UNIVERSITY OF CAPE COAST

EFFECT OF REACT AND 7E MODELS OF TEACHING ON SENIOR HIGH SCHOOL STUDENTS' ACHIEVEMENT IN MOLECULAR GENEICS

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BY

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Thesis submitted to the Department of Science Education of the Faculty of Science and Technology Education, College of Education Studies, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Philosophy degree in Science Education

SEPTEMBER 2019

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:..... Date:.....

Name: Benedicta Abeka Quainoo

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature:..... Date:.....

Name: Dr. Kofi Acheaw Owusu

Co-Supervisor's Signature: ..... Date:.....

Name: Dr. Charles Deodat Otami

ABSTRACT

The aim of this research was to compare the effectiveness of the REACT, 7E and conventional teaching approaches on Senior High School students' achievement in molecular genetics. The study also sought to determine students' perceptions about the REACT and 7E models of teaching. Three intact Form 2 Elective Biology classes from three public Senior High Schools in the Ajumako-Enyan-Essiam District were selected via random sampling using computer generated random numbers to participate in this research. The three intact classes were randomly assigned as the REACT, 7E and conventional groups. Seventy-nine students took part in this research. The data collection instruments used in the study were a semi-structured interview and two achievement tests on the diversity of life and life processes in living things, and Nucleic acids and protein synthesis. Each of the achievement tests consisted of 30 test items. One-way ANOVA, independent sample *t*-test and thematic content analysis technique were employed to analyse the data. The result of the study revealed that the performance of students in the REACT and 7E groups were at par. However, they outperformed their counterparts in the conventional group. Again, the study revealed that the REACT and 7E teaching models could not bridge the gap between the achievement of low and high achievers. The study also revealed that overall the student had positive perceptions about the REACT and 7E models of teaching. In view of the findings of the study, it was recommended that in teaching science concepts such as molecular genetics, the REACT and 7E models of teaching should be employed.

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DEDICATION

To my parents and siblings.

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CHAPTER ONE

INTRODUCTION

The issue of Ghanaian Senior High School students' low achievement in Biology and for that matter concepts on molecular genetics have been reported over the past year. Stakeholders and educators have expressed concern about this issue to determine the factors that are leading to the students' low achievement in Biology. Research has shown that of the several factors that cause students' low performance in Biology and for that matter concepts on molecular genetics, the teaching approaches employed by teachers is a critical factor. Even though concerns have been raised and literature shows that the teaching approach is a critical factor causing students low achievement in molecular genetics, little research have been done to determine the effective approaches to teach concepts on molecular genetics. This study, therefore sought to ascertain the effectiveness of REACT and 7E models of teaching, which have been proven to be effective in teaching challenging science concepts, and compared their effectiveness to that of the conventional approach to teaching Biology in the Ghanaian context. This will help educators and stakeholders to know some of the teaching strategies that are effective in improving learners' achievement in molecular genetics and hence their achievement in Biology as a whole.

Background to the Study

One of the aspects of the educational process that influence learners' academic performance is instructional approaches employed by teachers (Griffin, Care, Francis, Hutchinson & Pavlevic, 2014; Whittle, Telford &

Benson, 2018). There are many instructional approaches available to educators that they can employ in their classrooms. The various teaching approaches employed in the teaching and learning process are grouped into two main categories, thus, teacher-centered and student-centered approaches (Ahmed, 2013).

Considering the enactment of teacher-centered approaches, Emaliana (2017) noted that students tend to be passive receivers of information whiles teachers serve as evaluators to monitor learners to get correct answers. Garrett (2008) listed some examples of teacher-centered teaching approaches as lecture, recitation, drill and practice and teacher-led demonstration. Although students are generally passive in the teacher-centered approaches, it has been observed that such approaches are appropriate when introducing a new concept to students. Again, teacher-centered approaches help teachers in teaching a lot of content within a short period (Gengle, Abel & Mohammed, 2017). Due to the popularity of teacher-centered approaches, they are widely employed by teachers (Zhao, Valcke, Desoete, Sang & Zhu, 2014) notwithstanding some inherent weaknesses associated with the approaches.

Kompa (2012), indicated that teacher-centered approaches tend to focus on learning outcomes thereby leading to students merely mastering limited set of knowledge without taking into consideration the relevant process-skills they will require to be able to the work in the future. There is also teacher dependency in which the students rely on their teachers for information and knowledge. The development of meta-cognitive and high order thinking abilities like analysing, synthesising and evaluating what is

being learnt, and justifying and validating of arguments haven been found not to be taken into consideration in teacher-centered instructional strategies. Teacher-centered approaches having been identified as not being effective in improving students' performance due to the weaknesses they possess (Beausaert, Segers & Wiltink, 2013; Lak, Soleimani, & Parvaneh, 2017).

It has been revealed that effective teaching strategies are mostly methodologies that are student-centered (Marinko, *et al.*, 2016; Qutoshi & Poudel, 2014; Wright, 2011). In learner-centered strategies of teaching, teachers give opportunity to students to actively participate in classroom discourse and lead learning activities (Sawant & Rizvi, 2015). Some examples of student-centered approaches to teaching are problem based-learning, discovery methods, games and simulations, computer assisted instruction (CAI), inductive learning and cooperative learning (Gengle, Abel & Mohammed, 2017). Student-centered instructional strategies are often referred to as constructivist teaching strategies (Kumar & Teotia, 2017; Schreurs & Al-Huneidi, 2012).

Constructivist teaching strategies are learner-centered approaches in which knowledge is not simply given by teachers but students are actively engaged in the classroom to construct new knowledge (Dagnew, 2017). Fernando and Marikar (2017) elaborated that the principal idea underlying constructivist strategy to learning is that knowledge is actively created by the learner and not passively gained from elsewhere. Fernando and Marikar asserted that the role of the teacher is to consider the principal ideas of the constructivist learning theory and make effort to facilitate learning. Some of

the strength of the student-centered approach are students developing problem solving ability, increase in students' learning motivation, students develop collaborative and creativity skills and increase in the learners' ability to communicate effectively (Sumarni, 2015).

Although student-centered approach is considered to be effective for teaching, it comes with some disadvantages. Oinam (2017) noted that the student-centered classroom usually become noisy and disordered as students actively interact with each other hence making it challenging for educators to effectively manage every member of the class. Another weakness of this approach is that it demands a lot of instructional time for facilitators to teach and for students to learn a planned lesson (Sumarni, 2015).

Teaching approaches in general have been found to impact the learning of students. A study conducted on effectiveness of teaching approaches by Bullard, Felder and Raubenheimer (2008) showed that both teacher-centered and learner-centered approaches made relatively little difference to high achieving students but low achieving students who are taught with student-centered approaches consistently outperformed low achieving students who are taught with teacher-centered approach. The research brought to light that teacher-centered approaches tend to favour high achievers in the class to the neglect of low achievers as low achievers tend to benefit from student-centered approaches. Çelik (2018), reported that the academic achievement of students who were taught with a student-centered approach improved but the attitude towards learning activities improved for students who were taught with teacher-centered approach while attitude towards learning activities for

students taught with learner-centered approach did not improve. Also, Ganyaupfu (2013) researched into the deferential effectiveness of teacher and learner-centered, teacher-centered and learner-centered approaches on student's academic performance. The study found that with the three teaching approaches employed, thus, teacher-centered, learner-centered and teacher and learner-centered strategies, the teacher-centered strategy was the least effective teaching strategy.

Because the type of instructional approach a teacher employs in teaching greatly affect learners' academic achievement (Appiah, 2012; Chifwa, 2015; Ekong et al., 2015; Dogru-Atay &Tekkaya, 2008; Topçu & Sahin-Pekmez, 2009; Westwood, 2017), the Ghanaian Senior High School Biology syllabus prescribes that teachers employ constructivist teaching methodologies to teach Biology concepts for maximum conceptual understanding (CRDD, 2012). Although the Elective Biology syllabus prescribes constructivist teaching approaches for teachers to employ to teach, it does not give specific constructivist teaching approaches for the teachers to use to teacher in order to maximise students' achievement in the subject. Therefore, in tackling the issue of students' low performance in Biology, one can reason that effective constructivist teaching approaches that are being employed in other countries should be considered in teaching Biology concepts which will help in improving students' performance in the subject.

Research in Science Education has shown that students' achievement in science improves when they are taught with student-centered constructivist teaching approaches (Adak, 2017; Kim, 2005; Magak, 2016). However, there

are several constructivist approaches to teaching but the REACT and the 7E models have been revealed in many studies to be very effective in improving students' achievement in difficult science concepts.

Considering the effectiveness of the REACT model, Bilgin, Yürükel and Yiğit (2017) studied the effectiveness of REACT strategy on Turkish students' academic performance and conceptual change of concepts on particulate nature of matter. Their study revealed that both the academic performance and conceptual change of learners that were exposed to the REACT strategy were better than that of learners who were exposed to the conventional model. Also, in South Africa, the effect of the REACT strategy was compared to a traditional approach on students' performance in genetics by Kazeni and Onwu (2013). The outcome of their study brought to light that the REACT strategy was more efficient than the traditional instructional model in improving learners' performance. Ültay and Alev (2017) also investigated the effect of REACT strategy on Science student teachers' learning in collision, impulse and momentum concepts. The study revealed that REACT strategy was significantly more effective than the conventional teaching model on the collision, impulse and momentum concepts and again, most of the misconceptions the students had were significantly eliminated in the students who were exposed to the REACT approach.

When we consider the effectiveness of 7E learning cycle, Naade, Alamina and Okwelle (2018) studied the effect of 7E learning cycle on Nigerian Senior Secondary School students' achievement in electromagnetic induction. Their research showed that the students who learned by 7E model

outperformed their counterparts who learned by the conventional model. Another study conducted in Indonesia by Saleh, Suryadi and Dahlan (2018) to find out the effect of 7E model on learners' mathematical problem-solving skills revealed that the 7E approach proved to be more efficient than the conventional approach. Also, Gök (2014) investigated the relative effectiveness of 7E instruction and a conventional instruction of learners' conceptual understanding of concepts on human body systems. The study revealed that the 7E instruction was more efficient than the conventional instruction.

There is ample evidence to suggest that teachers teaching approach affects how they teach and how students learn. There is therefore the need for teachers to select and effectively enact appropriate teaching approaches in order for their students to maximize their learning. When appropriate teaching strategies are employed, students' learning outcomes as well as their overall educational goals can be improved. Thus, educators should be very cautious about the teaching approach they select and enact in the teaching of concepts to their students to learn.

Statement of the Problem

The methodologies for teaching Biology in Ghana are supposed to be student-centered and activity based where the educator facilitates the learning process (Curriculum Research and Development Division (CRDD), 2012) so that students can create their knowledge to maximize their academic achievement. Because the type of approach teachers employ in teaching greatly influences learners' academic achievement, various learner-centered

and activity-oriented teaching strategies have been spelt out in the Senior High School Biology syllabus to be employed by the teacher to teach Biology concepts (CRDD, 2012).

Although teachers have been teaching using various prescribed teaching approaches, the performances of students in science in general (Azure, 2015) and Biology in particular are not encouraging (Amoah, Eshun & Appiah, 2018; Amoah, Gyang & Agbosu, 2018). The Chief Examiners' reports of The West African Examination Council (WAEC) have over the past years reported Senior High School students' low performance in genetics concepts which include concepts on molecular biology (WAEC Chief Examiner's Report, 2011; 2013; 2015; 2016, 2017).

In 2011, the WAEC Chief Examiners' report on the West African Secondary School Certificate Examination (WASSCE) specified that Biology candidates could not accurately explain simple genetics terms such as polygenic inheritance and diploid (WAEC Chief Examiner's Report, 2011). The examiners also reported that candidates had difficulty with the role of ribonucleic acid (RNA) in the synthesis of protein in a cell (WAEC Chief Examiner's Report, 2011). Also, in the 2013 WASSCE, candidates were questioned to describe the structure of deoxyribonucleic acid and to state three structural differences between deoxyribonucleic acid and ribonucleic acid. The Chief Examiner's report noted that response from candidates to this question was not outstanding. In the 2015 Chief Examiners reported that Biology candidates had problems with spelling of technical terms and accurate presentation of genetic diagrams and they also had difficulties with

transcription of mRNA from a DNA sequence (WAEC, Chief Examiner's Report 2015). Similarly, in 2016 it was noted that questions on agglutination and gene interaction (the ABO blood group system) were avoided by most of the candidates and the few who attempted them answered the question poorly (WAEC Chief Examiner's Report, 2016). The WAEC Chief Examiners Report (2017) asserted that candidates showed lacked of adequate subject matter in Biology and an example was given as inaccurate construction of genetic diagram and candidates difficulty in providing explanation of recombinant DNA technology and its applications. (WAEC Chief Examiner's Report, 2017).

There seem to be a consistent poor performance of students in responding to questions on molecular genetics concepts which ultimately affect students' overall performance in Biology. Stakeholders in education are therefore eager to find the best possible ways to solve this chronic problem of students' poor performance.

Research shows that many factors lead to students' difficulty in molecular genetics (Appiah, 2012; Ekong, Akpan, Anongo & Okrikata, 2015; Chifwa, 2015). These factors can be categorized into four themes; the nature of genetics concepts factor (Ekon, *et al.*, 2015; Rotbain, Marbach-Ad, & Stavy, 2008), the student related factor (Considine & Zappalà, 2002; Thomson, 2018; Westwood, 2017), the teaching and learning resource factor (Adewale, Nzewuihe & Ogunshola, 2016; Chifwa, 2015) and the teaching approach factor (Appiah, 2012; Kılıç, Taber & Winterbottom, 2016). Because of the fact that the teaching approaches greatly influence learners'

achievement, the teaching syllabus for Senior High School Elective Biology prescribes that teachers employ constructivist teaching approaches in the classroom.

In spite of the fact that the SHS biology syllabus prescribes constructivist teaching approaches, it does not give specific constructivist teaching approaches to be employed by teacher. Therefore, specific effective constructivist teaching approaches can be explored to determine their efficacy in teaching Elective Biology concepts.

