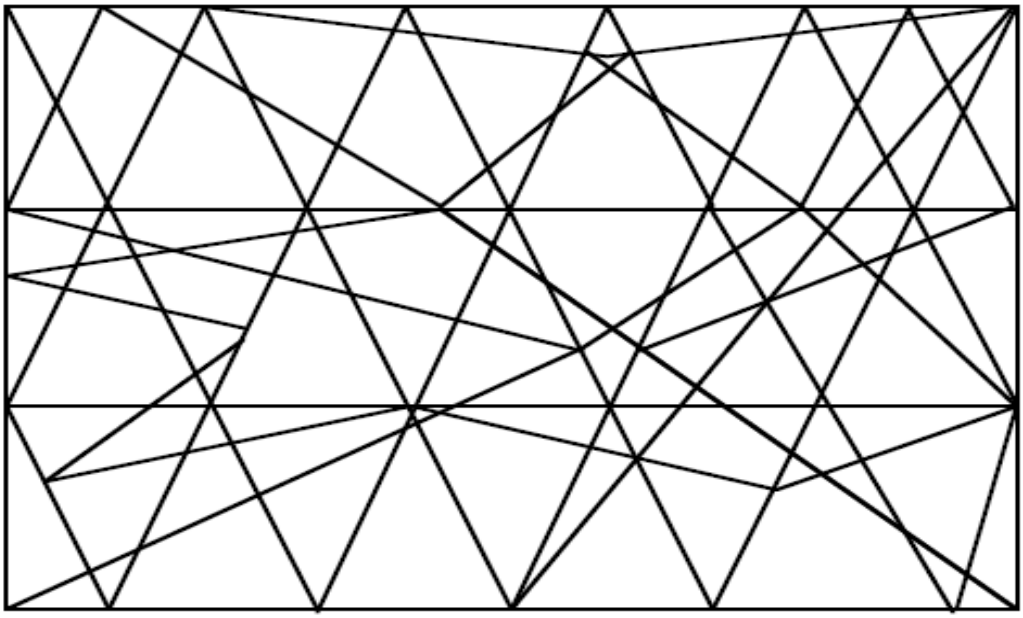
Study the shapes below and locate them in the embedded figure