The REACT (Kazeni & Onwu, 2013; Ültay & Alev, 2017) and 7E (Gök, 2014; Suryadi & Dahlan, 2018) models have been proven to be very effective for educators to use to teach and for learners to learn challenging science concepts. It appears in literature that the effectiveness of these two models have not been compared to ascertain the most effective of them. Again, because no research has been done on these two teaching models in the Ghanaian context, they can be employed in the Ghanaian context to determine their effectiveness in teaching science concepts.

To determine which of the two teaching models, that is, the REACT and 7E, would be more effective in the Ghanaian context, this study sought to compare the effect of the two constructivist teaching approaches with the conventional approach on Senior High School students' achievement in molecular genetics.

Purpose of the Study

The purpose of the study was to determine the effectiveness of REACT strategy and 7E learning cycle approaches on Senior High School students'

achievement in molecular genetics concepts as compared to the effectiveness of the curriculum-based conventional approach to teaching Biology concepts in Ghana. And also, to identify students' perceptions about the REACT strategy and 7E learning cycle.

Research Questions and Hypotheses

The study was guided by the following hypotheses and research questions.

Hypotheses

The following four null hypotheses were tested in this research:

H_{O1}: There is no statistically significant difference in the achievement scores of students exposed to the REACT model, the 7E model and the conventional approach.

H_{A1}: There is a statistically significant difference in the achievement scores of students exposed to the REACT model, the 7E model and the conventional approach.

H_{O2}: There is no statistically significant difference between the performance of high achievers and low achievers when exposed to the REACT model.

H_{A2}: There is a statistically significant difference between the performance of high achievers and low achievers when exposed to the REACT model.

H_{O3}: There is no statistically significant difference between the performance of high achievers and low achievers when exposed to the 7E model.

H_{A3}: There is a statistically significant difference between the performance of high achievers and low achievers when exposed to the 7E model.

H_{O4}: There is no statistically significant difference between the performance of high achievers and low achievers when exposed to the conventional approach.

H_{A4}: There is a statistically significant difference between the performance of high achievers and low achievers when exposed to the conventional approach.

Research Questions

1. What are students' perceptions about the REACT model of teaching?
2. What are students' perceptions about the 7E model of teaching?

Significance of the Study

The issue of students' low performance in the sciences and the ways to improve it have become a great concern for science teachers, stakeholders, students and parents. The researcher therefore, sees the findings of this research to be very beneficial to educators, curriculum developers and textbook writers.

Through workshops and in-service training, teachers can be trained on how to apply the REACT strategy and the 7E learning cycle to develop instructional materials for teaching science concepts and other subjects. The teachers can also apply the lesson plans developed in this study entirely or partly in teaching molecular genetics concepts to Senior High School students.

Curriculum developers can have benefits from the findings of this study and the lesson plans developed in the study for the development of new curriculum or revision of existing curriculum by incorporating the REACT strategy and 7E learning cycle into the curricula they develop.

Writers of textbooks can adapt the lesson plans developed in this research when they write books by writing teacher guide books by using the REACT strategy-based lesson plan and 7E learning cycle-based developed in the study.

Delimitation

There are several concepts in the Elective Biology syllabus that students' have difficulties in understanding them, but because all the difficult concepts in the syllabus could not be covered in a single study this research focused on molecular genetics concepts which includes the structures and functions of nucleic acids, duplication of deoxyribonucleic acid, transcription and protein synthesis. These molecular genetics concepts were considered because, they are the only molecular genetics concepts learned at the SHS level according to the Biology syllabus. Also, because the study involves a quasi-experiment, not all schools in Ghana can participate in this study. Therefore, only three schools from the Ajumako-Enyan-Essiam District were selected to participate in this study.

Limitations

Extraneous variables that can affect the result of this study such as students' experience, ability, maturation, and age could not be controlled in this research. Also, the results of this research were generalised to only the schools that participated in this study because only three intact classes of these schools were used in the study and not all Form two Biology classes in Ajumako-Enyan--Essiam District.

Definition of Terms

Achievement is the fruitful accomplishment in a certain subject area which is mostly shown by marks, grades and scores of descriptive commentaries (Dimbisso, 2009).

REACT model refers to a context-based teaching approach made up of five stages, these are; relating, experiencing, applying, cooperating and transferring. (CORD, 2016)

7E model refers to an inquiry-based teaching approach which is made up of seven stages, these are; eliciting, engaging, exploring, explaining, elaborating, evaluating and extending stages (Eisenkraft, 2003).

Molecular genetics, in this context, refers to the structures and functions of the nucleic acids, replication of deoxyribonucleic acid, transcription and protein synthesis.

Perception refers to an opinion, belief and thought held by someone and based on appearances.

Organisation of the Study

This study is organised into five chapters, each chapter deals with an aspect of the study. The chapter one dealt with the background to the study, statement of the problem, purpose of the study, hypothesis, research questions, significance of the study, delimitations, limitations and definition of terms. Literature related to this study was reviewed in the chapter two which includes theoretical framework and review of empirical studies. The chapter three was devoted to research design, population, sampling procedure, data collection instrument, data collection procedures and data processing and analysis. With

chapter four, there is the presentation of result and discussion of the results obtained. Chapter five was devoted to summary of the study, conclusions, recommendations and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

The aim of this study was to investigate the effect of REACT and 7E models of teaching on Senior High School Students' achievement in molecular genetics. Based on this aim, some literature related to this study have been reviewed in this chapter. The review and discussion of related literature were organized in thematic areas as theoretical framework, empirical studies on REACT strategy, perceptions about REACT strategy, empirical studies on 7E learning cycle, perceptions about 7E learning cycle and students' difficulties in leaning molecular genetics.

Theoretical Framework

The main goal of instructional process is for students to learn new concepts. There are different viewpoints about how individuals learn which therefore have led to the development of several theories on how people learn. The type of instructional approaches employed by teachers in their classroom are based on several learning theories. Behaviourism, cognitivism and constructivism are some of the prominent theories of learning. However, constructivism is the theory of learning that educators are promoting currently.

The constructivist theory of learning refers to the idea that students construct knowledge and meaning from their experiences either individually or socially through different learning events and interactions (Kazeni & Onwu, 2012). Bhutto and Chhapra (2013) asserted that in constructivism, the educators help learners to progress by creating a motivating and supportive learning environment for learners by taking into consideration learners'

individual needs, their prior experiences and learners-oriented goals through effective social communication. Constructivist ideas on learning have their historical roots in the work of Dewey, Bruner, Vygotsky and Piaget (Sarita, 2017). Three main categories of constructivism, namely, cognitive constructivism, social constructivism, and radical constructivism have been identified (Doolittle, 1999).

The three broad categories of constructivism are based on the same premise that learners construct their knowledge, albeit each of them considers the idea of learners constructing their knowledge from different perspectives (Singh & Rajput, 2013). Cognitive constructivism is based on the assumption that people learn by means of their minds actively creating knowledge by utilizing what they already know to make meaning of their new experiences (Okoroma, 2013). In the case of radical constructivism, Belbase (2014) argued that knowledge is actively constructed by an individual but not by passive reception via the sense organs or by means of communication, and the purpose of reasoning is adaptive which helps individuals in organizing the world they experience but not for discovering existing reality. Social constructivism, as explained by Mishra (2014), is a type of constructivism whereby in a physical and social situation, a learner, who is perceived to be a reflective being, creates his/her knowledge by taking part in authentic activities and adapting tools of practices through members in society. Classroom setting is a social environment where by students interact with their peers to create knowledge. Therefore, social constructivism has been found to be the most appropriate theory to support teaching and learning.

Social constructivism focuses on people constructing their knowledge in a social context as opposed to cognitive constructivism where people construct knowledge individually in their mind. Lev Semyonovich Vygotsky is believed to be the proponent of the social constructivist theory (Zhou & Brown, 2015). The main components of Vygotsky's theory are the internalization of culture means, individuals learning through the interpersonal process of mediation and a learner's knowledge is formed within the zone of proximal development (ZPD) which is defined by the learner's social interactive boundaries (Taylor & MacKenney, 2008).

The zone of proximal development as defined by Vygotsky is 'the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peer' (Vygotsky, 1978, p. 86). The ZPD deals with ideas like; the present developmental stage of a learner, the next developmental stage that the learner is capable of attaining through mediation, tools in the environment and facilitation from a capable colleague or adult (Shabani, Khalib & Edabi, 2010). Chaiklin (2003) elaborated that ZPD focuses on the interaction between a more capable individual and a less capable individual on a task whereby the less capable individual later on performs independently the task he or she initially performed with the more capable individual. The more capable person provides a scaffold, thus, a support for the learner to increase her current academic achievement to a higher level (Pathan, Memon, Memon, Khoso & Bux, 2018). As noted by Shabani et al, (2010) the ZPD portrays the idea that

people learn best through collaborations and it is through such collaborative activities that students conceptualize and learn new knowledge by being assisted by more capable people.

The zone of proximal development has some implications for instructional practices. The implications of ZPD as noted by Christmas, Kudzai and Josiah (2013), are that guidance must be given to the learner by a competent peer or the teacher, and also, collaborative learning among the learners should be ensured by the teacher. When teaching based on the idea of the ZPD, the new concept being learned should be of appropriate difficulty. The learning task should not be so easy that the learner will not need guidance which can cause boredom and it should not too difficult that the learner will give on learning the new concept. The difficulty level of the learning task should be such that guidance from a more capable person can result in the students mastering the new concepts being learned.

Based on the arguments of Vygotsky (1978), Kim (2001) asserted that social constructivism is based on three principles, 1) reality: social constructivists believe reality does not exist until members of society construct it hence it cannot be discovered; 2) knowledge: it is believed that knowledge is culturally constructed as people construct it by interacting with their environment and 3) learning: proponents of social constructivism perceive learning as a social process which is not shaped by outside forces nor occurs within an individual but it occurs meaningfully when learners interact socially. Amineh and Asl (2015, p. 13) stated that "the most important elements in this theory are (a) the assumption that human beings rationalize

their experience by creating a model of the social world and the way that it functions and, (b) the belief in language as the most essential system through which humans construct reality".

Based on the assumptions of social constructivism, social constructivists agree that social interactions have significant effect on the construction of knowledge even though learners actively create their knowledge; and as children develop, verbal communication between them and other members in their environment is a powerful factor that help children in knowledge conceptualization (Walker & Shore, 2015). Social constructivism advocates that knowledge conceptualization is influenced by environmental interactions (Allah Nawaz, 2012), thus, knowledge is not a constant stuff a person autonomously construct in his or her mind but rather, knowledge comes about as it is created and recreated among people in specific contexts who work to achieve a common goal by utilizing their culture (Yüksel, 2009).

To create a social constructivist classroom for effective learning, Adams (2006) noted some guidelines that teachers can consider. The guidelines are: learning should be the main focus but not students' performance; students should be perceived as co-creators of conceptual understanding; actively involve learners in activities that they perceive to be relevant and assess learners through recognition and acknowledgement of shared understanding. Moreno (2010) explained that when learners share ideas among themselves, it promotes understanding as they assess each other's ideas, make necessary correction and adapt new ideas that are similar to theirs, hence, cooperative learning is encouraged in the social constructivist

classroom (Allah Nawaz, 2012). The responsibility of the teacher is therefore to serve as a facilitator as students learn in groups (Allah Nawaz, 2012). As opined by Husain (2018), the role of learners is to construct new concepts by means of active enquiry as the instructional process appropriately engage all of them to be in the learning process.

The REACT teaching strategy model

The REACT strategy is a context-based teaching approach emanating from the social constructivism (Supandi, Waluya & Rochmad, 2016). REACT strategy was introduced by Center for Occupational Research and Development (CORD) in the United States of America (Rahayu & Kurniasih, 2014; Ültay, 2012). This teaching model involves five stages and derives its name from the first letters of the various stages. 'R' stands for the relating stage, 'E'stands for the experiencing stage, 'A' stands for the applying stage, 'C' stands for the cooperating and 'T' stands for the transferring stage (Karsli & Yiğit, 2016; Rahayu & Kurniasih, 2014).

The first stage of the REACT strategy is the relating stage. Here, learners learn in the context of their life experiences or prior knowledge (Özbay & Kayaoğlu, 2015). The students' attention must be called to everyday life experiences and these experiences must then be related to the new concepts to be learned or the problem at hand that is to be solved (Utami, 2016).

The second stage of the REACT strategy is the experiencing stage. The purpose of the experiencing stage is to give students the opportunity to experience activities that is related to real life occurrences as they learn in the

context of discovery, exploration and invention (Ültay *et al.*, 2014). As elaborated by CORD (2016), the experiencing stage is regarded to be the core of contextual learning and hence, to get students to be interested in learning, text and/or audiovisual-based activities can be incorporated into the instructional process.

After the experiencing stage is the applying stage where opportunity is given to learners to apply what they have learned. During the applying stage learners apply the new concepts they have learned or information they have obtained in useful context through class activities, laboratory work and projects (Ültay, Güngören & Ültay, 2017). At this stage of the context-based learning, guidance is given to students to apply the new knowledge they have obtained in everyday cases (CORD, 2016).

The stage that comes after the applying stage is the cooperating stage. During the cooperating stage students learn by sharing, responding and communicating with other students (Tural, 2013). Utami (2016) opined that, learning in the context of cooperation does not only get most of the students to learn but it also help them acquire real life skills that will be of an advantage for them in the workplace, thus, the ability to communicating effectively, share information freely and work comfortably in a team setting. Tural suggested that these skills can be developed through group activities such as problem solving, projects and laboratory activities.

The fifth stage of the teaching model is the transferring stage which comes after the cooperating stage. This is the final stage of the REACT strategy where students learn in the context of utilizing the newly learned

concepts in a novel setting, thus, concepts that have not been covered in class (Ültay, 2012). As reported by CORD (2016), students learning in the context of transferring can be done by using and building upon the new concepts they have learned that are familiar to the novel concepts that is to be learned.

Based on the components of the REACT strategy such as students learning by relating new concepts to already learned concepts and learning through cooperation, Utami (2016) considers the REACT model as the fundamental principles of constructivist theory of learning. It is confirmed by Ültay, Durukan and Ültay (2015) that the REACT strategy is pronounced to be rooted in principles of constructivism whereby learners employ problem solving and critical thinking skills so that they can construct concepts easily.

The 7E learning cycle model

The 7E learning cycle is an extended version of the 5E learning cycle developed by Arthur Eisenkraft in 2003 (Sharma & Sankhian, 2018). The learning cycle model is an inquiry-based instructional strategy (Hanuscin & Lee, 2010) where learners are provided with a structured means to create concepts through direct experience with science phenomena (Maier & Marek, 2006) In the transition of the 5E learning cycle model to 7E cycle model, the elicit and extend phases were added to the 5E learning cycle (Baybars & Kucukozer, 2018). The seven phases of the 7E learning cycle model are explained in the following paragraphs.

The first phase of the 7E model is elicit. Learners' previous knowledge is a crucial factor affecting their future learning as their previous knowledge influences the learning of new concepts (Mecit, 2006). Therefore, the elicit

phase of the 7E learning cycle requires teachers to take into consideration learner's previous knowledge and conceptions (Yerdelen-Damar, 2013). At this stage, Siribunnaam and Tayraukham (2009) reported that educators are to prompt learners to motivate them to bring out their understanding and knowledge. Since learners are not tabula rasa, Sharma and Sankhain (2018) asserted that the core aim of this stage is to give students the chance to express their existing knowledge and understanding which have a great influence on students' learning of new concepts.

The phase that comes after the elicit phase is the engage phase. During the engage stage, learners' interest and motivation to learn are increased which helps in getting the learners to be mentally focused on the new concept to be learned (Karagöz & Saka, 2015). Eisenkraft (2003) opined that the engage phase should entail generating students' enthusiasm and assessment of prior understanding of the topic to be learned because, if students prior understanding are not assessed at this phase, they may construct concepts that differ from what the teacher expect them to construct. Based on Eisenkraft's assertion, (Mecit, 2006) reported that educators can employ meaningful scenarios or simple experiments to gain learners attention for the learners to ask questions through which their prior knowledge about that the concept to be learned can be assessed.

The third phase of the 7E learning cycle is the explore phase where the needed materials are made available to learners to construct their knowledge. Learners are given the opportunity to record data, isolate variables, design experiments, create graphics, interpret results and organize their findings

(Eisenkraft, 2003; Adesoji & Idika, 2015). During the explore stage of the learning cycle the learners actively create their knowledge by making reference to their prior knowledge (Turgut, Colak & Salar, 2016). Bülbül (2010) opined that, framing of questions, suggestion of methods to be followed, provision of feedback and assessment of understanding may be done by teachers at this stage.

The fourth phase of the 7E model is the explain phase. During this phase, learners present the information that was obtained from the activities done in explore stage (Turgut, *et al.*, 2016). Introduction of law, models and theories to learners is done at this phase by the teacher so that learners summarize their achievements in the light of the laws, models and theories whiles the teacher guides learners towards comprehensible and consistent generalization (Eisenkraft, 2003).

The next stage after the explain stage of the 7E learning cycle model is the elaborate stage. After receiving explanations about the main ideas and terms for their learning activities, it is crucial to involve the learners in further experiences that elaborate, the concepts, processes and skills. This elaboration phase facilitates the transfer of knowledge to closely related but new knowledge. In some instances, learners may still have misconceptions, or they may only understand a concept in terms of the exploratory experience. Elaboration activities, therefore, provide another opportunity to the learners who still having misconceptions time and experiences that will help them understand the concepts being learned very well (Bülbül, 2010).

The evaluate phase is the sixth phase of the 7E learning cycle. In this phase, learners evaluate themselves about the new concepts and skills they have acquired (Turgut *et al.*, 2016). Here, the teacher employs different assessment and evaluation instruments to evaluate learners (Turgut *et al.*, 2016). Aside oral questioning, other assessment tools teachers may employ to evaluate students' learning are multiple choice, quiz, puzzle, structured grid and true-false questions (Balta & Sarac, 2016). Karagöz and Saka (2015), explained that learners try to answer different questions by referring to concepts they have learned and the teacher does a formal evaluation as he gives feedback to student to improve their learning. This phase helps the continuity of both formative and summative evaluations (Turgut, Gürbüz & Salar, 2013).

The next phase that comes after the evaluate phase is the extend phase. The extend phase is the last phase of the 7E learning cycle. At this phase, it is expected of the learners to transfer and expand the new concepts they have learned to everyday life experiences (Balta & Sarac, 2016). Learner relate the newly gained knowledge with their everyday experiences or concepts in other to transfer knowledge and skills they have learned (Karagö & Saka, 2015). As explained by Adesoji and Idika (2015), the essence of the inclusion of the extend stage to the learning cycle was to remind educators of the necessity of transfer of learning.

Relationship of social constructivist theory to REACT and 7E models of teaching

The REACT strategy and the 7E learning cycle models of teaching are based on the idea of social constructivism. Collaborative learning, which is promoted by the adherents of social constructivism (Secore, 2017) is employed in both REACT and 7E teaching approaches.

As noted by Amineh and Asl (2015), Vygotsky (1978) believes that effective learning occurs in a collaborative learning environment where guidance is given to the learner as he/she interacts with more capable persons. The idea of collaborative learning is employed in both REACT and 7E models of teaching where the teacher and/or competent peers of the learner gives guidance to the learner during instructional processes. With the REACT strategy, the students collaboratively learn new concepts in the context of their prior knowledge; experiencing of the new knowledge; application of the new knowledge; cooperating with colleagues and transferring of learned concepts in new situations. Also, in the case 7E, the learners' interest in learning is elicited and they are engaged after which they collaborate to learn new concepts by exploring to learn new concepts, explanation of the new concepts, elaborate on the new concept they have learned with assistance from the teacher, evaluation of their understanding of the learned concept and extension of the newly learned concept to learn a different concept.

Collaborative learning can be explained as a teaching strategy in which emphasis is placed on the interactions among members in a classroom and team work such that learners work together to achieve common goals (Ruys,

Keer, & Aelterman, 2012). For a collaborative learning to be implemented effectively, Wood, McCormack, Lapp and Flood (1997), noted the following seven steps that teacher must take into consideration.

1. Identification of lesson objectives, thus, before the group of students are formed for collaborative learning the objectives of the lesson must be specified to the students.
2. The facilitator should orient the learners on rational, procedures and anticipated results of the lesson before the collaborative learning begins.
3. The teachers should form groups of students by taking into consideration the size and composition of the groups, available resources and how the groups will be arranged in the class.
4. Explanations of guidelines for working in groups and activities that the groups are to complete have to be made known to the students.
5. The teacher must observe and facilitate team members interactions as they go about their tasks to identify and address the challenges they may encounter in their various groups.
6. Educate the learners on the ways and the time to utilize their textbooks as they engage in collaborative learning. This is because, information that learner obtain in collaborative learning are not only obtained directly from their textbooks.
7. Evaluation of achievement of individual and group should be done. This is because, participation of all group members in the collaborative activities indicates that the learning process has been successful.

Therefore, regular evaluation should be done to ensure success of the collaborative learning.

The collaborative nature of the REACT and 7E models follow the points listed above. In both teaching models, the lesson objectives are made known to the learners. Groups are formed for collaborative learning based on the available resources and characteristics of the learners, and the learners are informed on the rules and tasks that comes with working in groups. In the REACT and 7E learning cycle, the teacher monitors and facilitates the group learning. Again, the achievement of the groups and individual members of the groups are evaluated.

One can conclude that REACT and 7E models of teaching are supported by the social constructivist theory of learning. This is due to the application of the ideas of the zone of proximal development where by learners interact with the teacher and their classmates for effective learning, and the teacher providing support to the learners. Therefore, social constructivism serves as the basis for designing collaborative learning approaches such as the REACT strategy and 7E learning cycle.

Effectiveness of REACT strategy

The constructivist REACT strategy has been compared to conventional approaches to teaching by several researchers to ascertain the effectiveness of the REACT strategy. The result of some of the research are presented in the following paragraphs.

Gül (2016) compared the effectiveness of the REACT strategy with that of a conventional approach on 11th grade Turkish students' retention of

understanding of concepts on photosynthesis. The result of the study showed that the REACT strategy was more effective in retention of learning of concepts in photosynthesis. Another study conducted by Doğru and Özsevgeç (2014) resulted in a similar result in which the REACT strategy was effective in helping students understand challenging Biology concept. Doğru and Özsevgeç (2014) studied the effectiveness of the REACT strategy supported with concept caricature in eliminating eighth grade Turkish students' misconceptions about nitrogen cycle. Their study showed that the REACT strategy was more effective than the conventional approach in eliminating misconceptions and increasing understanding levels. Based on the finding of these studies, it can be concluded that the REACT strategy is effective in teaching concepts in Biology.

Günter (2018) investigated the effect of REACT strategy on health college students' achievement in concepts solubility equilibrium. Her study showed students who were exposed the REACT strategy performed better than those who were exposed to the conventional approach. Also, Ültay and Çalik (2016) compared the effect of REACT strategy, 5E learning cycle and traditional approach on Turkish preservice science teachers' conception and attitude concerning concepts on acid and base. Their study revealed that REACT strategy was the most efficient among the three approaches in retaining concepts that have been learned in long term memory. Again, Bilgin and Yiğit (2017) investigated the effect of teaching materials developed based on REACT strategy on sixth grade students learning of the concepts on density. Their study revealed that the REACT strategy was more effective than

the traditional approach. Bílgín, Yürükel and Yiğit (2017) also investigated the effect of the REACT and 5E approaches on sixth grade students' learning of particulate nature of matter. The result of their study showed that both the conceptual change and academic performance were better with students that were exposed to REACT strategy than the students who were exposed to the 5E learning cycle. The results of these studies suggest that REACT strategy is effective in teaching concepts in Chemistry at both the lower and higher levels of education.

Studies by Ültey (2012) and Ültey and Alev (2017) brought to light that REACT strategy is effective in teaching and learning of Physics concepts. Ültey compared the effect of REACT strategy with a conventional approach on students conceptual learning on impulse and momentum. The study revealed that students' conceptual learning improved when they were taught using REACT strategy. Ültey's study is supported by a study conducted by Ültey and Alev (2017) on the effectiveness of REACT strategy on prospective science teachers' learning in impulse, momentum and collision. The findings of the study showed that students who were taught with the REACT strategy out performed those who were taught with a traditional approach, and most of the misconceptions in impulse, momentum and collision topics held by students who were taught with the REACT model were eliminated.

In Indonesia, Supandi *et al.* (2016) researched on the ability of mathematical representations of eighth grade students in the learning of Realistic Mathematics Education (RME) by employing the REACT model. Supandi *et al.*, found out that the students who were taught RME by REACT

strategy had better mathematical representation ability than students who were taught RME by conventional approach. Also, Jelatu, Sariyasa and Ardana (2018) investigated the effect of GeoGebra-aided REACT strategy on eighth grade students' understanding of geometry concepts. Their study revealed that the REACT strategy led to higher achievement of students on the understanding of concept on geometry as compared to the conventional approach. Rahayu and Kurniasih (2014) investigated the effect of REACT strategy on students' mathematical belief and the result of the study revealed that REACT strategy is effective in improving students' mathematical belief as compared to a conventional approach. The results of the aforementioned studies indicate that REACT strategy is more effective that conventional teaching strategies in the teaching and learning of mathematics.

The effectiveness of the REACT strategy has been investigated in other subjects aside the sciences and mathematics. The REACT strategy has been shown to be effective in engaging students in speaking activity, increase students' motivation, help students to be problem solvers and aid students to cooperate with their colleges when Wahyuni (2013) studied the effect of REACT strategy on speaking practice for Business English class. Similarly, in the case of language learning, Rohayati (2013) also found that REACT strategy improves students' mastery of vocabulary when he investigated the effect of context-based REACT approach on Indonesian students' vocabulary mastery and students' response towards contextualization in teaching and learning of vocabulary. With the writing aspect of teaching and learning of languages, Satriani, Emili and Gunawan (2012) studied the effect of REACT

strategy on Indonesian students' writing programme. Their study showed that students writing skills improved when they were thought based on the REACT strategy. In the teaching and learning of Geography, Utami (2016) investigated the effect of REACT strategy on the development of Geography skills for Indonesian high school students and it was found out that the REACT strategy is effective in developing Geography skill as compared to a conventional model. Based on the aforementioned studies it can be concluded that the effectiveness of REACT strategy is not limited to the teaching and learning of the sciences but the approach is also effective in other subjects as well.

Perceptions about REACT strategy

To determine students' perception about REACT strategy, Karsli and Yiğit (2016) conducted a semi-structured interview on 12th grade students after they have been taught concepts on alkanes using a worksheet developed based on REACT strategy. The result of the content analysis of the study showed that the students view the alkane worksheet based on REACT strategy to have connected school knowledge with daily life situations, made chemistry lesson interesting, appealing and motivating. A similar result was obtained by Günter (2018) when she investigated the effect of REACT strategy on students' achievement in concepts on solubility equilibrium and then conducted a structured and semi structured interview on the students' perception about the REACT strategy. The content analysis of the interviews of Günter's study revealed that, majority of the students viewed the REACT strategy to have made the concept they were taught to be memorable, understandable,

interesting, relevant to everyday life and they also thought groupwork helped them to share information through discussion.

Aside the views students have on REACT strategy, it is also important to know teachers' perception about the REACT strategy. Therefore, Ültay, Durukan and Ültay (2014) assessed student teachers' view about REACT strategy after the strategy had been used to teach the student teachers a general Chemistry course. The study showed that the students teachers accepted the REACT strategy and perceived the approach to have facilitated their learning by hands-on activities and the use of daily life examples. Also, the study showed that despite these positive views, thus, the REACT strategy improving the students' attitude and increasing their interest, some of the student teachers felt the absence of explanation part of the strategy. The absence of the explanation in stage in REACT strategy led to a study by Ültay and Alev (2017) where they investigated the effectiveness of explanation assisted REACT strategy on prospective science teachers learning in impulse, momentum and collision. Their study revealed that the explanation assisted REACT strategy was more effective than the traditional approach and some of the alternative conceptions that the students who were taught with the explanation assisted REACT strategy held were significantly eliminated.