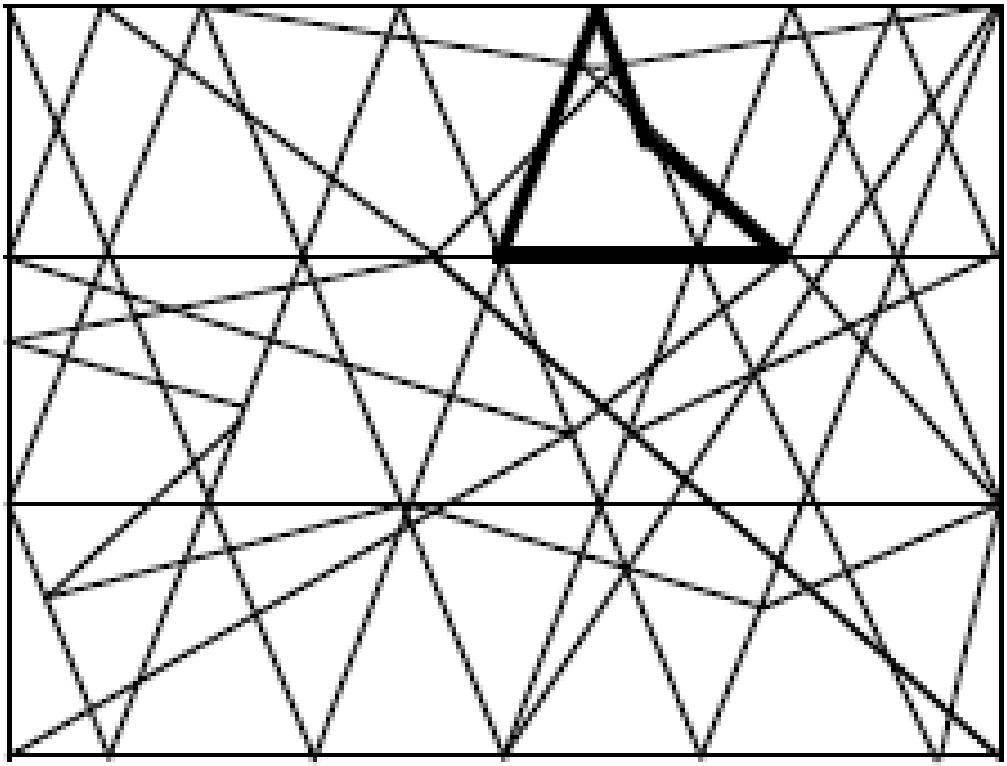


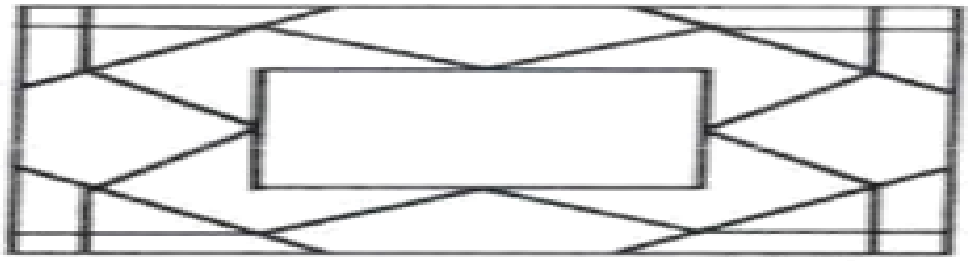


Example

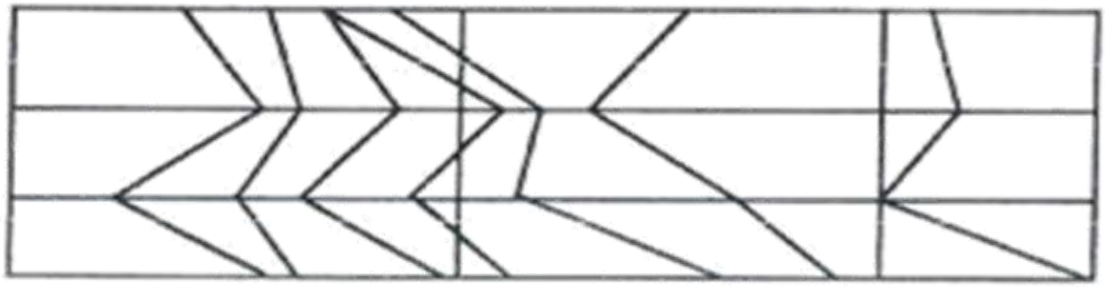


Find shape A

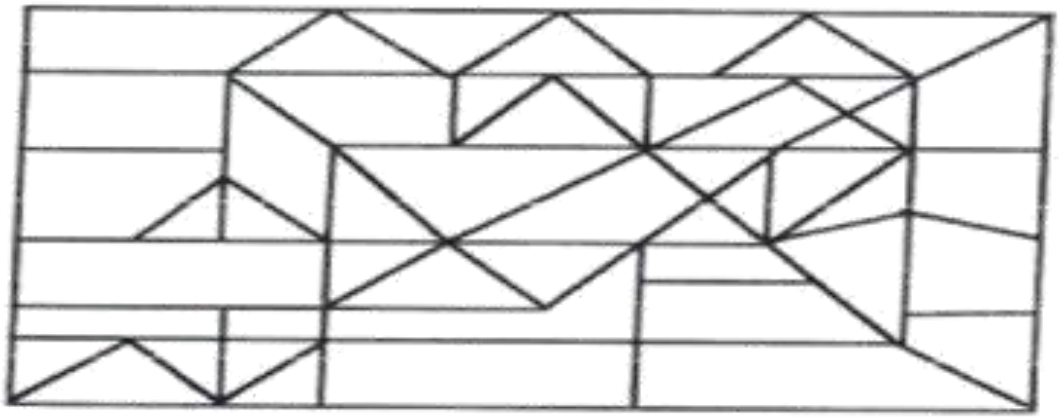




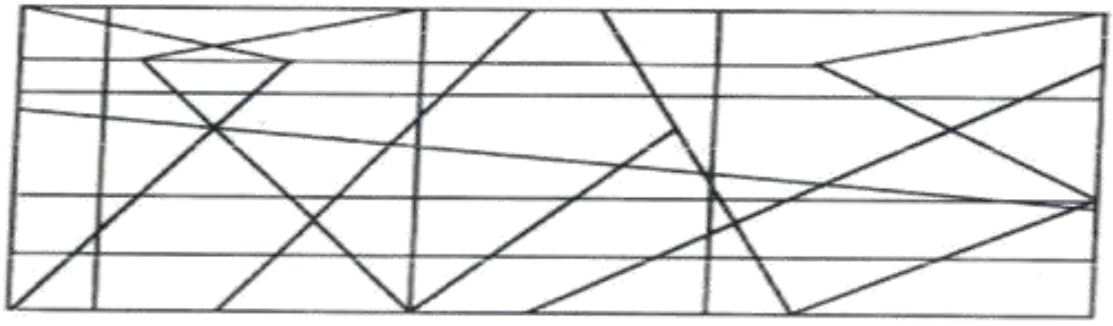
Find shape B



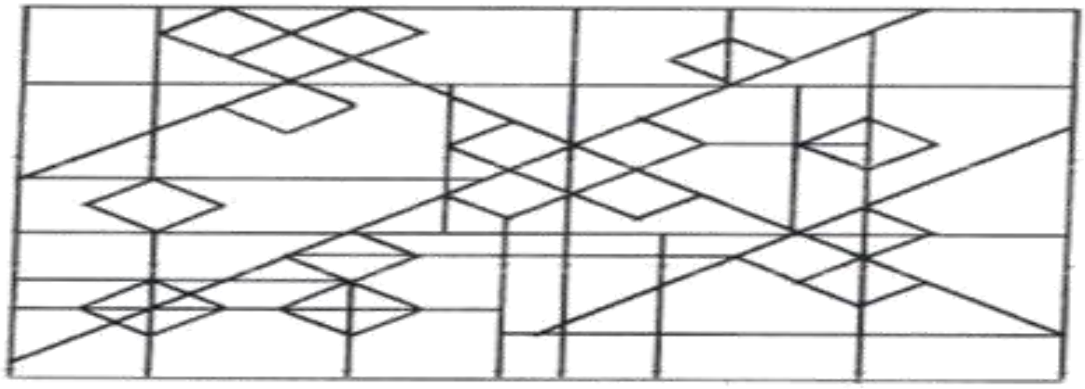
Find shape D



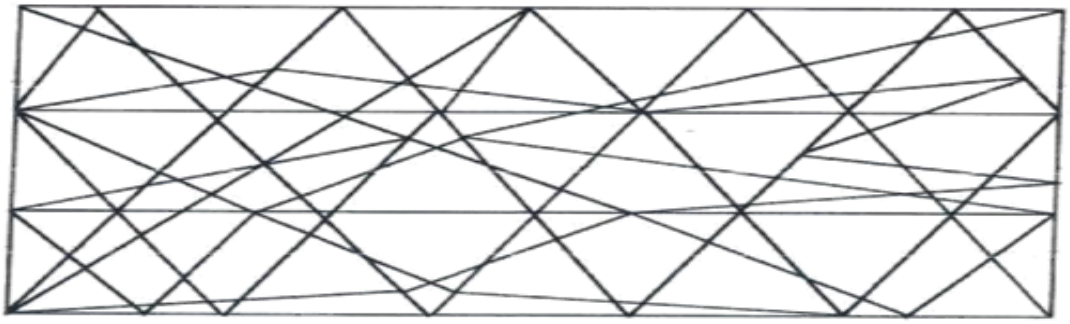
Find shape H



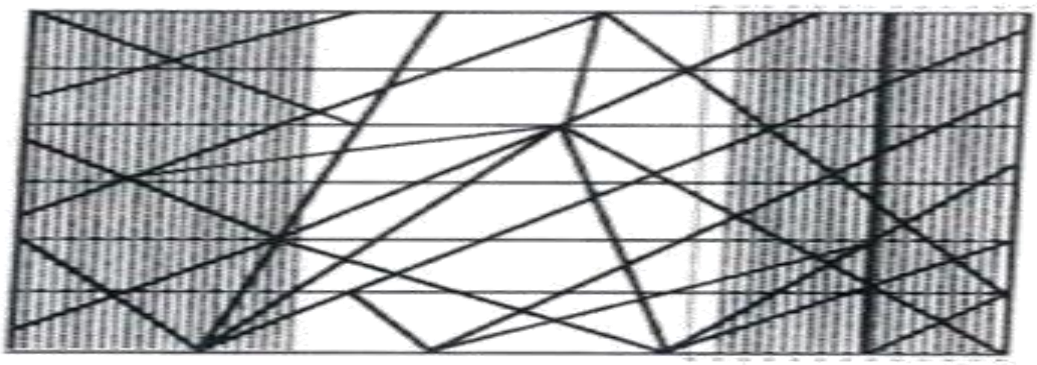
Find shape E



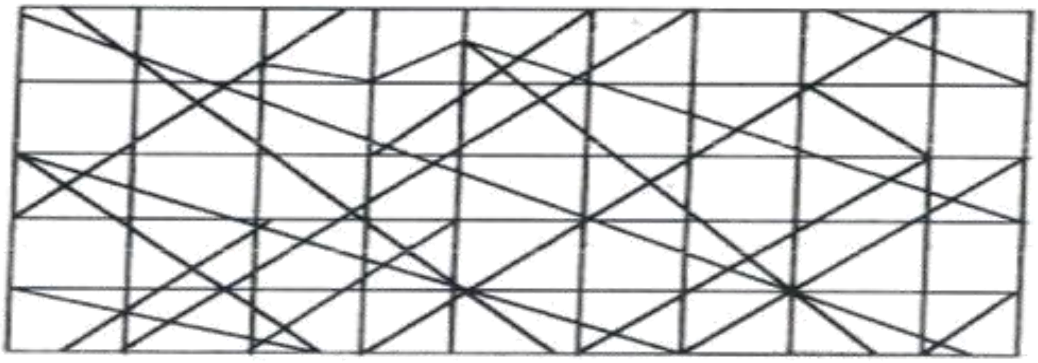
Find shape F



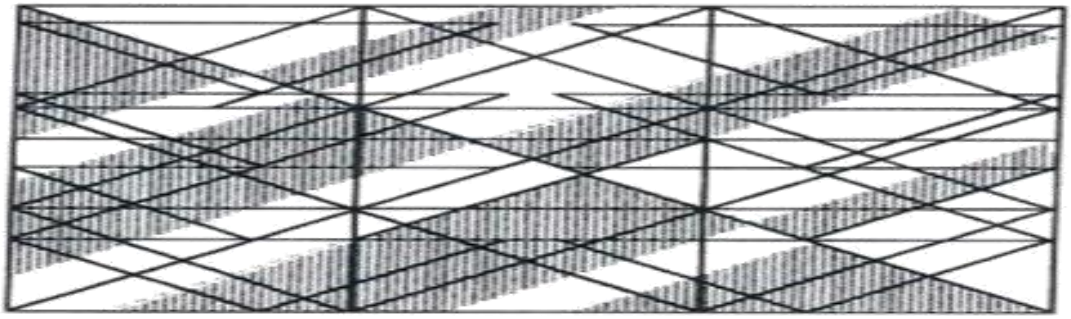
Find shape A



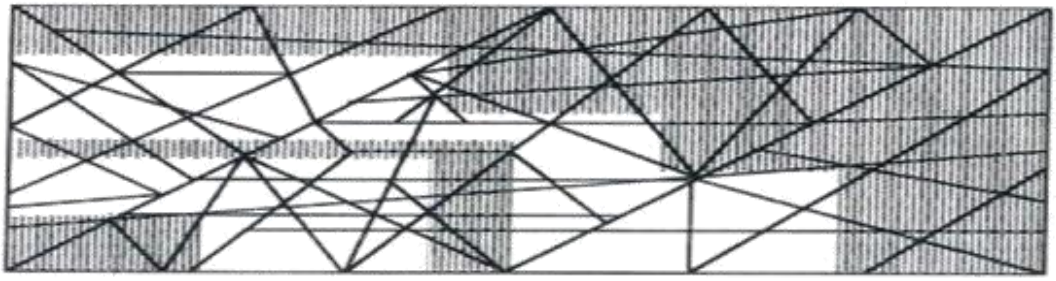
Find shape E



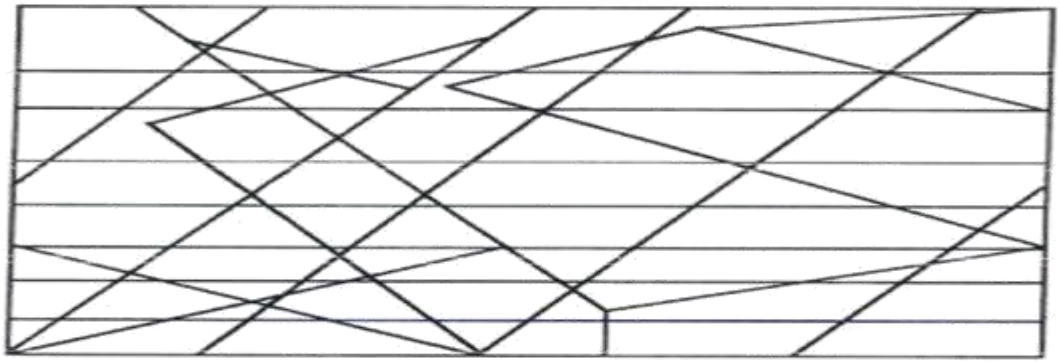
Find shape H



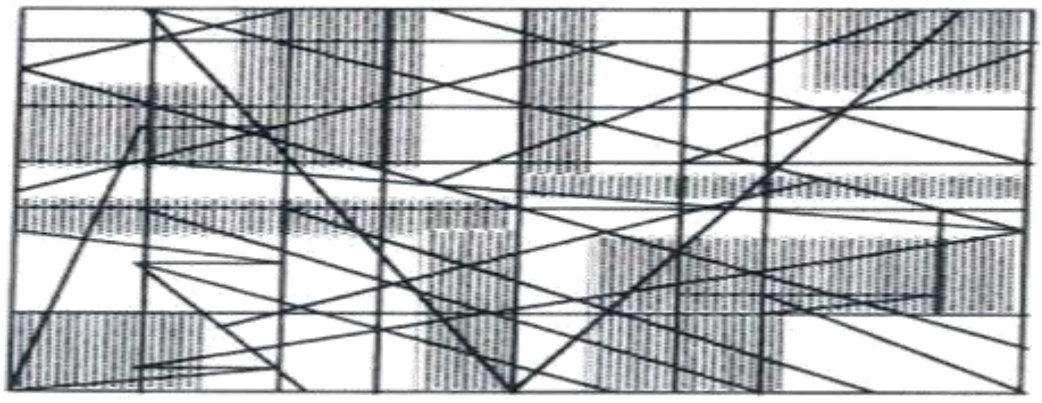
Find shape D



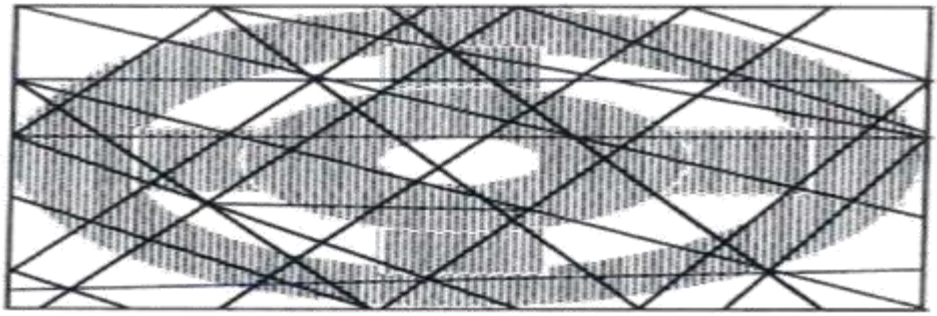
Find shape G



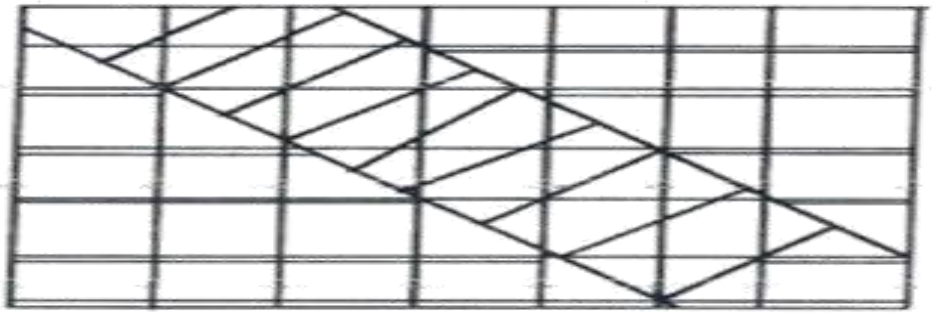
Find shape C



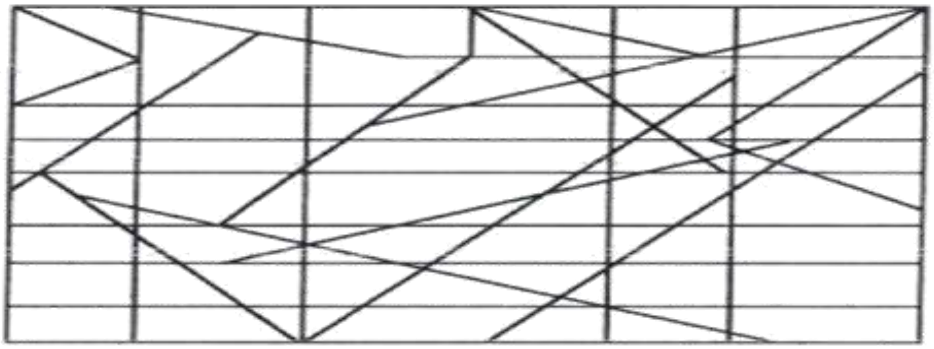
Find shape B



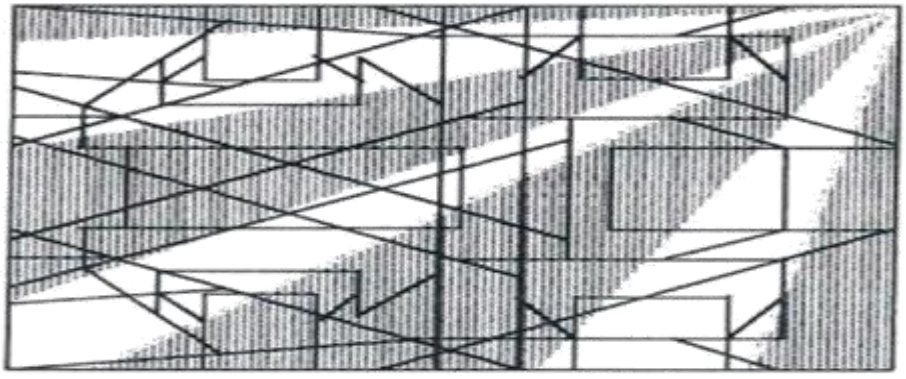
Find shape G



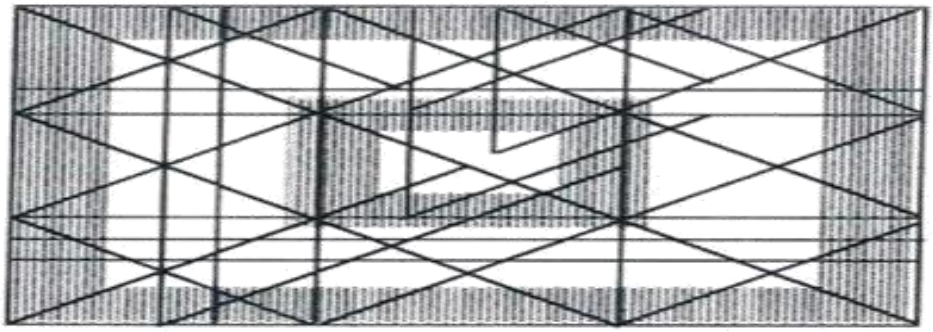
Find shape H



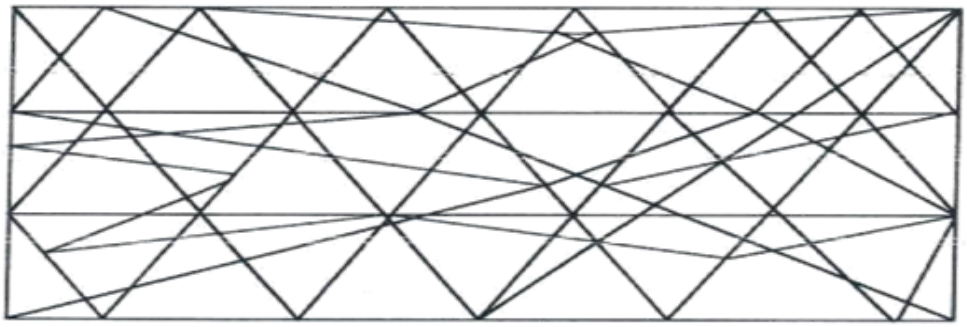
Find shape C



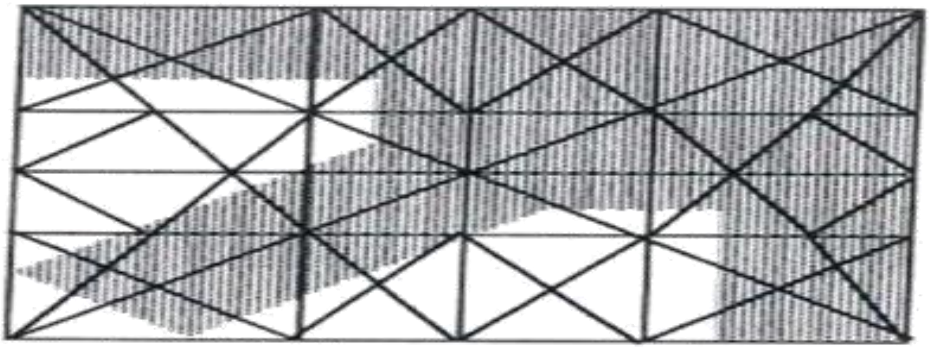
Find shape B



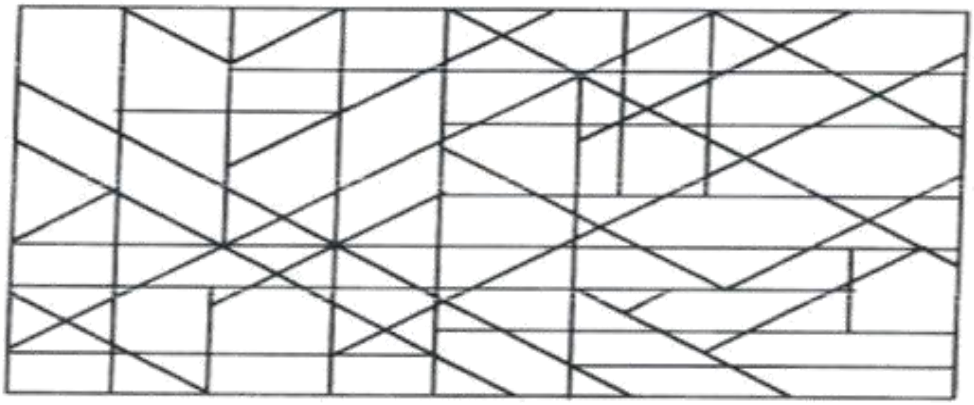
Find shape D



Find shape A



Find shape E



Find shape F

Appendix J

Item Analysis Table of CDPT

S/N	Item Difficulty (p) $p = \frac{R}{T} \times 100$	Discrimination Index (D) $D = \frac{R_U - R_L}{\frac{1}{2}T}$	Decision
1	97	0.06	Restructured
2	86	0.27	√
3	88	0.24	√
4	82	0.36	√
5	92	0.15	Restructured
6	83	0.33	√
7	76	0.36	√
8	17	0.18	Restructured
9	67	0.30	√
10	80	0.33	√
11	65	0.27	√
12	52	0.36	√
13	62	0.42	√
14	77	0.46	√
15	67	0.42	√
16	74	0.27	√
17	73	0.33	√
18	17	0.15	Restructured
19	64	0.33	√
20	88	0.18	√
21	83	0.21	√
22	99	0.03	Restructured
23	65	0.33	√
24	58	0.27	√
25	32	0.30	√
26	89	0.21	√
27	41	0.39	√
28	53	0.49	√
29	61	0.36	√
30	70	0.33	√
31	79	0.30	√
32	85	0.27	√
33	55	0.39	√
34	65	0.36	√
35	86	0.27	√
36	44	0.52	√
37	70	0.27	√
38	39	0.42	√
39	50	0.39	√
40	60	0.33	√
41	80	0.24	√

S/N	Item Difficulty (p) $p = \frac{R}{T}$ X 100	Discrimination Index (D) $D = \frac{R_U - R_L}{\frac{1}{2}T}$	Decision
42	71	0.33	√
43	59	0.42	√
44	64	0.46	√
45	73	0.36	√
46	82	0.27	√
47	67	0.30	√
48	96	0.09	Restructured