Effectiveness of 7E learning cycle

To determine the effectiveness of the 7E learning cycle, researchers have employed the 7E model to teach some concepts and compared its effectiveness with that of conventional teaching approaches and other constructivist approaches. The following paragraphs talk about some empirical

studies on the effectiveness of the 7E learning cycle in teaching the sciences and other subjects.

Bülbül (2010) compared the effectiveness of the 7E learning cycle with a traditional approach on ninth grade Turkish students' understanding of concepts on diffusion and osmosis. The study showed that the 7E model caused significantly better acquisition of the scientific conceptions than the traditional approach. Similarly, Mecit (2006) also obtained a positive effect with the 7E approach when he investigated the effect of 7E learning cycle on fifth grade students' critical thinking by teaching concepts on water cycle. His study showed that students who were exposed to the 7E learning cycle achieved significantly better than those who were exposed to the traditional approach. A study by Shaheen and Kayani (2015) supports the findings of Bülbül (2010) and Mecit (2006) when they compared the effectiveness of an instruction based on the 7E model and traditional instructional model in teaching Biology on ninth grade students' achievement. Their study revealed that the 7E model was more effective on students' achievement than the traditional model.

Again, Gök (2014) found out that 7E learning cycle instruction was more effective than a conventional approach when both approaches were used to teach concepts on human body systems to middle school students. However, the two approaches did not indicate a significant effect on students' scientific epistemological belief and science process skills. The finding that the 7E model was not able to have a significant effect on science process skills as revealed by Gök (2014) is supported by a study conducted by Polyiem,

Nuangchalerm and Wongchantra (2011), on the effectiveness of 7E learning cycle approach in teaching genetic science, found out that the effect of 7E was not statistically significant on Thai students' science process skills when the approach was compared with the effectiveness of Socioscientific Issue-based learning approach. Based on findings of the studies discussed above, it can be concluded that, overall the 7E model is effective in teaching Biology concepts at the various levels of the educational ladder.

Sarac and Tarhan (2017) investigated the effect of a tradition approach and multimedia assisted 7E learning cycle model on the achievement and retention of fifth grade students by teaching concepts on change of matter. Their study revealed that the multimedia assisted 7E model had a significantly positive effect on students' achievement and retention than the traditional approach. Also, Siribunnam and Tayraukham (2009) compared the effect of 7E approach with the effect of the constructivist approach Know-Want-Learn (KWL) and a conventional approach on Thai students' analytical thinking, achievement and attitude towards chemistry learning. Their study indicated that the students who were taught with the 7E approach outperformed their colleagues who were taught with the KWL and conventional approaches. Meanwhile, Adesoji and Idika (2015) obtained a result which was not in agreement with of Siribunnam and Tayraukham's study when they compared the effectiveness of 7E approach to another constructivist approach Case-Based Learning (CBL) and a conventional approach on Nigerian Secondary School students' achievement in and attitude toward chemistry. They found out that both 7E and CBL are more effective than the conventional approach

in improving students' achievement and attitude. However, CBL proved to be the most efficient approach among the three teaching approaches. The findings of these studies therefore suggest that the 7E learning cycle is an effective approach to teach Chemistry concepts.

In the United States of America, Vick (2018) investigated the effectiveness of the 7E model inquiry labs in Advance Placement (AP) Physics on students' performance in AP exams by employing an action research which involved a one group pretest-posttest design. Vick's study showed that the 7E model inquiry labs have a positive effect on the students' achievement. However, a study by Yerdelen-Damar (2013) gave a detailed result of the effect of 7E learning cycle on students' achievement in physics. Yerdelen-Damar studied the effect of 7E model on tenth grade Turkish students' achievement and epistemological understanding in physics. The study revealed that although the students who were exposed to the 7E outperformed those who were exposed to the traditional approach in terms of epistemological understanding, the traditional approach was more effective for promoting the physics achievement for students with low epistemological stance whiles the 7E was effective for promoting the physics achievement for students with high epistemological stance. This therefore indicates that the 7E learning cycle favours students with high abilities than students with low abilities in terms of teaching and learning of Physics.

Considering the effectiveness of 7E learning cycle on remedying students' misconceptions in Physics, Kanli and Yagbasan (2008) compared the effect of a laboratory activity based on the 7E learning cycle approach with a

conventional approach on university students' development of science process skills and conceptual achievement in force and motion. Their study revealed that the laboratory activities based on the 7E approach was more effective than conventional approach in developing the students' science process skills and remedying students' misconceptions about force and motion. The effectiveness of 7E in correcting students' misconception as revealed by Kanli and Yagbasan (2008) was confirmed by Turgut, Colak and Salar (2016), where they investigated the effect of course material developed based on 7E model on the unit of electromagnetism. Turgut, Colak and Salar (2016) determined the effectiveness of the course material on high school students' conceptual achievement by employing action research design. Their study showed that, the 7E was effective on conceptual development and eliminated existing misconceptions of the student about electromagnetism. The findings of the above studies therefore indicate that the 7E model is effective in teaching and learning of various concepts in Physics at the various levels of education.

When mathematics teaching is taken into consideration, Saleh, Suryadi and Dahlan (2018) compared the effect of 7E approach with a conventional approach on Indonesian students' mathematical problem-solving skills. Their study revealed that the achievement in mathematical problem skill of student who learned by 7E approach was higher than that of the student who learned by the conventional approach. A similar result of the effect of 7E in the learning of mathematics was obtained by Widyaningsih, Waluya and Kurniasih (2018) when they investigated the effect of 7E model and

expository model on students' critical thinking ability in mathematics. Their study revealed that, critical thinking ability of students who were taught with the 7E model was better than that of students who were taught with the expository model. It can therefore be asserted that the 7E model is also effective in the teaching and learning of mathematics.

In addition to the sciences and mathematics, some studies have been conducted on the effectiveness of 7E model in teaching subjects that are not within the field of science and mathematics. In India, George (2016) investigated the effect of 7E model in teaching geography at secondary school level. His study revealed that the 7E model is more effective than the traditional method of teaching geography. In Iran also, Bozorgpour (2016) investigated the effectiveness 7E learning cycle and traditional approach in teaching and learning of English language. The study revealed that the performance of students who were taught with 7E performed better than the students who were taught with the traditional approach. Based on the findings of these studies, it can be concluded that the positive effect of 7E model is not limited to the teaching and learning of Science and Mathematics only but in all other subjects.

Perceptions about 7E learning cycle

Saraç and Sekerci (2018) assessed the opinions of students about a multimedia assisted instruction designed based on 7E. Their study revealed that students perceived the phases of the 7E model of giving them the opportunity to work in group and becoming actively involved in the lesson through brainstorming. The study also revealed that the students were of the

opinion that the 7E learning cycle made them excited about the lesson and increased their interest to learn. A similar result was obtained by Turgut, *et al.* (2013) when they investigated the effect of 7E model of teaching on the achievement and retention of sixth grade Science and Technology course students in the unit Electricity in Our Life. Their study revealed that, the students perceived the 7E learning cycle to have aroused their interest to learn and provided them the opportunity to connect learned concept to daily life events. Another study that confirms students' positive views about the 7E learning cycle was conducted by Yerdelen-Damar (2013) who showed that the instruction based on 7E helped them to learn for understanding instead of memorizing. Yerdelen-Damar (2013) reported that although the learners have positive opinions on the 7E model, their teacher met some difficulties such as 7E model implementation being time consuming and classroom management being challenging.

To assess teachers' perception about the 7E learning cycle approach, Yenilmez and Ersoy (2008) investigated mathematics teacher candidates' opinion towards the application of computer aided 7E instructional model. The study revealed that the mathematics teacher candidates' opinions related to the use of computer aided 7E model were positive irrespective of their gender, frequency of computer usage, computer ownership status, affinity status and computer aided instruction lesson scores. Demġrdağ, Feyzġoğlu, Ateġ, Çobanoğlu and Altun (2011) obtained a result different from that of Yenilmez and Ersoy when they investigated chemistry teachers' view on the requirement and difficulties of developing instructional activities based on 7E model. The

study revealed that the chemistry teachers indicated that it was difficult and time consuming for them to develop activities based on 7E model although they implied that the model provides positive contributions to meaningful learning and learning by inquiry.

Students' difficulties in learning Molecular genetics

The West African Examination Council (WAEC) Chief Examiner's reports have brought to light that most Biology candidate have difficulties in answering questions on genetics which includes concepts on molecular genetics (WAEC Chief Examiner's Report, 2011, 2013, 2015, 2017). The Chief Examiners' Report stated that simple biological terms such as polygenic inheritance and diploid could not be properly explained by candidates (WAEC Chief Examiner's Report, 2011). The examiners also reported that candidates had difficulty with the role of RNA in the synthesis of protein in the nucleus of a cell.

Also, in the 2013 WASSCE, candidates were asked to describe the structure of DNA and state three structural differences between DNA and RNA. The Chief Examiner's report revealed that the candidates' responses to this question was not outstanding. There was a question in the 2015 WASSCE, testing candidates on molecular genetics involving concepts on RNA and DNA, candidates could differentiate between RNA and DNA but most of them could not present the mRNA sequence that would be transcribed from the DNA sequence, $\begin{matrix} TACTTAAGAG \\ ATGAATTCTC \end{matrix}$ (WAEC Chief Examiner's Report, 2015). The Chief Examiner's Report (2017) made it known that candidates showed

lack of adequate subject matter in Biology and an example was given as inaccurate construction of genetic diagram (WAEC, 2017).

Students difficulties in learning genetics and for that matter molecular genetics have been reported not only in Ghana but in other countries around the world (Wright, Fisk & Newman, 2014; Langheinrich & Bogner, 2015). In Nigeria for instance, Etobro and Banjoko (2017) determined misconceptions held by pre-service Biology teachers about genetics using Multiple-Choice Genetic Concept Test and Pre-service Teachers' Genetics Misconception Checklist. The result of their study revealed that among the genetics concepts that were covered in the study, that is, concepts on DNA had the highest number of preserve Biology teachers having misconception on these concepts.

Taking into consideration countries outside Africa, Kılıç, Taber and Winterbottom (2016) conducted a cross-national study on students understanding of genetics concepts in England and Turkey. The study showed that, in general there were some differences between English students and Turkish students understanding of genetics concepts, there were some similarities among their difficulties, these are, the students' inability to accurately understand the structure and relationships among gene, chromosomes and DNA. Also, Vlckova, Kubiatko and Usack (2016) in Czech Republic assessed high school students' difficulties in learning basic genetics concepts using two tier questions. Their study revealed that among concepts such as chromosomes, DNA, alleles and gene, DNA was the most problematic for the students. To focus more on molecular genetics, Briggs, Morgan, Sanderson, Schulting and Wieseman (2016) investigated USA college students

understanding of the central dogma of molecular biology using concept mapping. The analysis of students' concept maps on central dogma of molecular biology before and after a course in Briggs *et al.*'s study showed that the students had difficulties with the mechanisms of transcription and mechanism of translation.

There is ample evidence that shows that students at the various levels of education have difficulties in learning concepts on molecular genetics. One way to improve students' learning of concepts on molecular genetics is by employing effective teaching and learning approaches to teach these concepts in the classroom at the various levels of education.

Summary of the literature reviewed

The constructivist theory of learning refers to the idea that learners construct knowledge from experience (Onwu, 2012) when they are provided the necessary materials to learn (Bhutto and Chhapra, 2013). Constructivism is divided into three broad categories, thus, cognitive constructivism, social constructivism and radical constructivism (Singh & Rajput, 2013).

Vygotsky's (1978) social constructivism which is based on the idea that individuals who are perceived as reflective beings actively construct new knowledge through social activities and interactions (Mishra, 2014) supports both the REACT and 7E models. The aspect of the social constructivism that is most relevant to teaching and learning of science is the zone of proximal development. As opined by Shabani et al, the ZPD portrays the idea that people learn best through collaborations and it is through such collaborative

activities that people who are more capable guide learners to conceptualize and learn new knowledge.

The context-based REACT strategy which was developed by Center for Occupational Research and Development (Rahayu & Kurniasih, 2014) consists of five stages: Relating, Experiencing, Applying, Cooperating and Transferring (Karsli & Yiğit, 2016). REACT strategy has been proven to be more effective than traditional approaches in teaching of challenging concepts in Biology (Gül, 2016); Chemistry (Günter, 2018); Physics (Ültay & Alev, 2017); Mathematics (Jelalu, 2018) and other non-science subjects (Utami, 2016). Ültay and Calik (2016) compared the REACT strategy to the 5E learning cycle and the results they obtained showed that REACT was more effective than 5E in terms of the students' ability to retain learned concepts whiles the 5E was more effective that REACT in terms of conceptual learning. Bilbin *et al.* (2016) also compared the effectiveness of REACT and 5E and they found out that REACT strategy was more effective than 5E in terms of both conceptual change and academic performance.

Research has shown that students have positive perceptions about the REACT strategy (Karsli & Yiğit, 2016; Günter, 2018). Teacher also have positive perceptions about REACT strategy although some student teachers suggested that addition of explanation stage to the REACT strategy will make it more effective (Ültay, *et al.*, 2014).

The 7E learning cycle which was developed by Arthur Eisencraft (Eisencraft, 2003) is made up of seven phases: elicit, engage, explore, explain, elaborate, evaluate and extend (Baybars & Kucukozer, 2018). Studies have

shown that the 7E model is more effective than traditional approach in teaching difficult concepts in Biology (Shaheen & Kayani, 2015); Chemistry (Yerdelen-Damar, 2013); Physics (Vick, 2018); Mathematics (Saleh, *et al.*, 2018) and other non-science subject (Ginu, 2016). Siribunnam and Tayraukham (2009) compared the effect of 7E approach with the effect of the constructivist approach KWL and a conventional approach on Thai students' analytical thinking, achievement and attitude towards chemistry learning. The study showed that the students who were taught with the 7E approach outperformed the students who were taught with the KWL and conventional approaches whiles the students who were taught with the KWL outperformed the students who were taught with the conventional approach. Adesoji and Idika (2015) obtained a different result when they compared the effectiveness of 7E approach to another constructivist approach CBL and a conventional approach on students' achievement in and attitude toward chemistry. Their study revealed that both 7E and CBL are more effective than the conventional approach in improving students' achievement and attitude. However, CBL proved to be the most efficient approach.

Assessment of students' perceptions about 7E learning cycle shows that most students have positive perceptions about the 7E learning cycle (Saraç & Sekerci, 2018; Turgut, *et al.*, 2013). Also, assessment of teachers' perceptions about 7E model of teaching reveals that teacher perceive 7E learning cycle to be an effective teaching approach (Yenilmez & Ersoy, 2008; Demirdag, *et al.*, 2011). However, some teachers perceived instructions

developed based on 7E learning cycle to be challenging and time consuming (Demirdag *et al.*, 2011).

Reports by the West African Examination Council revealed that Ghanaian SHS biology candidates have difficulties in answering questions on molecular genetics concepts (WAEC, 2011; 2013; 2015; 2016). The students' difficulties in learning concepts on molecular genetics have been reported not only in Ghana but in other parts of the world (Wright, Fisk & Newman, 2014; Langheinrich & Bogner, 2015).

Even though WEAC Chief Examiners report has revealed that Biology students have difficulties with concepts on genetics which includes molecular genetics, little research or no research has been conduct to determine effective approaches to teach genetics concepts that will result in an improvement in students' achievement in genetics in Ghana. Also, a literature review shows that both the REACT strategy and 7E learning cycle have been proven to be effective in teaching challenging science concepts, the effectiveness of REACT model has not been compared to that of 7E model. This study therefore sought to fill the gap in literature as far as molecular genetics teaching in the Ghanaian context is concerned by employing the REACT strategy and the 7E learning to teach and compared the effectiveness of the two teaching constructivist approaches to that of the conventional approach.

CHAPTER THREE

RESEARCH METHODS

This research sought to investigate the effectiveness of the REACT, 7E and conventional models of teaching on Senior High School students' achievement in molecular genetics. This chapter dealt with the research design, the population for the study and the sampling procedure that was used for selecting participants that took part in the study. In addition, it dealt with the data collection instruments, data collection procedure and data processing and analysis.

Research Design

A mixed methods design was employed in this research, this is because, both quantitative and qualitative data were collected and analysed. According to Creswell (2012), the explanatory sequential, embedded, transformative, convergent parallel, multiphase and exploratory sequential designs are some of the types of mixed methods approaches that researchers can make use of. The embedded mixed methods design in which the qualitative data serves a supporting role to the quantitative data (Creswell, 2012) was employed in this study.

An embedded mixed methods approach was employed in this research because a quantitative design was used to find out the effects of the REACT strategy, 7E learning cycle and conventional approach on students' achievement in molecular genetics. After which a qualitative design was used to find out the students' perceptions about the REACT strategy and the 7E learning cycle, hence serving as a support for the quantitative data. Thus, the

students' achievement scores of the post-test was the quantitative data that was given more emphasis whiles the students' perceptions about the REACT and 7E models of teaching after they had been used to teach them was the qualitative data that served a supporting role to the quantitative data for a better insight.

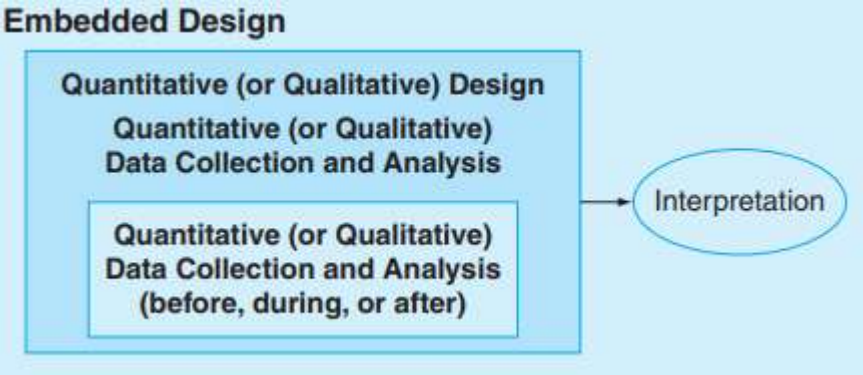

Figure 1: The embedded mixed method design (Creswell, 2012)

With the quantitative approach a quasi-experiment, that is, a pretest-posttest non-equivalent group approach was used. This is because, students were not assigned randomly into groups but rather, intact classes were used where there was the possibility that there were dissimilarities in the groups that were used for the study (Campbell & Stanley,1963). The use of intact classes means that the internal validity of the research may be reduced when compared to true experiments where participants are randomly assigned to groups (Campbell & Stanly, 1963). Interactions between groups is also a weakness of this design that can affect internal validity. This weakness was taken care of as each of the intact classes were selected from different schools and from different towns.

The qualitative approach employed in this study involved the use of semi-structured interview to determine the students' perceptions about the REACT strategy and 7E learning cycle after each of these teaching approaches had been used to teach their allocated group of students. The perceptions of the students about the REACT strategy and the 7E learning cycle served as the qualitative data for the study.

Population

The target population was all Form 2 Senior High School (SHS) students in Ghana who read Elective Biology as a high school subject. The accessible population was all Form 2 Senior High School students who read Elective Biology in the five public Senior High Schools that offer Elective Biology as a subject in the Ajumako-Enyan-Essiam District. The Form 2 students were selected to take part in this study because, by the time the study was conducted they had been taught the topic; Cell Biology I as a prerequisite for learning concepts on molecular genetics. Again, by the time the study was conducted the students had not yet been taught the concepts on molecular genetics.

Sampling Procedure

Three schools from the five public Senior High School in the Ajumako-Enyan-Essiam District who run programmes with Elective Biology as a subject, were selected randomly with the use of computer-generated random numbers. One intact Form 2 Elective Biology class from each of the selected schools were sampled randomly using computer-generated random numbers. Also, assignment of the three intact classes as the REACT, 7E and

the conventional groups were randomly done through the use of computer-generated random numbers. In all 79 students participated in the study.

The random selection of schools and the intact classes was to ensure that all students from the accessible population had equal chance of participating in this research. The three selected intact classes were allocated to the three groups because, in a quasi-experiment of this nature, random assignment of participants to groups is unethical or not allowed. Also, only three classes took part in this research because the design involved two treatment and one control groups with the intact class that was exposed to the conventional approach serving as the control group.

For the sampling of students to take part in semi-structured interview, 10 students were randomly selected from each of the class that was exposed to the REACT strategy and the class that was exposed to the 7E learning cycle.

Data Collection Instruments

The instruments employed in collecting the quantitative data were two achievement tests which were constructed by the researcher and a semi-structured interview guide. The achievement test instruments were made up of 30 multiple-choice items with four answer options to each.

Validity of instrument

The content validity of the achievement tests was established by consultations from Science Education lecturers from the University of Cape Coast.

Pilot testing of instruments

The achievement tests were administered to students in a Senior High School in the Cape Cost Metropolis to determine their reliability. The school used for the pilot testing of the instrument was part of the target population but they did not take part in the main study. Thirty Form 2 students were used for pilot testing of the achievement test for the pretest and thirty Form 3 students were used for pilot testing of the achievement test instrument for the posttest. The students took approximately 40 minutes to complete the tests and both question papers and answer sheets were collected from the students just after the test. Students' scores for the items in the pretest ranged from 10 to 28 and for the posttest they ranged from 8 to 25.

The reliability of the test was calculated using the KR-20 formula because the items in the achievement tests were having varying difficulty levels and were scored dichotomously (Creswell, 2012). The reliability for the pretest was found to be 0.73 and the reliability of the posttest was found to be 0.71. The difficulty and the discrimination indices of the items were also determined (see Appendices C and D).

The lesson plans that were developed for the REACT, 7E and the conventional approaches to teach the concepts on molecular genetics were shown to Science Education lecturers in the University of Cape Coast for their appraisal. In all six lesson plans were designed, there were two lesson plans each for the REACT strategy, the 7E and the conventional approach.

Semi-structured interview was employed as the instrument for collecting the qualitative data, thus, students' perceptions about the REACT

strategy and the 7E learning cycle. The questions, what are the positive and negative aspects of the style used to teach this topic was asked in the semi-structured interview.

Data Collection Procedures

Permission was sought from the authorities of the three Senior High Schools that participated in the study. I administered the achievement test on the topics, diversity of life and life processes to the three selected classes as the pretest to determine if performance of the students in the three classes are at par and also to categorised the members of each class into low achievers and high achievers based on their scores from the pretest. After the pretest, I taught each intact class with one of the teaching approaches (REACT, 7E and conventional). The REACT, 7E and conventional groups were taught the same concepts on molecular genetics. Two days after each of the interventions, the posttest was administered to each group to assess their achievement on concepts on molecular genetics that they were taught. The teaching of the concepts on molecular genetics to the students and the administration of the posttest to the students lasted for two weeks, thus, from 30th April 2019 to 13th May 2019. During the period for the data collection, some members of the each of the classes that participated in the study were absent from school.

After each of the REACT and 7E groups had been exposed to the REACT strategy and the 7E learning cycle respectively, I randomly selected 10 members from each group to be interviewed. A semi-structured interview was employed to determine the students' perceptions about the REACT strategy and the 7E learning cycle after they have been taught with the

REACT strategy and the 7E learning cycle respectively. The interview sections with the students were audiotaped after which they were transcribed.

Lesson plans used for the study

Conventional lesson plan 1

Topic: CELL II

Subtopic: Nucleic Acids

Duration: 70 minutes

Specific objectives: By the end of the lesson the student will be able to:

i. explain the term nucleic acid.

ii. name the types of nucleic acids.

iii. describe the double helix model of the structure of DNA.

iv. describe the structure of RNA.

v. outline the process of DNA replication.

Relevant previous knowledge: Students have learnt about the parts and functions of cells therefore; they will be able to mention the parts of the cell where genetic materials are stored.

Teaching/Learning materials: Model of the structure of DNA, video on DNA replication, computer and projector.

Introduction (5 minutes)

Teacher activity: Teacher uses questions to review students' relevant previous knowledge. E.g., Which part of a cell are genetic material located?

Student Activity: Students respond to teacher's questions. E.g., Genetic materials are found in the nucleus of the cell.

Content Development (30 minutes)

Step 1: Meaning of nucleic acid and types of nucleic acid.

Teacher activity:

a. Teacher asks students to brainstorm to come up with the meaning of nucleic acids.
b. Teacher asks students to come up with the types of nucleic acids.

Student activity:

a. Students brainstorm to come up with the meaning of nucleic acid.
b. Students brainstorm to come up with the types of nucleic acid.

Step 2: The structure of DNA and RNA

Teacher activity: Through the use of the model of the structure of DNA, teacher discusses with students to describe the structure of DNA and RNA.

Student activity: students observe the model of DNA structure and participate in the discussion.

Step 3: DNA replication

Teacher activity: Through the use of video on DNA replication, teacher discusses with students to describe the mechanism of DNA replication and the enzymes involved in DNA replication.

Student activity: students watch video on DNA replication and participate in the discussion.

Main Ideas

1. Nucleic acid is a complex substance found in the nucleus of cells which consists of nucleotides connected in a long chain.

2. The two types of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
3. The unit structure of DNA is called nucleotide which is made up of sugar, phosphate and nitrogenous bases. There are two types of nitrogenous bases; purines (Adenine [A] and Guanine [G]) and pyrimidines (Cytosine [C] and Thymine [T]). Two polynucleotide strands twisted about each other forms the DNA. The two strands run in opposite directions which makes the pairing of the bases possible. The adenine always pairs with thymine and cytosine always pairs with guanine. Hydrogen bonds link the bases. There are two hydrogen bonds between A and T and three hydrogen bonds between C and G.
4. RNA is made up of a single strand polynucleotide. In RNA the base thymine is replaced by the base Uracil [U]. There are three types of RNA, these are, messenger RNA (mRNA), transfer RNA (tRNA) and ribosomal RNA (rRNA).
5. DNA replication occurs prior to cell division. Weak hydrogen bonds holding the two strands of DNA are broken under the influence of helicase, as a result the DNA unwinds into two strands. Free nucleotides in the nucleus assemble alongside each half strand to form two pairs of half strands. Hydrogen bonds between complementary base pairs join the half strands to form two identical double strands of DNA. The roles enzymes involved in DNA replication are; helicase breaks the hydrogen bonds to unwind the DNA strand, polymerase

makes a copy of the DNA in the 5´ to 3´ direction on the leading strand and ligase binds Okazaki fragments on the lagging strand.

Application (20 minutes)

Teacher activity: Teacher creates a scenario for students to apply what they have learnt. Example, which of these DNA double helix will be more difficult to unwind into two strands: DNA made up of more Adenine – Thymine base pair or DNA made up of more Guanine – Cytosine base pair? Why?

Student activity: students respond to teacher's question using what they have learned.

Closure (15 minutes)

Teacher activity:

a. Teacher summarises the lesson.
b. Teacher evaluates the lesson using questions based on the set objectives.

Student activity: students listen to teacher and respond to teacher's question.

Assignment

Students are asked to do the following:

1. Draw and label the structure of DNA consisting of five (5) nucleotides.
2. Mention three differences between the structures of DNA and RNA.
3. Describe the process of DNA replication using diagrams.

Conventional lesson plan 2

Topic: CELL II

Subtopic: Protein synthesis

Duration: 110 minutes

Specific objectives: By the end of the lesson the student will be able to:

i. outline the process of RNA transcription.

ii. describe the process of protein synthesis.

iii. explain the importance of protein synthesis for living things.

Relevant previous knowledge: student have learnt about the structure of RNA therefore; they will be able to mention the nitrogenous bases in RNA molecule.

Teaching/Learning materials: videos on RNA transcription and protein synthesis, cardboard.

Introduction (5 minutes)

Teacher activity: Teacher uses questions to review students' relevant previous knowledge. E.g., What are the nitrogenous bases found in RNA molecule?

Student Activity: students respond to teacher's questions. E.g. Adenine, uracil, cytosine and guanine.

Content development (40 minutes)

Step 1: RNA transcription.

Teacher activity: Through the use of video on RNA transcription, teacher discusses with students the process of RNA transcription and ask learners to practice RNA transcription on cardboards.

Student activity: Students watch video on RNA transcription, participate in the discussion and practice RNA transcription on cardboards.