49	53	0.30	√
50	62	0.27	√
51	56	0.42	√
52	52	0.24	√
53	65	0.49	√
54	74	0.36	√
55	85	0.24	√
56	19	0.06	Restructured
57	77	0.33	√

Note. p = difficulty index; R = number of students that got the item correctly; T = total number of students; D = discrimination index; R_U = number of students in the upper third that got the item correctly; R_L = number of students in the lower third that got the item correctly; $\frac{1}{2}T$ = total number of students in the upper or lower third; √ = accepted questions.

Item Difficulty (p)	Range of values	Item Discrimination (D)	Range of values
Easy items	> 90%	Very good	> 0.40
Moderate item	20% - 90%	Reasonably good	0.30 – 0.39
Difficult	< 20%	Marginal	0.20-0.29
		Poor	< 0.19

Source: Adapted from "Item analysis of student comprehensive test for research in teaching beginner string ensemble using model-based teaching among music students in public universities," by S. Sabri, 2013, *International Journal of Education and Research, 1*, p. 4.

Appendix K

Distractor Analysis of the CDPT

Item	Group	Options			
		A	B	C	D
1	Upper	0	1	*32	0
	Lower	0	1	30	0
2	Upper	1	2	0	*30
	Lower	2	3	1	27
3	Upper	*29	4	0	0
	Lower	29	4	0	0
4[a]	Upper	*15	0	0	**18**
	Lower	7	0	0	**26**
5	Upper	*33	0	0	0
	Lower	28	0	1	4
6	Upper	*33	0	0	0
	Lower	22	4	0	7
7	Upper	*32	0	0	1
	Lower	17	5	2	9
8	Upper	0	0	0	*11
	Lower	10	11	13	21
9	Upper	*24	0	9	0
	Lower	9	2	21	1
10	Upper	0	0	0	*33
	Lower	0	11	2	20
11	Upper	*30	1	2	0
	Lower	10	5	15	3
12	Upper	*20	2	0	11
	Lower	13	6	1	13
13	Upper	0	1	4	*28
	Lower	1	3	16	13
14	Upper	0	0	0	*33
	Lower	12	3	0	18
15	Upper	*30	1	0	2
	Lower	14	3	1	15
16	Upper	0	*31	2	0
	Lower	4	18	9	2
17	Upper	1	*32	0	0
	Lower	13	16	4	0
18[b]	Upper	**23**	2	*6	2
	Lower	**21**	3	5	4
19	Upper	0	*28	5	0
	Lower	3	14	16	0
20	Upper	0	0	0	*33
	Lower	8	0	0	25

Item	Group	Options			
		A	B	C	D
21	Upper	1	0	*32	0
	Lower	7	2	23	1
22	Upper	0	*33	0	0
	Lower	0	32	1	0
23	Upper	*26	4	0	3
	Lower	17	13	1	2
24	Upper	6	1	*24	2
	Lower	12	3	14	4
25	Upper	6	7	5	*15
	Lower	9	8	10	6
26	Upper	0	0	0	*33
	Lower	1	6	0	26
27	Upper	5	*21	6	1
	Lower	11	8	9	5
28	Upper	*22	0	0	11
	Lower	13	3	1	16
29	Upper	3	0	*26	4
	Lower	7	1	14	11
30	Upper	0	3	*29	1
	Lower	1	12	17	3