Step 2: Protein synthesis

Teacher activity: Through the use of video on protein synthesis, teacher discusses the process of protein synthesis with students.

Student activity: Students watch video on protein synthesis and participate in the discussion.

Step 3: Importance of protein synthesis

Teacher activity: Teacher asks students to brainstorm to come up with the importance of protein synthesis.

Student activity: Students brainstorm to come up with the importance of protein synthesis.

Main ideas

1. A specific region of DNA molecule unzips to expose a sequence of base triplet for the synthesis of a particular protein. Free ribonucleotides now form a new strand as in DNA replication except that the new strand is made up of mRNA. The mRNA molecule formed is complementary to the coded message on the DNA strand on which it was produced. The mRNA moves out of the nucleus through a nuclear pore into the cytoplasm and becomes attached to a ribosome.
2. Messenger RNA moves out of the nucleus of the cell into the cytoplasm where it associates itself with ribosomes and forms a site for the synthesis of protein, as it carries the template from the DNA. Transfer RNA folds to form a branched chain. There are 20 or more in a cell. One end of the transfer RNA links up with a specific amino acid during protein synthesis. A sequence of three bases called anticodon occurs at a point along the transfer RNA chain. The anticodon of each

transfer RNA matches up alongside its complementary three bases called codon on the messenger RNA. Simultaneously, the amino acids on the transfer RNA links up with another amino acid already in place on the messenger RNA by a peptide link. This process continues as a chain of amino acids (polypeptide chain) is formed. When the process ends, the polypeptide chain formed moves from the transfer RNA into the cytoplasm of the cell and links up with other poly peptide chains to form a protein molecule.

3. Importance of protein synthesis: protein helps in building and repairing tissues, proteins are used in making enzymes and hormones and proteins are building block of bones, blood, skin and muscle.

Application (20 minutes)

Teacher activity: Teacher creates a scenario for the students to apply what they have learned. For example, three messenger RNA involved in the synthesis of a certain protein is having the codons CGA, GUC and GAC, what will be the bases of the anticodon that will pair with each of the codon?

Student activity: Students respond to teacher's question using what they have learned.

Closure (15 minutes)

Teacher activity: Teacher summarises the lesson and evaluates the lesson by asking questions based on the set objectives.

Student activity: Students take note and respond to the teacher's questions.

Assignment

Students are asked to do the following exercise:

Describe the relationship among DNA, RNA and protein molecule.

REACT lesson plan 1

Topic: CELL II

Subtopic: Protein synthesis

Duration: 150 minutes

Specific objectives: By the end of the lesson the student will be able to:

i. explain the term nucleic acid.

ii. name the types of nucleic acids.

iii. describe the double helix model of the structure of DNA.

iv. describe the structure of RNA.

v. outline the process of DNA replication.

Teaching/Learning material: Model of the structure of DNA and video on DNA replication.

Relating

1. Students are given a reading text on the application of the concept of nucleic acids, structure of DNA and RNA, protein synthesis and importance of protein synthesis in everyday life to read.
2. Teacher asks questions based on the reading text to activate students' prior knowledge on the concepts of nucleic acid, structure of DNA and RNA and DNA replication. Example, in which organelle of a cell are genetic materials found?
3. Students respond to teacher's questions. Example, genetic materials are found in the nucleus of a cell.

Experiencing

1. Students form groups of four and visit the school library to explore on the concept of nucleic acid, types of nucleic acid, structure of DNA and RNA and DNA replication using a printed guide given to them by the teacher.
2. Members of each group of students present their findings to the whole class for the other groups to assess and make corrections to their findings on the concepts they presented on.
3. Students observe a model of the structure of DNA and watch video the mechanism of DNA replication.

Main ideas

1. Nucleic acid is a complex substance found in the nucleus of cells which consists of nucleotides connected in a long chain.
2. The two types of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
3. The unit structure of DNA is called nucleotide which is made up of sugar, phosphate and nitrogenous bases. There are two types of nitrogenous bases; purines (Adenine [A] and Guanine [G]) and pyrimidines (Cytosine [C] and Thymine [T]). Two polynucleotide strands twisted about each other forms the DNA. The two strands run in opposite directions which makes the pairing of the bases possible. The adenine always pairs with thymine and cytosine always pairs with guanine. Hydrogen bonds link the bases. There

are two hydrogen bonds between A and T and three hydrogen bonds between C and G.

4. RNA is made up of a single strand polynucleotide. In RNA the base thymine is replaced by the base Uracil [C]. There are three types of RNA, these are, messenger RNA (mRNA), transfer RNA (tRNA) and ribosomal RNA (rRNA).
5. DNA replication occurs prior to cell division. Weak hydrogen bonds holding the two strands of DNA are broken under the influence of helicase, as a result the DNA unwinds into two strands. Free nucleotides in the nucleus assemble alongside each half strand to form two pairs of half strands. Hydrogen bonds between complementary base pairs join the half strands to form two identical double strands of DNA. The roles enzymes involved in DNA replication are; helicase breaks the hydrogen bonds to unwind the DNA strand, polymerase makes a copy of the DNA in the 5´ to 3´ direction on the leading strand and ligase binds Okazaki fragments on the lagging strand.

Applying

1. Students form groups of four and each group of students select five nitrogenous bases and construct:
   a. DNA molecule consisting of five nucleotides using the bases they selected.
   b. RNA molecule consisting of five nucleotides using the bases they selected.

2. Students answer few questions of the mechanism of DNA replication based a scenario created by the teacher.

Cooperating

1. Students form groups of two and through think-pair-share, they construct a Venn diagram on the difference between DNA and RNA and present their diagram to the class.
2. Students form groups of four members and each group of student discusses what will happen when particular enzyme is absent during DNA replication and present their responses to the class.

Transferring

Through groupwork, students find out the importance of DNA replication in living things.

REACT lesson plan 2

Topic: CELL II

Subtopic: Protein synthesis

Duration: 150 minutes

Specific objectives: By the end of the lesson the student will be able to:

i. outline the process of RNA transcription.

ii. describe the process of protein synthesis.

iii. explain the importance of protein synthesis for living things.

Teaching/Learning materials: Video on protein synthesis, computer and projector.

Relating

1. Students are given reading text on the concept of transcription, protein synthesis and importance of protein synthesis in everyday life.
2. Teacher ask questions based on the reading text to activate students' prior knowledge on the concepts of transcription, protein synthesis and importance of protein synthesis. Example, what nitrogenous bases are found in RNA molecule?
3. Students respond to teacher's questions. Example, the nitrogenous bases found in RNA molecule are adenine, cytosine, guanine and uracil.

Experiencing

1. Students form groups of four and visit the school library to explore on the concept of transcription, protein synthesis and importance of protein synthesis using a printed guide given to them by the teacher.
2. Members of each group of students present their findings to the whole class for the other groups to assess and make corrections to their findings on the concepts they presented on.
3. Students watch videos of the process of transcription and the process of protein synthesis.

Main ideas

1. A specific region of DNA molecule unzips to expose a sequence of base triplet for the synthesis of a particular protein. Free ribonucleotides now form a new strand as in DNA replication except that the new strand is made up of mRNA. The mRNA molecule

formed is complementary to the coded message on the DNA strand on which it was produced. The mRNA moves out of the nucleus through a nuclear pore into the cytoplasm and becomes attached to a ribosome.

2. Messenger RNA moves out of the nucleus of the cell into the cytoplasm where it associates itself with ribosomes and forms a site for the synthesis of protein, as it carries the template from the DNA. Transfer RNA folds to form a branched chain. There are 20 or more in a cell. One end of the transfer RNA links up with a specific amino acid during protein synthesis. A sequence of three bases called anticodon occurs at a point along the transfer RNA chain. The anticodon of each transfer RNA matches up alongside its complementary three bases called codon on the messenger RNA. Simultaneously, the amino acids on the transfer RNA links up with another amino acid already in place on the messenger RNA by a peptide link. This process continues as a chain of amino acids (polypeptide chain) is formed. When the process ends, the polypeptide chain formed moves from the transfer RNA into the cytoplasm of the cell and links up with other poly peptide chains to form a protein molecule.
3. Importance of protein synthesis: protein helps in building and repairing tissues, proteins are used in making enzymes and hormones and proteins are building block of bones, blood, skin and muscle.

Applying

3. Students form groups of four and each group of students will be a printed image of DNA molecules with different sequences bases to construct:
    a. RNA molecule that would be transcribed from their various DNA molecules.
    b. Students answer few questions of the mechanism of protein synthesis and importance of protein synthesis based on a scenario created by the teacher.

Cooperating

1. Students form groups of four and use a diagram to describe how protein is synthesised from a DNA molecule in the cell of an organism.
3. Through discussion, each group of students explain why it is necessary for cells to produce protein.

Transferring

1. Students are asked to find out where amino acids used for protein synthesis in the cell comes from.
2. Students are asked to find out how transcription and protein synthesis lead to variations in traits of humans.

7E lesson plan1

Topic: CELL II

Subtopic: Protein synthesis

Duration: 130 minutes

Specific objectives: By the end of the lesson the student will be able to:

i. explain the term nucleic acid.

ii. name the types of nucleic acids.

iii. describe the double helix model of the structure of DNA.

iv. describe the structure of RNA.

v. outline the process of DNA replication.

Teaching/Learning material: Model of the structure of DNA and video on DNA replication.

Elicit

Teacher asks students questions to gain attention of the students. Example, what are some of the organelles of a cell?

Students respond to teacher's questions. Example, some of the organelles of a cell are nucleus, ribosome, cytoplasm, mitochondrion and cell wall.

Engage

Teacher ask students to engage in think-pair-share to come up with the function of the nucleus of a cell.

Students engage in think-pair-share and present their answers to the class. Example, the nucleus contains the genetic materials.

Explore

1. Students are given printed guide help them explore on the concepts; nucleic acid, types of nucleic acid, the structure of DNA and RNA and DNA replication.
2. Students form groups of four and each group of students visits the school library to explore and come up with the meaning of nucleic

acid, type of nucleic acid, the structure of DNA and RNA and the mechanism of DNA replication.

Explain

1. Members of each group of students present their finding from the exploration on the concepts of nucleic acid, types of nucleic acid, structure of DNA and RNA and the mechanism of DNA replication to the class.
2. Students assess each groups' presentation.

Elaborate

1. Students make contributions and corrections to the concepts that each group presented in class.
2. Students observe a model of the structure of DNA and watch video on the process of DNA replication.

Main Ideas

1. Nucleic acid is a complex substance found in the nucleus of cells which consists of nucleotides connected in a long chain.
2. The two types of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
3. The unit structure of DNA is called nucleotide which is made up of sugar, phosphate and nitrogenous bases. There are two types of nitrogenous bases; purines (Adenine [A] and Guanine [G]) and pyrimidines (Cytosine [C] and Thymine [T]). Two polynucleotide strands twisted about each other forms the DNA. The two strands run in opposite directions which makes the pairing of the bases possible.

The adenine always pairs with thymine and cytosine always pairs with guanine. Hydrogen bonds link the bases. There are two hydrogen bonds between A and T and three hydrogen bonds between C and G.

4. RNA is made up of a single strand polynucleotide. In RNA the base thymine is replaced by the base Uracil [C]. There are three types of RNA, these are, messenger RNA (mRNA), transfer RNA (tRNA) and ribosomal RNA (rRNA).
5. DNA replication occurs prior to cell division. Weak hydrogen bonds holding the two strands of DNA are broken under the influence of helicase, as a result the DNA unwinds into two strands. Free nucleotides in the nucleus assemble alongside each half strand to form two pairs of half strands. Hydrogen bonds between complementary base pairs join the half strands to form two identical double strands of DNA. The roles enzymes involved in DNA replication are; helicase breaks the hydrogen bonds to unwind the DNA strand, polymerase makes a copy of the DNA in the 5´ to 3´ direction on the leading strand and ligase binds Okazaki fragments on the lagging strand.

Evaluation

1. Teacher administer a short test on the concepts of nucleic acids and DNA replication.
2. Individual students take the test and the test is scored by the students.
3. Through discussion teacher discusses the answers to the test items with the students.

Extend

Through groupwork, students find out the importance of DNA replication to organisms.

7E lesson plan 2

Topic: CELL II

Subtopic: Protein synthesis

Duration: 200 minutes

Specific objectives: By the end of the lesson the student will be able to:

i. outline the process of RNA transcription.

ii. describe the process of protein synthesis.

iii. explain the importance of protein synthesis for living things.

Teaching/Learning materials: Video on protein synthesis, computer and projector.

Elicit

Teacher asks questions to gain attention of the students. Example, what the benefits of protein to the human body?

Students respond to teacher's questions. Example helps in the repair of tissues in the human body.

Engage

Teacher asks questions to review students' relevant previous knowledge. Example, Describe the structure of RNA molecule.

Students respond to teacher's questions. Example, RNA is a single strand nucleic acid with the nitrogenous bases; adenine, cytosine, guanine and uracil.

Explore

1. Students are given a printed guide to help them explore on the concepts of transcription and protein synthesis and importance of protein synthesis.
2. Students form groups of four and each group of students visit the library to explore on the concepts of transcription, protein synthesis and importance of protein synthesis.

Explain

1. Members of each group of students present their findings from the exploration on the concepts on transcription, protein synthesis and importance of protein synthesis to the class.
2. Students assess the findings presented by each group of students.

Elaborate

1. Through discussion, students make contributes and corrections to findings presented by each group of students.
2. Students watch video on transcription and protein synthesis.

Main ideas

1. A specific region of DNA molecule unzips to expose a sequence of base triplet for the synthesis of a particular protein. Free ribonucleotides now form a new strand as in DNA replication except that the new strand is made up of mRNA. The mRNA molecule formed is complementary to the coded message on the DNA strand on which it was produced. The mRNA moves out of the nucleus through a nuclear pore into the cytoplasm and becomes attached to a ribosome.

2. Messenger RNA moves out of the nucleus of the cell into the cytoplasm where it associates itself with ribosomes and forms a site for the synthesis of protein, as it carries the template from the DNA. Transfer RNA folds to form a branched chain. There are 20 or more in a cell. One end of the transfer RNA links up with a specific amino acid during protein synthesis. A sequence of three bases called anticodon occurs at a point along the transfer RNA chain. The anticodon of each transfer RNA matches up alongside its complementary three bases called codon on the messenger RNA. Simultaneously, the amino acids on the transfer RNA links up with another amino acid already in place on the messenger RNA by a peptide link. This process continues as a chain of amino acids (polypeptide chain) is formed. When the process ends, the polypeptide chain formed moves from the transfer RNA into the cytoplasm of the cell and links up with other poly peptide chains to form a protein molecule.
3. Importance of protein synthesis: protein helps in building and repairing tissues, proteins are used in making enzymes and hormones and proteins are building block of bones, blood, skin and muscle.

Evaluation

1. Teacher administer a short test on the concepts of transcription, protein synthesis and importance of protein synthesis.
2. Individual students take the test.
3. Each student's paper is scored by another student and the solutions to the test items are discussed by the teacher with the students.

Extend

Through groupwork, each group of students identify two proteins synthesised in the human body and they:

vi. Identify the amino acids that forms the protein they selected.

vii. Identify the codons and anticodons associated with the amino acid they identify.

Data Processing and Analysis

The data that were collected were coded, and they were analysed to test the stated null hypothesis and answer the research questions. To obtain accurate statistical results, the students' pretest scores with missing corresponding posttest scores were remove and the posttest scores with missing corresponding pretest scores were also removed. Some test scores were missing because, some of the students were not present in class during the data collection period.

One-way analysis of variance (one-way ANOVA) was employed to analyse the achievement test scores of the pretest and the posttest. One-way ANOVA was used because, the data involved only one independent variable (teaching approach) with three groups (REACT, 7E and Conventional approaches). The pretest scores were analysed to determine whether the performance of the students in the three groups were at par. The posttest scores were analysed to test the first null hypothesis and because the first null hypothesis was rejected, a post-hoc analysis was done by means of the Bonferroni test to establish where the differences in the means scores occurred. Independent sample t-test was employed to analyse the achievement

test scores of the posttest to test the second, third and fourth null hypotheses. Independent sample t-test was employed because, the data involved one categorical independent variable with only two groups, thus, level of achievement (low achievers and high achievers) and one continuous dependent variable (achievement test score).

With the research questions, students' perceptions about the REACT strategy and the 7E learning cycle which were obtained from the interview served as the qualitative data. Thematic content analysis technique was employed to analyse the students' perceptions about the REACT and 7E models of teaching to answer the two research questions. Thematic content analysis was employed because, grouping the students' perceptions from the semi-structured interview about the REACT and 7E models of instruction will help in easier understanding and interpretations of the students' thoughts about the approaches they were exposed to.

Chapter Summary

The research design, population used for the study, procedures used for sampling, data collection instruments and data processing and analysis are the aspects of the study which were dealt with in this chapter. The sampling technique used in this study is the simple random sampling of schools, classes and students in the Ajumako-Enyan-Essiam District while one-way ANOVA, and independent sample t-test were used to analyse the quantitate data and thematic content analysis technique was employed to analyse the qualitative data.

Extraneous variables that can affect the result of this study such as students' experience, ability, maturation, and age could not be controlled in this study. The findings of this study are generalised to only the schools that participated in this study because only three intact classes of these schools were used in the study and not all Form two Biology classes in the Ajumako-Enyan-Essiam District.

CHAPTER FOUR

RESULTS AND DISCUSSION

This study sought to find out the effect of the REACT model, 7E and conventional models of teaching on Senior High School students' achievement in molecular genetics concepts as well as identify students' perceptions about the REACT strategy and 7E learning cycle model of teaching. In this chapter, the results of the data collected for the study are presented and discussed in relation to the hypotheses and research questions that guided the research.

To obtain appropriate data for the research, embedded mixed methods design was employed in the study where the quantitative aspect involved quasi-experimental design specifically the pretest-posttest nonequivalent group design and the qualitative aspect involved semi-structured interview. The quantitative data was analyzed using one-way analysis of variance (one-way ANOVA) and independent samples t-test. Effect size was also calculated to identify the practical significance of the statistical results. For the qualitative aspect of the research, data was analyzed using thematic content analysis technique and the results were presented narratively.

Three schools from the five public Senior High Schools in the Ajumako- Enyan-Essiam District who offer elective Biology were randomly selected. One intact Form 2 Biology class from each of the selected schools was randomly selected. Each of the three intact classes was randomly assigned to a group, thus, the REACT group, 7E group and the conventional group. All members of each of the selected intact class participated in the study. There were 27 students in the REACT group, 22 students in the 7E group and 30

students in the conventional group. Also, 10 students were randomly selected from each of the REACT and 7E groups and interviewed to gouge their perceptions of the teaching approaches.

Analysis and discussion of hypotheses and research questions

Null Hypothesis one: There is no statistically significant difference in the achievement scores of students exposed to the REACT model, the 7E model and the conventional approach.

The first hypothesis sought to find out if there was any statistically significant difference among the REACT, 7E and conventional approaches of teaching. To ensure that all the groups were at par at the onset of the research, the pretest scores of the REACT group, 7E group and conventional groups were compared using one-way ANOVA. As shown in Table 1, there was no statistically significant difference in the pretest scores among the REACT group, the 7E group and the conventional group ($F(2, 76) = 3.073$, $p = .072$). This means that, on the average, the achievement of the students in all the three groups were similar before the interventions were introduced.

Table 1: Results of One-way ANOVA for Pretest of REACT, 7E and Conventional Groups

Sources	df	Sum of Squares	Mean Squares	F	*p*
Between Groups	2	137.316	68.658	3.073	.072
Within Groups	76	1698.229	22.345		
Total	78	1835.544			

Sources: Field survey (2019)

The one-way ANOVA was again used to compare the posttest scores of the three groups and the results presented in Table 2. As seen from Table 2,

there was a statistically significant difference among the posttest scores of the REACT group, the 7E group and the conventional group (F (2,76) = 15.484, p < .001). The null hypothesis which stated that there is no statistically significant difference in the achievement scores of students exposed to the REACT model, the 7E model and the conventional approach is therefore rejected.

Table 2: Results of One-way ANOVA for Posttest of REACT, 7E and Conventional Groups

Sources	df	Sum of Squares	Mean Squares	F	*p*
Between Groups	2	380.385	190.193	15.484	.000*
Within Groups	76	933.513	12.283		
Total	78	1313.899			

*Significant, since p < 0.05

Sources: Field survey (2019)

Since there were three groups, it was necessary that further analysis was conducted to determine where the difference lay. Thus, to identify where the difference lay, post-hoc comparisons using Bonferroni test was conducted and the results shown in Table 3. The Bonferroni test indicates that there was no statistically significant difference in the posttest scores between the REACT group (M = 16.48, SD = 3.567) and the 7E group (M = 15.18, SD = 3.936, p = .602). There was, however, a statistically significant difference in the posttest scores between the REACT group (M = 16.48, SD = 3.567) and the conventional group (M = 11.50, SD = 3.093, p < .001). From the mean values, the students in the REACT group outperformed their counterparts in the conventional group. Again, there was a statistically significant difference

in the posttest scores between the 7E group (M = 15.18, SD = 3.936) and the conventional group (M = 11.50, SD = 3.093, *p* = .001) with their means indicating that the 7E group performed significantly better than the conventional group.

To determine the magnitude of the difference in the posttest scores among the REACT, 7E and conventional group, effect size was calculated using partial eta squared. An effect size index of .290 was obtained which according to Cohen (1988) indicates a large effect size for the difference among the posttest scores of the REACT, 7E and conventional groups.

Table 3: Post Hoc Analysis of Posttest Scores for REACT Group (RG), 7E Group (7E) and Conventional Group (CG) Using Bonferroni Test

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence interval for Difference[b]	
					Lower Bound	Upper Bound
RG	7E	1.300	1.007	.602	-1.16	3.76
	CG	4.981*	.930	.000	2.71	7.26
7E	RG	-1.300	1.007	.602	-3.76	1.16
	CG	3.682*	.984	.001	1.27	6.09
CG	RG	-4.981*	.930	.000	-7.26	-2.71
	7E	-3.682*	.984	.001	-6.09	-1.27

*Significant, since p < 0.05

Source: Field survey (2019)

The results of this research mean that the students who were taught with the REACT and 7E models performed at a similar level after the

treatment but they outperformed the students who were taught with the conventional approach.

The finding that students instructed with REACT outperformed their counterparts in the conventional approach, agrees with Doğru and Özsevgeç (2014) who found that REACT strategy was more effective than the conventional approach in increasing Turkish students' level of understanding on nitrogen cycle concepts. Gül (2016) also found that the REACT strategy improved retention of learning in photosynthesis better than the conventional approach when she investigated the effect of the REACT strategy on 11th grade Turkish students' retention of understanding of the concept of photosynthesis.

Ültey (2012), Ültey and Alev (2017), Bilgin and Yiğit (2017) and Günter (2018) all found the REACT strategy to be more effective and efficient in improving students' academic achievement than the conventional approach. Ültey (2012) and Ültey and Alev (2017) found that students' conceptual learning on impulse and momentum were improved when the REACT strategy was employed whereas Bilgin and Yiğit (2017) and Günter (2018) found the REACT strategy to have produced better academic achievement in Chemistry students.

The discussion shows that the REACT strategy has been found to be effective in improving students' achievement across all the science subjects. Aside the subject areas, REACT has been revealed to be appropriate for teaching at all levels. For instance, Gül (2016) worked with 11th graders in biology related area while Bilgin and Yiğit (2017) used 6th graders in their

research. At the higher academic levels, REACT has also been found to be effective and appropriate since Ültey and Alev (2017) worked on prospective science teachers and Günter (2018) used college students in her research. The results of the current study which was conducted on senior high students support the effectiveness of the REACT strategy at all levels of the educational system.

The results of the current research also show the effectiveness of the 7E approach in improving students' achievement as compared to the conventional approach. The outcome of the current research is not an isolated case in that Shaheen and Kayani (2015) also found that the 7E model proved to have increased Pakistani students' achievement in Biology more than the traditional instructional model. In Turkey, Gök (2014) revealed that 7E learning cycle instruction was more effective than the curriculum-oriented instruction when both instructions were used to teach concepts on human body systems to Turkish middle school students.

Sarac and Tarhan (2017) investigated the effect of a tradition approach and multimedia assisted 7E learning cycle model on the achievement and retention of fifth grade Turkish students by teaching concepts on change of matter and identified that the multimedia assisted 7E model had a significantly positive effect on students' achievement and retention than the traditional approach. Siribunnam and Tayraukham (2009) compared the effect of 7E approach with the effect of the constructivist approach Know-Want to know-Learned (KWL) and a conventional approach on Thai students' analytical thinking, achievement and attitude towards chemistry learning. The study

showed that the students who were taught with the 7E approach outperformed the students who were taught with the KWL and conventional approaches in terms of analytical thinking, achievement and attitude.

In teaching and learning of Physics, the results of the study by Kanli and Yagbasan (2008) revealed that the laboratory activities based on the 7E approach was more effective than conventional approach in developing Turkish university students' science process skills and remedying misconceptions about force and motion. At the lower level of the educational system, Yerdelen-Damar (2013) investigated the effect of 7E model on tenth grade Turkish students' achievement and epistemological understanding in physics, and realized that the students exposed to the 7E outperformed those exposed to the traditional approach.

There seems to be enough evidence to support the fact that students instructed through the 7E approach usually outperform their counterparts instructed through the conventional approach. The discussion has provided ample support for the findings and outcome of the current study whereby the 7E group had better achievement scores than their colleagues in the conventional group. Overall, the REACT and 7E approaches are predominantly effective in improving students' achievement at all levels of the educational ladder and across different subject areas.

Null Hypothesis two: There is no statistically significant difference between the performance of high achievers and low achievers when exposed to the REACT model.

The null hypothesis two sought to indicate that there is no statistically significant difference in the posttest scores of low achievers and high achievers when they were exposed to the REACT model. Independent sample t-test was used to analyze the pretest scores and posttest scores of the REACT group's low achievers and high achievers. Table 4 indicates that there was a statistically significant difference in the pretest scores between the low achievers (M = 14.57, SD = 3.502) and the high achievers (M = 22.00, SD = 2.677, t (25) = 6.156, $p < .001$). With the posttest scores, Table 4 indicates that there was a statistically significant difference in the posttest scores between the low achievers (M = 14.07, SD = 2.702) and high achievers (M = 19.08, SD = 2.362, t (25) = 5.108, $p < .001$). Therefore, the null hypothesis which states that there is no statistically significant difference between the performance of high achievers and low achievers when exposed to the REACT model is rejected.

Table 4: Results of Independent Sample T-test for Pretest and Posttest Scores of Low and High Achievers in the REACT Group (RG)

Variable	Achievement level	N	Mean	t	df	p
Pretest	Low achievers in RG	14	14.57	-6.156	25	.000*
	High achievers in RG	13	22.00			
Posttest	Low achievers in RG	14	14.07	-5.108	25	.000*
	High achievers in RG	13	19.08			

*Significant, since p < 0.05.

Source: Field survey (2019)

This result means that the REACT strategy could not bridge the gap between high and low achievers within the group. This finding agrees with that of Jelatu, Sariyasa and Ardana (2018) when they investigated the effect of GeoGebra-aided REACT strategy on eighth grade Indonesian students' understanding of concepts on geometry. Their study revealed that the REACT strategy led to higher achievement in high ability students than low ability students in the understanding of concept on geometry. Also, the finding of Demircioğlu, Vural and Demircioğlu (2012) supports the findings of the current study when they sought to identify the effect of teaching material developed based on REACT strategy on students' achievement. The study revealed that the REACT strategy was more effective in improving the achievement of high achievers.

Even though the students in the REACT group were randomly grouped so that the high achievers can assist the low achievers in constructing and understanding the new knowledge they were to learn, the gap between the achievement levels of the high and low achievers could not be bridged after they were exposed to the REACT strategy. Hence, if the enabling environment was created by the teacher and the low achievers could not perform better, then the inability of the REACT strategy to bridge the gap between performance of the low and high achievers in the current study could possibly be due to the low achievers' individual construction of knowledge.

Null Hypothesis three: There is no statistically significant difference between the performance of high achievers and low achievers when exposed to the 7E model.