31	Upper	*31	0	0	2
	Lower	21	2	1	9
32	Upper	0	*32	0	1
	Lower	0	24	3	6
33	Upper	0	5	3	*25
	Lower	1	13	8	11
34	Upper	0	6	*27	0
	Lower	1	14	15	3
35	Upper	0	0	*33	0
	Lower	3	6	24	0
36	Upper	*22	7	3	1
	Lower	7	12	10	4
37	Upper	3	0	0	*30
	Lower	11	5	1	16
38	Upper	2	7	5	*19
	Lower	4	13	9	7
39	Upper	*21	1	8	3
	Lower	12	2	14	5
40	Upper	0	*27	0	6
	Lower	1	14	7	11
41	Upper	*32	1	0	0
	Lower	21	4	8	0
42	Upper	0	3	*29	1
	Lower	1	8	18	6

Item	Group	Options			
		A	B	C	D
43	Upper	5	*26	1	1
	Lower	16	13	3	1
44	Upper	3	1	*28	1
	Lower	12	3	14	4
45	Upper	*31	2	0	0
	Lower	18	12	2	1
46	Upper	0	*33	0	0
	Lower	10	21	0	2
47	Upper	6	*27	0	0
	Lower	14	17	1	1
48	Upper	0	0	0	*33
	Lower	3	0	0	30
49	Upper	*26	7	0	0
	Lower	9	14	0	10
50	Upper	*27	2	0	4
	Lower	14	4	2	13
51	Upper	*25	3	4	1
	Lower	12	4	15	2
52	Upper	6	4	*23	0
	Lower	11	11	11	0
53	Upper	2	0	3	*28
	Lower	4	1	13	15
54	Upper	*30	3	0	0
	Lower	19	10	1	3
55	Upper	*32	0	0	1
	Lower	24	1	0	8
56[c]	Upper	0	**16**	3	*14
	Lower	1	**21**	9	2
57	Upper	0	*29	3	1
	Lower	2	18	11	2

Note. * = correct options

[a]Distractor 'D' of question 4 was confusing and was restructured from vacuoles to large cell vacuoles. [b]Distractor 'A' of question 18 was confusing and was restructured from chromatids arrives at opposite poles to chromatids starts to move to opposite poles. [c]Distractor 'B' of question 56 was confusing and was restructured from chromatin to chromosome.

Appendix L

UNIVERSITY OF ILORIN, ILORIN, NIGERIA
FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE EDUCATION

Research Assistant Informed Consent Form

Dear Sir/Ma

You have been chosen to participate in a research study. However, your consent is required to take part in the study. Comprehensive information about the research is provided below. If you are willing to participate in the study, kindly endorse this consent form after reading about the research.

Purpose of the Research: the purpose of the research is to determine the effects of modelling clay and demonstration kit on senior school students' performance in cell division in Omu-Aran, Nigeria, as parts of efforts to promote meaningful learning of biology aimed at enhancing students' performance.

Procedure: student participants will be required to attend series of class lessons on cell division. The lessons will take place during the periods allocated to biology on the class timetable. The lessons will last for two weeks only, after which student participants will be required to write a performance test on the topic learnt.

Anonymity: the names of the participating schools, as well as your identity, will not be disclosed at any point in this study.

Confidentiality: all information provided by you will be treated with utmost confidentiality and used for the purpose of the research only.

Risk: the procedure will take place in the school within the school hours. Therefore, no risk is envisaged to you as a person during the research.

Benefit: Your participation would offer you a chance to understand study technology tools that could improve students' achievement and interest in different biology concepts in both internal and external examinations.

Right of Volunteers: Your participation in this research is voluntary. Hence, if you decide not to take part or stop your participation in the research at any time, it will not affect your personality. If you have any question about this research, you may contact the Department of Science Education, Faculty of Education, University of Ilorin, Ilorin, Nigeria or call the researcher on cell phone number 08062624181.

Teacher's Agreement: I hereby voluntarily consent to participate in the research. I am aware I may refuse to participate or opt out of the study at any time. Also, I understand that if I have any question about the research or my right as a student participant, I may contact the Department of Science Education, Faculty of Education, University of Ilorin, Ilorin, Nigeria, or call the researcher on the cell phone number 08062624181.

Subject Teacher	Signature	12-10-2018 Date
HOD	Signature	12/10/2018 Date
ADEOYE, G. A. Researcher	Signature	12/10/2018 Date

OMU - ARAN, KWARA STATE
PRINCIPAL
Date 12/10/2018

Appendix M

UNIVERSITY OF ILORIN, ILORIN, NIGERIA
FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE EDUCATION

Student's Informed Consent Form

Dear Student,

You are selected to participate in a research. However, your consent is required to take part in the study. Detailed information about the research is provided in this form. Kindly endorse this consent form if you volunteer to participate in the study after reading about the research.

Purpose of the Research: The purpose of the research is to determine the effects of modelling clay and demonstration kit on senior school students' performance in cell division in Omu-Aran, Nigeria, as parts of efforts to promote meaningful learning of biology aimed at enhancing students' performance.

Procedure: Student participants will be required to attend series of class lessons on cell division, using either of playdough, demonstration kit or conventional method. The lessons will take place during the periods allocated to biology on the class timetable and will be handled by your biology teachers, who will serve as Research Assistants. The lessons will last for two weeks only, after which student participants will be required to write a performance test on the topic learnt.

Anonymity: The names of the participating schools, as well as the identity of the respondents, will not be disclosed at any point in this study.

Confidentiality: All information provided by you will be treated with utmost confidentiality and used for the purpose of the research only.

Risks: The health risk of using modelling clay such as gastrointestinal offset due to the ingestion of small parts and dirt will be avoided by using non-toxic playdough made

from flour and washing of hands after each lesson. The risk associated with the use of demonstration kit such as cut from sharp parts which may cause infection will be avoided by not allowing students to share the items in the demonstration kit and through proper guidance of the students.

Benefit: The likely benefits to you include meaningful learning of cell division and other related concepts in biology. You are likely to obtain a good grade in biology in the West African Senior School Certificate Examinations and other examinations required for admission into University.

Rights of Volunteers (Student Participants): Your participation in this research is voluntary. Hence, if you decide not to take part or stop your participation in the research at any time, it will not affect your personality. If you have any question about this research, you may contact the Department of Science Education, Faculty of Education, University of Ilorin, Ilorin, Nigeria or call the researcher on cell phone number 08062624181.

Student Respondent Agreement: I hereby voluntarily consent to participate in the research. I am aware I may refuse to participate or opt out of the study at any time. Also, I understand that if I have any question about the research or my right as a student participant, I may contact the Department of Science Education, Faculty of Education, University of Ilorin, Ilorin, Nigeria, or call the researcher on the cell phone number 08062624181.

[redacted]	[redacted]	15-10-2018
Student Participant	Signature	Date
[redacted]	[redacted]	15/10/2018
Student Parent/Guardian	Signature	Date
ADEOYE, G. A.	[redacted]	16/10/2018
Researcher	Signature	Date

Appendix N

Lesson Plan

Experimental Group One

Week One

Name: ADEOYE, Gabriel Ademakinwa

Matric. No.: 04/25OC068

Class: SSS 2

Subject: Biology

Lesson Topic: Mitosis

Duration: 80 minutes. **Date**:

Period: **Time**:

Average Age of Students: 14 years.

Instructional Materials: modelling clay, course guide, biology textbooks and dictionaries.

References:

Michael, M. C. (2017). *Essential biology for senior secondary school.* Ibafo: Tonad Publisher Limited.

Ramalingam, S. T. (2013). *Modern biology for senior secondary schools* (6th ed.). Onitsha: Africana First Publishers Plc.

Objectives: At the end of the lesson, students should be able to:

(i) define the terms mitosis

(ii) mention all the mitotic cell division stages in the hierarchical order

(iii) illustrate the events occurring at the different stages of mitosis using the modelling clay;

(iv) state the site of mitosis in plants and animals.

Entry Behaviour: The students are already familiar with some of the terms related to cell division.

Introduction (5mins): The teacher drills the students on their previous knowledge by asking the following questions;

(i) what is a cell?

(ii) what is the name of the organelle that controls all the activities of the cell?

(iii) state the location of the nucleolus and chromatin in a cell?

(iv) what are centrioles?

Presentation (66mins)

Step 1 (10mins): the teacher writes the lesson topic on the chalkboard and gives each student the course guide. The students are allowed to pair up and sit down quietly. The teacher refers the students to the modelling clay already provided on the tables and briefly describe its usage in teaching and learning. The teacher then directs each pair of the student to follow the course guide procedure in the use of modelling clay for learning mitosis. The teacher refrains from giving answers to students but provides guidance when necessary.

How to use modelling clay for learning

- students open their textbooks and read through a given concept or process taking note of the keywords;
- the students make a model of such concept or process using the modelling clay and labelling every part correctly and show their partners;
- If only one study partner understands he/she guides the other partner to re-study the material;

- when the two study partners have understood the material being studied based on their modelling clay demonstrations, they both append their signatures while the teacher come over and access their demonstrations.

Step 2 (10mins): students open their textbooks to appropriate pages on mitosis and read the meaning. Each student then demonstrates the meaning with modelling clay and show it to their partner. Students also take cognisance of the site of mitosis in plants and animals.

Step 3 (36mins): students open their biology textbooks to the appropriate pages on the stages of mitosis (for instance, pages 55 – 60 in Essential Biology for Senior Secondary Schools by Michael, M. C.) and read the different stages and demonstrate the processes taking place at each stage with the modelling clay. Both partners show their demonstrations to each other and append their signature to show mastery.

Step 4 (5mins): students who experience difficulties in the use of modelling clay for learning mitosis are guided by the teacher on its usage.

Recapitulation (5mins): the teacher answer questions raised by the students in the cause of using the modelling clay and give further explanations where necessary

Evaluation (5mins): the students solve the following questions in order to test their understanding of the topic;

(i) define the term mitosis

(ii) state the site where mitosis occurs in plants and animals

(iii) describe the third stage of mitotic cell division using modelling clay

(iv) how many daughter cells are produced after mitosis

(v) the diploid number of chromosomes in mitosis is depicted by _____

Assignment (4mins):

(1) Differentiate between cell enlargement and cell differentiation.

(2) Enumerate three importance of mitosis.

(3) List all the stages of meiotic cell division.

Teacher's Evaluation of the Lesson:

Week Two

Name: ADEOYE, Gabriel Ademakinwa

Matric. No.: 04/25OC068

Class: SSS 2

Subject: Biology

Lesson Topic: Meiosis

Duration: 80 minutes. **Date**:

Period: **Time**:

Average Age of Students: 14 years.

Instructional Materials: modelling clay, course guide, biology textbooks and dictionaries.

References:

Michael, M. C. (2017). *Essential biology for senior secondary school.* Ibafo: Tonad Publisher Limited.

Ramalingam, S. T. (2013). *Modern biology for senior secondary schools* (6^{th} ed.). Onitsha: Africana First Publishers Plc.

Objectives: At the end of the lesson, students should be able to:

(i) define the terms meiosis

(ii) mention all the meiotic cell division stages in hierarchical order

(iii) illustrate the events occurring at the different stages of meiosis using modelling clay;

(iv) state the site of meiosis in plants and animals.

Entry Behaviour: The students had learnt mitosis.

Introduction (5mins): The teacher drills the students on their previous knowledge by asking the following questions;

(i) define the term mitosis

(ii) mention all the mitotic cell division stages in the hierarchical order

(iii) use the modelling clay to show the telophase stage of mitotic cell division

(iv) how many daughter cells are produced after mitosis

Presentation (65mins)

Step 1 (6mins): the teacher writes the lesson topic on the chalkboard and give each student the course guide. The students pair up and sit down quietly. The teacher refers the students to the modelling clay already provided on the tables, briefly describe how it can be used for learning. The teacher then directs each pair of student to follow the course guide procedure in their use of modelling clay for learning meiosis. The teacher refrains from giving answers to students but provides guidance when necessary.

Step 2 (7mins): students open their textbooks to appropriate pages on meiosis and read the meaning. Each student then demonstrates the meaning with the modelling clay and show it to their partner. Students take cognisance of the site of mitosis in plants and animals.

Step 3 (43mins): students open their biology textbooks to the appropriate pages on the first and second meiotic division (for instance, pages 58-60 in Essential Biology for Senior Secondary Schools by Michael, M. C.). They read the different stages and demonstrate the processes taking place at each stage with the modelling clay. Both partners show their demonstrations to each other and append their signatures to show mastery.

Step 4 (5mins): students who experience difficulties in the use of modelling clay for learning meiosis are guided by the teacher on its usage.

Recapitulation (4mins): the teacher answer questions raised by the students in the cause of using the modelling clay and give further explanations where necessary

Evaluation (6mins): the students solve the following questions in order to test their understanding of the topic;

(i) define the term meiosis

(ii) state the site where meiosis occurs in plants and animals

(iii) describe the third stage of meiotic cell division using modelling clay

(iv) at which stage does crossing over occurs

(v) how many daughter cells are produced after meiosis

(vi) the haploid number of chromosomes in meiosis is depicted by _____

Assignment (4mins):

(1) Enumerate four importance of meiosis.

(2) In a tabular form differentiate between mitosis and meiosis.

Teacher's Evaluation of the Lesson:

Experimental Group Two

Week One

Name: ADEOYE, Gabriel Ademakinwa

Matric. No.: 04/25OC068

Class: SSS 2

Subject: Biology

Lesson Topic: Mitosis

Duration: 80 minutes. **Date**:

Period: **Time**:

Average Age of Students: 14 years.

Instructional Materials: demonstration kit, course guide, biology textbooks and dictionaries.

References:

Michael, M. C. (2017). *Essential biology for senior secondary school.* Ibafo: Tonad Publisher Limited.

Ramalingam, S. T. (2013). *Modern biology for senior secondary schools* (6^{th} ed.). Onitsha: Africana First Publishers Plc.

Objectives: At the end of the lesson, students should be able to:

(i) define the terms mitosis

(ii) mention all the mitotic cell division stages in the hierarchical order

(iii) illustrate the events occurring at the different stages of mitosis using demonstration kit

(iv) state the site of mitosis in plants and animals

Entry Behaviour: The students are already familiar with some of the terms related to cell division.

Introduction (5mins): The teacher drills the students on their previous knowledge by asking the following questions;

(i) what is a cell?

(ii) what is the name of the organelle that controls all the activities of the cell?

(iii) state the location of the nucleolus and chromatin in a cell?

(iv) what are centrioles?

Presentation (66mins)

Step 1 (10mins): the teacher writes the lesson topic on the chalkboard and gives each student the course guide. The students are allowed to pair up and sit down quietly. The teacher refers the students to the demonstration kit already provided on the tables, briefly describe how it can be used for learning. The teacher then directs each pair of student to follow the course guide procedure in the use of demonstration kit for learning mitosis. The teacher refrains from giving answers to students but provides guidance when necessary.

How to use the demonstration kit for learning

- Identify the words of significance in the content being studied
- Pick different items from the demonstration kit and use it to represent each keyword
- Pick other items to represent the linking words or expressions
- Read through the content being studied again and use the demonstration kit to show it
- Show the demonstration to your partner and append your signatures to indicate mastery

Step 2 (10mins): students open their textbooks to appropriate pages on mitosis and read the meaning. Each student then demonstrates the meaning with the

demonstration kit and show it to their partner. Students also take cognisance of the site of mitosis in plants and animals.

Step 3 (36mins): students open their biology textbooks to the appropriate pages on the stages of mitosis (for instance, pages 55 – 60 in Essential Biology for Senior Secondary Schools by Michael, M. C.) and read the different stages and demonstrate the processes taking place at each stage with demonstration kit. Both partners describe their demonstrations to each other and append their signature to indicate mastery.

Step 4 (5mins): students who experience difficulties in the use of demonstration kit for learning mitosis are guided by the teacher on its usage.

Recapitulation (5mins): the teacher answer questions raised by the students in the cause of using the demonstration kit and give further explanations where necessary

Evaluation (5mins): the students solve the following questions in order to test their understanding of the topic;

(i) define the term mitosis

(ii) state the site where mitosis occurs in plants and animals

(iii) describe the third stage of mitotic cell division using modelling clay

(iv) how many daughter cells are produced after mitosis

(v) the diploid number of chromosomes in mitosis is depicted by _____

Assignment (4mins):

(1) Differentiate between cell enlargement and cell differentiation.

(2) Enumerate three importance of mitosis.

(3) List all the stages of meiotic cell division.

Teacher's Evaluation of the Lesson:

Week Two

Name: ADEOYE, Gabriel Ademakinwa

Matric. No.: 04/25OC068

Class: SSS 2

Subject: Biology

Lesson Topic: Meiosis

Duration: 80 minutes. **Date**:

Period: **Time**:

Average Age of Students: 14 years.

Instructional Materials: demonstration kit, course guide, biology textbooks and dictionaries.

References:

Michael, M. C. (2017). *Essential biology for senior secondary school.* Ibafo: Tonad Publisher Limited.

Ramalingam, S. T. (2013). *Modern biology for senior secondary schools* (6^{th} ed.). Onitsha: Africana First Publishers Plc.

Objectives: At the end of the lesson, students should be able to:

(i) define the terms meiosis

(ii) mention all the meiotic cell division stages in the hierarchical order

(iii) illustrate the events occurring at the different stages of meiosis using demonstration kit;

(iv) state the site of meiosis in plants and animals.

Entry Behaviour: The students had been learnt mitosis.

Introduction (5mins): The teacher drills the students on their previous knowledge by asking the following questions;

(i) define the term mitosis

(ii) mention all the mitotic cell division stages in the hierarchical order

(iii) use the demonstration kit to show the telophase stage of mitotic cell division

(iv) how many daughter cells are produced after mitosis

Presentation (65mins)

Step 1 (6mins): the teacher writes the lesson topic on the chalkboard and give each student the course guide. The students pair up and sit down quietly. The teacher refers the students to the demonstration kit already provided on the tables, briefly describe how it can be used for learning. The teacher then directs each pair of student to follow the course guide procedure in their use of demonstration kit for learning meiosis. The teacher refrains from giving answers to students but provides guidance when necessary.

Step 2 (7mins): students open their textbooks to appropriate pages on meiosis and read the meaning. Each student then demonstrates the meaning with the demonstration kit taking and show it to their partner. Students take cognisance of the site of mitosis in plants and animals.

Step 3 (43mins): students open their biology textbooks to the appropriate pages on the first and second meiotic division (for instance, pages 58-60 in Essential Biology for Senior Secondary Schools by Michael, M. C.). They read on the different stages and demonstrate the processes taking place at each stage with the demonstration kit. Both partners show their demonstrations to each other and append their signatures to show mastery.

Step 4 (5mins): students who experience difficulties in the use of demonstration kit for learning meiosis are guided by the teacher on its usage.

Recapitulation (4mins): the teacher answer questions raised by the students in the cause of using the demonstration kit and give further explanations where necessary

Evaluation (6mins): the students solve the following questions in order to test their understanding of the topic;

(i) define the term meiosis

(ii) state the site where meiosis occurs in plants and animals

(iii) describe the third stage of meiotic cell division using modelling clay

(iv) at which stage does crossing over occurs

(v) how many daughter cells are produced after meiosis

(vi) the haploid number of chromosomes in meiosis is depicted by _____

Assignment (4mins):

(1) Enumerate four importance of meiosis.

(2) In a tabular form differentiate between mitosis and meiosis.

Teacher's Evaluation of the Lesson:

Control Group

Week One

Name: ADEOYE, Gabriel Ademakinwa

Matric. No.: 04/25OC068

Class: SSS 2

Subject: Biology

Lesson Topic: Mitosis

Duration: 80 minutes. **Date**:

Period: **Time**:

Average Age of Students: 14 years.

Instructional Materials: cut tip of a flowering plant, onion bulb and biology textbooks

References:

Michael, M. C. (2017). *Essential biology for senior secondary school.* Ibafo: Tonad Publisher Limited.

Ramalingam, S. T. (2013). *Modern biology for senior secondary schools* (6^{th} ed.). Onitsha: Africana First Publishers Plc.

Objectives: At the end of the lesson, students should be able to:

(i) define the terms mitosis

(ii) mention all the mitotic cell division stages in the hierarchical order

(iii) illustrate the events occurring at the different stages of mitosis

(iv) identify the site where mitosis takes place in plant and animal.

Entry Behaviour: The students are already familiar with some of the terms related to cell division

Introduction (8mins): The teacher drills the students on their previous knowledge by asking the following questions;

(i) what is a cell?

(ii) what is the name of the organelle that controls all the activities of the cell?

(iii) state the location of the nucleolus and chromatin in a cell?

(iv) what are centrioles?

Presentation (56mins)

Step 1 (10mins): the teacher writes the lesson topic on the chalkboard and define the term mitosis and state the site where it occurs in plants and animals. The teacher also uses the instructional materials to explain the site of mitosis in plants.

Mitosis is a cell or nuclear division which takes place during growth and development. It takes place in the body or somatic cells yielding two daughter cells only. This type of cell division may occur in connection with growth or in unicellular organisms e.g. Amoeba, Euglena, etc. In plants, mitosis occurs only in cells located at the tips of shoots and roots, in the cambium, or in other specific parts. Mitosis produces a diploid number of cells (2n) in an organism.

Step 2 (5mins): the teacher lists all the stages of mitotic division on the chalkboard.

Mitosis can be divided into the following sequential stages; prophase, metaphase, anaphase and telophase.

Step 3 (35mins): the teacher explains the different stages of mitotic cell division and also direct the students to their textbooks for the diagrammatic representation of the process taking place at each of the stages.

Stages of Mitosis

Prophase: this stage signifies the beginning of cell division processes. It can be divided into the early and late prophase. At the early Prophase, the chromosomes become visible as they contract and the nucleolus shrink. The centrioles are formed at opposite sides of the nucleus and the spindle fibres start to form. During the late

prophase, the chromosomes are seen to be composed of two strands chromatids held together by the centromere.

Metaphase: metaphase is the second stage of mitotic cell division where the chromosome connected by the spindle fibres lies at the equatorial plane.

Anaphase: this is the third stage of mitotic cell division where the chromosome separates at the centromere into two chromatids and migrate to opposite poles.

Telophase: this is the end of nuclear division (mitosis) which is followed by cytoplasmic division thereby leading to the formation of a diploid number of cells (**2n**). Chromatids arrive at the poles, spindle gradually disappears, nuclear membrane forms around each set of chromatids and the chromatids gradually become invisible.

Recapitulation (6mins): the teacher goes over the lesson again explaining the salient points

Evaluation (10mins): the teacher asks the following questions from the students to test their understanding of the topic;

(i) define the term mitosis

(ii) state the site where mitosis occurs in plants and animals

(iii) describe the third stage of mitotic cell division using modelling clay

(iv) how many daughter cells are produced after mitosis

(v) the diploid number of chromosomes in mitosis is depicted by _____

Assignment (6mins):

(1) Differentiate between cell enlargement and cell differentiation.

(2) Enumerate three importance of mitosis.

(3) List all the stages of meiotic cell division.

Teacher's Evaluation of the Lesson:

Week Two

Name: ADEOYE, Gabriel Ademakinwa

Matric. No.: 04/25OC068

Class: SSS 2

Subject: Biology

Lesson Topic: Meiosis

Duration: 80 minutes. **Date**:

Period: **Time**:

Average Age of Students: 14 years.

Instructional Materials: hibiscus flower and biology textbooks

References:

Michael, M. C. (2017). *Essential biology for senior secondary school.* Ibafo: Tonad Publisher Limited.

Ramalingam, S. T. (2013). *Modern biology for senior secondary schools* (6^{th} ed.). Onitsha: Africana First Publishers Plc.

Objectives: At the end of the lesson, students should be able to:

(i) define the terms meiosis

(ii) mention all the meiotic cell division stages in the hierarchical order

(iii) illustrate the events occurring at the different stages of meiosis

(iv) state the site of meiosis in plants and animals.

Entry Behaviour: The students had learnt mitosis.

Introduction (6mins): The teacher drills the students on their previous knowledge by asking the following questions;

(i) define the term mitosis

(ii) mention all the mitotic cell division stages in the hierarchical order

(iii) describe the telophase stage of mitotic cell division

(iv) how many daughter cells are produced after mitosis

Presentation (61mins)

Step 1 (10mins): the teacher writes the lesson topic on the chalkboard and define the term meiosis and state the site where it occurs in plants and animals. The teacher also uses the instructional materials to explain the site of meiosis in plants.

Meiosis is a form of cell division that leads to the formation of haploid number of cells. It is also called reduction division. Unlike mitosis, meiosis occurs in the reproductive cells of plants and animals. Meiosis consists of two successive cell division: the first meiotic division also called reduction division and second meiotic division which is similar to mitosis.

Step 2 (5mins): the teacher lists all the stages of meiotic division on the chalkboard

Meiosis can be divided into two main stages; the first and second meiotic divisions which are composed of the following stages first meiotic - prophase, metaphase, anaphase and telophase. There is also the second meiotic - prophase, metaphase, anaphase and telophase.

Step 3 (25mins): the teacher explains the stages of first mitotic division and also direct the students to their textbooks for the diagrammatic representation of the process taking place at each of the stages

First Meiotic Division or Reduction Division

First Meiotic Prophase: Chromosomes become visible, homologous chromosomes lie side by side forming a bivalent, the chromatids may become joined at a point called chiasmata and when they separate portions of chromatids may have been swapped (crossing over).

First Meiotic Metaphase: The nuclear membrane disappears and the chromosomes connected by the spindle fibres lies at the equator.

First Meiotic Anaphase: Each member of the bivalent chromosomes moves apart towards the poles in different directions. The spindle also becomes shortened.

First Meiotic Telophase: Chromatids arrive at the poles, spindle gradually disappears, nuclear membrane forms around each group of chromatids and the chromatids becomes visible as threadlike structures.

Step 4 (16mins): the teacher explains the stages of second mitotic division and also direct the students to their textbooks for the diagrammatic representation of the process taking place at each of the stages

Second Meiotic Division or Reduction Division

Second Meiotic Prophase: Chromosomes become visible in the two nuclei, centrioles divide and migrate to opposite poles of the cell and spindles emerges from the centrioles

Second Meiotic Metaphase: The centromere starts to divide and the chromosomes joined by the spindle fibres lies along the equatorial plane.

Second Meiotic Anaphase: The chromatids separate and are pulled by the spindle fibres towards opposite poles of the cell

Second Meiotic Telophase: The two cells are divides into four which is tetrads. New nuclear membrane is formed. Cleavage of the cytoplasm then occurs and each cell holds haploid number (n) of cells

Recapitulation (5mins): the teacher goes over the lesson again explaining the salient points

Evaluation (8mins): the teacher asks the following questions from the students to test their understanding of the topic;

(i) define the term meiosis

(ii) state the site where meiosis occurs in plants and animals

(iii) describe the third stage of meiotic cell division using modelling clay

(iv) at which stage does crossing over occurs

(v) how many daughter cells are produced after meiosis

(vi) the haploid number of chromosomes in meiosis is depicted by _____

Assignment (5mins):

(1) Enumerate four importance of meiosis.

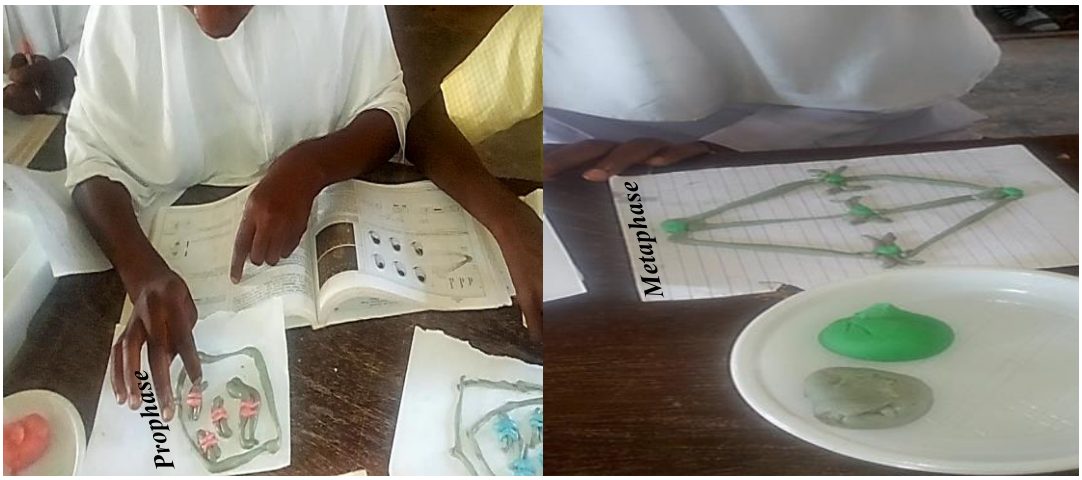
(2) In a tabular form differentiate between mitosis and meiosis.

Teacher's Evaluation of the Lesson:

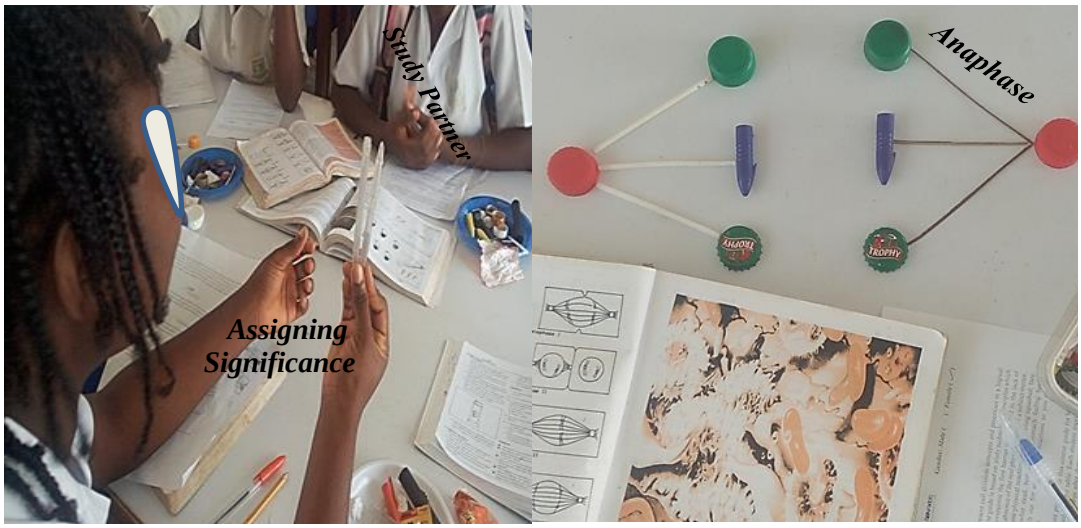
Appendix O

Students use of the Modelling Clay, Demonstration Kit, and Conventional Method for Learning Cell Division

Modelling Clay



Demonstration Kit



Conventional Method



Appendix P

Research Ethical Certificate

UNIVERSITY OF ILORIN, ILORIN, NIGERIA
UNIVERSITY ETHICAL REVIEW COMMITTEE

Vice Chancellor: Prof. S.A. Abdulkareem
B.Che, M.ChE, (Detroit); Ph.D. (Louisville),
MNAICh, MNSE, MACS, R.Eng. (COREN).
Registrar: Dr, (Mrs) F.M. Olowoleni
B.Sc (Zaria); MBA, M.Sc. PGDE (Ilorin)

E-mail: P.M.B. 1515, Ilorin
uerc@unilorin.edu.ng
unilorin.uerc@gmail.com
Website: ethicalrview.unilorin.edu.ng
www.unilorin.edu.com

Our Ref: UIL/UERC/04/25OC068

Date: 14th February, 2019

Protocol Identification Code: UERC/EDU/302
UERC Approval Number: UERC/ASN/2019/1585

EFFECTS OF MODELLING CLAY AND DEMONSTRATION KIT ON SENIOR SCHOOL STUDENTS' PERFORMANCE IN CELL DIVISION IN OMU-ARAN, NIGERIA

Name of applicant/Principal Investigator: **ADEOYE,** Gabriel Ademakinwa.
Address of Applicant: Department Science Education
Faculty of Education,
University of Ilorin, Ilorin.
Type of Review: Full Committee Review...
Date of Approval: 14/02/2019

Notice of Full Committee Approval

I am pleased to inform you that the research described in the submitted proposal has been reviewed by the University Ethical Review Committee (UERC) and given full Committee approval.

This approval dates from 14/02/2019 to 13/02/2022, and there should be no participant accrual or any activity related to this research to be conducted outside these dates.

You are requested to inform the committee at the commencement of the research to enable it appoints its representative who will ensure compliance with the approved protocol. If there is any delay in starting the research, please inform the UERC so that the dates of approval can be adjusted accordingly.

The UERC requires you to comply with all institutional guidelines and regulations and ensure that all adverse events are reported promptly to the UERC. No charges are allowed in the research without prior approval by the UERC. Please note that the UERC reserves the right to conduct monitoring/oversight visit to your research site without prior notification.

Thank You,

Ismaila Isah
For: University Ethical Review Committee

UNIVERSITY ETHICAL REVIEW COMMITTEE
University of Ilorin,
Ilorin, Nigeria

"....If it's not ethical, it's not scientific, if it's not scientific it's not ethical"

Appendix Q

Research Protocol Certificate

UNIVERSITY OF ILORIN, ILORIN, NIGERIA.

POSTGRADUATE SCHOOL

Vice-Chancellor:
Prof. S. A. AbdulKareem
B.ChE (Detroit); Ph.D. (Louisville);
MNAICh; MNSE; MACS; R.Eng (COREN)

Dean:
Prof. S. A. Bolu
B. Agric; M. Sc; Ph.D (Ilorin)
(Animal Nutrition) MNSAP, MASAN RAS.

Zahra Ishowo-Jaji House

PMB 1515, Ilorin, Nigeria.
website: www.unilorin.edu.ng
Tel: +234 903 092 4197
+234 811 114 1632
E-mail:pgschool@unilorin.edu.ng

UIL/PGS/91/42 **20th June, 2019**

ADEOYE, Gabriel Ademakinwa
Matric. No.: 04/25OC068
Department of Science Education
Faculty of Education
University of Ilorin
Ilorin.

Dear **Adeoye,**

APPROVAL OF DOCTORAL RESEARCH PROTOCOL

I am pleased to inform you that, the Board of Postgraduate School at its 279th Meeting held on Wednesday, 22nd May, 2019 considered and approved your Doctoral Research Protocol titled:

Effects of Modelling Clay and Demonstration Kit on Senior School Students' Performance in Cell Division in Omu-Aran, Nigeria

You are therefore, to proceed with your Ph.D. programme accordingly, please.

Congratulations.

Yours sincerely,

M.A. Alfanla
Secretary, Postgraduate School

MA/JB

Appendix R

Ph.D. Research Schedule and Timeline

MONTH	19/02/2017	19/03/2017	19/04/2017	19/05/2017	19/06/2017	19/07/2017	19/08/2017	19/09/2017	19/10/2017	19/11/2017	19/12/2017	19/01/2018	19/02/2018	19/03/2018	19/04/2018	19/05/2018	19/06/2018	19/07/2018	19/08/2018	19/09/2018	19/10/2018	19/11/2018	19/12/2018	19/01/2019	19/02/2019	19/03/2019	19/04/2019	19/05/2019	19/06/2019	19/07/2019	19/08/2019	19/09/2019	19/10/2019	19/11/2019	19/12/2019	19/01/2020	19/02/2020
TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Survey of Literature																																					
Write Proposal																																					
Gather Data																																					
Thesis Writing																																					
Write Introduction																																					
Revise Introduction																																					
Writing Methodology																																					
Revise Methodology																																					
Result and Discussion																																					
Revise Result and Discussion																																					
Write Conclusion																																					
Revise Conclusion																																					
Acknowledgements and Appendices																																					
Revise First Draft																																					
Proof Reading																																					
Printing and Binding																																					

Appendix S

Dissemination of Results

The findings of the study may be promulgated among stakeholders in education through the following means:

Conferences: The researcher will attend and present papers at conferences organised by professional bodies like Science Teachers Association of Nigeria (STAN), Science Association of Nigeria (SAN), and other institutionally based conferences to enlighten educators on the significance and use of modelling clay and demonstration kit for teaching and learning.

Journal Publication: The outcome of the study will be published in journal articles like STAN, SAN, and the Journal of Research in Education which is the official journal of the Collaboration of Education Faculties in West Africa (CEFWA), among others.

Seminars: The researcher will organise workshops for secondary school teachers and students on the use of modelling clay and demonstration kit for classroom teaching and learning.

Media: The results of this study may be published in prints media such as magazines and newspapers among others to intimate the general public most especially students on the use of modelling clay and demonstration kit for teaching and learning.

Appendix T

Budget Proposal

Description of items	Expected from			Total
	Sponsor	Student	Others	
1.0 Personal Cost/Allowances				
1.1 Research Assistants (3)		Student		15,000
1.2 Research Information		Student		15,000
1.3 Technical Assistants				
Sub-total (not>20% of budget)				**30,000**
2.0 Equipment (List & Specify)				
2.1 Acer Mini Laptop		Student		86,000
2.2 Printer		Student		30,000
2.3 Flash Drive		Student		4,000
2.4 Modem		Student		6,500
Sub-total				**126,500**
3.0 Supplies and Consumables				
3.1 Oxford Advanced Learner's Dictionary		Student		2,100
3.2 Purchase of Textbooks and Pen		Student		11,500
3.3 Papers/Toner		Student		30,000
3.4 Monthly Subscription of Data Bundle at ₦2,500 x 30 months		Student		75,000
3.5 Modelling clay and Demonstration kits		Student		29,500
Sub-total				**148,100**
4.0 Data Collection Analysis				
4.1 Analysis		Student		10,000
4.2 Test Administration and Data Collection		Student		20,000
Sub-total				**30,000**
5.0 Travels				
5.1 Researcher		Student		15,000
Sub-total				**15,000**
6.0 Dissemination				
6.5 Conferences		Student		80,000
6.6 Journal Publications		Student		53,000
Sub-total				**133,000**
7.0 Others and Miscellaneous				
7.1 Accommodation during Research		Student		75,000
7.2 Miscellaneous		Student		220,000
Sub-total				**295,000**
GRAND TOTAL				**₦ 777,600**