The third null hypothesis sought to indicate that there is no statistically significant difference in the posttest score between low achievers and high achievers when they were exposed to the 7E model. Independent sample t-test was used to analyze the pretest scores and posttest scores of the 7E group's low achievers and high achievers. Table 5 indicates that there was a statistically significant difference in the pretest scores between the low achievers (M = 16.80, SD = 3.615) and the high achievers (M = 24.58, SD = 2.466, t (20) = 5.985, $p < .001$). With the posttest scores, Table 5 indicates that there was a statistically significant difference in the posttest scores between the low achievers (M = 12.70, SD = 2.908) and high achievers (M = 17.25, SD = 3.519, t (20) = 3.261, $p = .004$). Therefore, the null hypothesis which states that there is no statistically significant difference between the performance of high achievers and low achievers when exposed to the 7E model is rejected.

Table 5: Results of Independent Sample T-test for Pretest and Posttest Scores of Low and High Achievers in the 7E Group (7E)

Variable	Achievement level	N	Mean	t	df	p
Pretest	Low achievers in 7E	10	16.80	-5.985	20	.000*
	High achievers in 7E	12	24.58			
Posttest	Low achievers in 7E	10	12.70	-3.261	20	.004*
	High achievers in 7E	12	17.25			

*Significant, since p < 0.05

Source: Field survey (2019)

This result means that the 7E learning cycle could not bridge the gap between high and low achievers within the group.

This finding agrees with findings of Sornsakda, Suksringarm and Singseewo (2009) when they compared the effectiveness of 7E learning cycle approach to a conventional approach on the achievement, integrated science processing skills and critical thinking of students. Their study revealed that the high achievers performed better than the low achievers in terms of the achievement, integrated science processing skills and critical thinking. A study by Yerdelen-Damar (2013) revealed that although the students exposed to the 7E outperformed the students who were exposed to the traditional approach, the 7E was effective for promoting the physics achievement for high achievers than the achievement of low achievers.

The inability of the 7E learning cycle to bridge the gap between the performance of the high and low achievers in the 7E group may possible be due to the differences in how individual students construct their knowledge. This is because, the necessary conducive environment was created by the teacher using collaborative group facilitation whereby students were to help each other to construct a socially acceptable knowledge. The inability of the low achievers to construct appropriate knowledge which reflected in their low performance exposes the strength in individual abilities in the learning process.

Null Hypothesis four: There is no statistically significant difference between the performance of high achievers and low achievers when exposed to the conventional approach.

The null fourth hypothesis sought to indicate that there is no statistically significant difference in the posttest score between low achievers and high achievers when they were exposed to the conventional approach. Independent sample t-test was used to analyze the pretest scores and posttest scores of the conventional group's low achievers and high achievers. Table 6 indicates that there was a statistically significant difference in the pretest scores between the low achievers (M = 14.29, SD = 2.758) and the high achievers (M = 21.38, SD = 2.473, t (28) = 7.425, $p < .001$). With the posttest scores, Table 6 indicates that there was a statistically significant difference in the posttest scores between the low achievers (M = 10.14, SD = 3.134) and high achievers (M = 12.69, SD = 2.600, t (28) = 2.431, $p = .022$). Therefore, the null hypothesis which states that there is no statistically significant difference between the performance of high achievers and low achievers when exposed to the conventional approach is rejected.

Table 6: Results of Independent Sample T-test for Pretest and Posttest Scores of Low and High Achievers in the Conventional Group (CG)

Variable	Achievement level	N	Mean	t	df	p
Pretest	Low achievers in CG	14	14.29	-7.425	28	.000*
	High achievers in CG	16	21.38			
Posttest	Low achievers in CG	14	10.14	-2.431	28	.022*
	High achievers in CG	16	12.69			

*Significant, since p < 0.05

Source: Field survey (2019)

The results mean that the conventional approach could not bridge the gap between high and low achievers within the group. This finding agrees with the study conducted by Jelatu, Sariyasa and Ardana (2018) when they compared the effect of a conventional approach with REACT strategy on Indonesian eighth grade students' understanding of geometry concepts. Their study revealed that the conventional approach led to higher achievement in high ability students than low ability students in the understanding of concept on geometry. A similar finding was also obtained by Sam, Owusu and Anthony-Krueger (2018) when they compared the effectiveness of 3E, 5E and conventional teaching strategies on Senior High School students' achievement in high school biology. Their study revealed that the high achievers performed better than the low achievers when they were taught using the conventional approach.

Although the students who were taught with the conventional approach received direct instructions and teacher's explanations, the gap between the performance of high and low achievers could not be bridged just as in the cases of the REACT and 7E approaches. Therefore, the low performance of the low achievers may possible be due to differences individual students' construction of knowledge and differences in the level of students' innate abilities to achieve academically.

Research Question One: What are students' perceptions about the REACT model of teaching?

To determine the students' perception about the REACT strategy, semi-structured interviews were conducted after they had been taught with the REACT strategy and thematic content analysis technique was used to analyze the responses from the students. Students were asked to indicate the positives and negatives associated with the REACT strategy they had been exposed to during the lesson. On the positive perceptions side, students' views were put into four themes. These themes are understanding of concepts, searching for information, relating concepts to prior learning and sharing of information or group work.

The students that were interviewed noted that the REACT strategy made the lessons understandable. The aim of every teacher is to represent the concepts such that their students will be able to conceptualize and comprehend the concepts easily. It is therefore refreshing to glean that most of the students that were interviewed had the view that the REACT approach used to teach them helped them to understand the lessons. In talking about the approach, for example, Student 3 noted that she "got the understanding of the topic". This view was not expressed by her alone since Student 6 also noted that "for now my understanding about the DNA and RNA has increased". Student 7 was very confident about the level of his understanding in the concepts he has learnt and accentuated that he has "understood it [lesson] very well and if they give me any test on it, I can answer".

Most of the students perceived the REACT strategy to have led them to search for information on by themselves. The students asserted that the approach moved away from the teacher-led teaching they were used to where

the information on concepts were provided by the teacher to where they had to search for information on the concepts to be learnt. “You made us get a lot of information because you told us to find out about the topic” is how Student 1 captured his views about the REACT strategy. From the perspective of Student 3 the search for information made her “gain information before we went through the lessons”. Student 5 argued that “she got more information and explored very much” because students were allowed to search for information.

Meaningful learning is achieved when new learning can be related to prior learning as a form of anchorage or subsumption. Thus, most teachers seek to establish a connection between new ideas being presented and the learners’ relevant previous knowledge and learning. In REACT, students are encouraged to relate concepts to their prior learning. Students in the current study received the idea of relating new concepts to prior learning extremely well. “In the course of the lesson, you brought what we have already been taught, that is the parts of the cell to make the topic easy” was how Student 2 captured her views on the REACT strategy. Student 3 also noted that “because you brought in the parts of the cell that we already know, that helped us a lot.” Student 4 asserted that “the cell we have learned it already and for you introducing it again made the learning became easier for us to learn the new thing.”

As a constructivist strategy, REACT emphasizes the sharing of ideas among students. In view of that students were grouped during the instructional delivery process. Most of the students had the view that the REACT strategy

helped them to share information among themselves. For example, Student 3 asserted that 'the groupwork was good because for some information, it was my friends that gave them to me." Although in group work some students tend to be passive if care is not taken, students in the REACT group accentuated team effort during the learning process as expressed by Student 5 that "everybody in my group brought his or her ideas for us to combine them and so, we got more information." The group effort was also appreciated by Student 7 who asserted that "being in the group helped us to join our hands together through discussion and had solution to the questions that you gave to us."

All the students had the view that the REACT strategy was completely positive and did not hold any negative view about it. Student 2 alluded that "for the lessons, I couldn't see any negative thing about it. All that I saw good (sic).' Student 4 felt "the teaching style was perfect. There was nothing wrong with it." Student 6 seemed to have agreed with his colleagues when he emphasized that "there wasn't any bad thing about the new teaching style you used to teach.' Student 8: 'I did not see anything bad about it. It was good."

The teacher observed that even though the REACT strategy motivated the students to learn the concepts on their and the instructional activities were learner-centered instead of teacher-centered, the approach was time consuming. As it took about two hours for the teacher to teach the lessons using the conventional approach, it took about five hours for the REACT group to complete the same lesson.

These findings of the current study agree with the research by Karsli and Yiğit (2016) when they conducted a semi-structured interview on 12th grade students' perceptions about the REACT strategy after they have been taught concepts on alkanes using a worksheet developed based on REACT strategy. The result of their study showed that the students perceived the alkane worksheet based on REACT strategy to have connected the new concept they learned to what they already know, made the chemistry lesson easy to understand and motivating. A similar result was obtained by Günter (2018) when she investigated the effect of REACT strategy on students' achievement in concepts on solubility equilibrium and then conducted a structured and semi structured interview on the students' perception about the REACT strategy. The thematic content analysis of the interviews of Günter's study revealed that, majority of the students viewed the REACT strategy to have made the concept they were taught to be understandable, relevant to everyday life and they also thought groupwork helped them to share information through discussion.

Research Question Two: What are students' perceptions about the 7E model of teaching?

To determine the students' perception about the 7E learning cycle, thematic content analysis technique was employed to analyze the students' responses from the semi-structured interviews conducted after they have been taught with the 7E learning cycle. Students were asked to indicate the positives and negatives associated with the 7E learning cycle they had been exposed to during the lessons. On the positive perception side, the views of the

students were grouped into four themes. These themes are understanding of concepts, lesson being interesting, searching for information and group work.

All the students that were interviewed noted that the 7E approach made the lesson understandable. Student 1 stated that he "got the understanding as we [students] were doing the presentation''. Aside student 1, Student 5 also had the same view when she noted that "the style of teaching made me understood it [lesson]". Student 6 confirmed this view of the other students when she asserted that "the way we learn topic increased my understanding"

Some students held the thought that the 7E model made the lessons interesting. The students opined that the approach made them become interested in the lesson as some aspect of the teaching approach attracted and held their attention. "I think the topic was so interesting because the video we watched can help us to remember certain steps in protein synthesis and transcription" is how Student 2 captured his view about the approach. Student 3, also viewed the approach to be interesting as she noted that "the style of teaching was interesting, so, I was interested in learning the topic''.

In inquiry-based learning, teachers provide enabling environment for learners to explore by searching for information to construct and understand new concepts they are to learn. The 7E learning cycle requires that learners search for relevant information to create new knowledge. Students in the current study were given the opportunity to explore which helped them to learn effectively. Most of the students had the perception that the 7E learning cycle approach provided the opportunity for them to search for information. As noted by Student 1 "we [group members] consulted some textbooks which

helped us to get more ideas of the things we were learning". A similar view held by Student 4 when she noted that "the style we used to learn helped us to get more information on the topic.' Student 6 asserted that "when we were learning, we gave portions to everyone to search for information and bring them so we can all benefit".

The 7E learning cycle as student-centered strategy gives importance to collaborative learning so that students can learn from each other through sharing pf information. In view of that students were grouped during the instructional delivery process. All the students had the perception that group learning in the 7E learning cycle was helpful. For example, Student 1 asserted that "working in groups was very helpful as were able to compare information". Also, Student 2 noted that "the groupwork helped us to share the ideas from each other". The students embraced the collaborative learning they engaged in during the instructional process as can be seen in the comment of Student 4 that "you did not just come and teach us the topic but every group learned it and came and presented so, it helped us to do more work on the topic". Even though there was the possibility that some group members will be passive, the collaborative learning environment helped all group members to be active. For instance, Student 3 noted that "all the group members brought their ideas as we were learning". Student 4 also had the same view as she asserted that "we all came together to do the group discussion, so I got more information about the topic". Student 7 was convinced that the groupwork was helpful and this is how she captured her view; "we all contributed during the group studies which helped us".

Most of the students viewed the 7E learning cycle of teaching to be completely positive and had no negative perception about the teaching approach. For example, Student 3 indicated that "I did not see anything bad thing about the teaching style". Student 7 seemed to have agreed with her colleague when she noted that "I do not have any negative thing to say about the style of teaching".

However, there were few students who provided some negative perceptions about the 7E approach. Few of the students had the perception that the teacher was passive during the 7E instructional process. Student 6 asserted that "we needed more explanations from you [teacher] too, so that we can get more knowledge". Student 2 appeared to agree with her colleague when she indicated that "madam, the only thing I can say is that you should have given us notes too.'

The teacher observed that the 7E learning cycle was time intensive as it involves several stages of learning. It took about five and half hours to complete the lessons using the 7E approach whiles the same lessons were taught by the teacher using the conventional approach in a less time.

The findings of the current study agree with the study by Saraç and Sekerci (2018) when they assessed the opinions of students about a multimedia assisted instruction designed based on 7E. Their study revealed that students perceived the 7E model to have given them the opportunity to work in group and hence they were actively involved in the lesson, made them excited about the lesson and increased their interest to learn. Again, a study by Turgut, Gürbüz and Salar (2013) also support the findings of the current study

when they investigated the effect of 7E model of teaching on the achievement and retention of sixth grade Science and Technology course students in the unit Electricity in Our Life. Their study revealed the students perceived the 7E learning cycle to have aroused their interest to learn.

Demirdag *et al.* (2011) investigated chemistry teachers' view on the requirement and difficulties of developing instructional activities based on 7E model. The study revealed that, even though the teachers had the view that the model provides positive contributions to meaningful learning and learning by inquiry, they held the view that it was difficult and time consuming for them to develop activities based on 7E model.

Chapter summary

This chapter discussed the finding of the study. Four null hypotheses and two research questions were tested and answered respectively when the data were analysed and the results of the analysis were discussed. From null hypothesis one, the study found out that both REACT strategy and 7E learning cycle were more effective than the conventional approach but the effectiveness of REACT strategy and 7E learning cycle were at par when they were used to teach concepts on molecular genetics.

From null hypothesis two, the study found out that although the REACT strategy was effective than the conventional approach, the REACT strategy could not bridge the gap between the performance of the low achievers and the high achievers in the group.

From null hypothesis three, the study found out that generally the 7E learning cycle was effective but it was not able to bridge the gap between the performance of low achievers and high achievers in the group.

From null hypothesis four, the study found out that the conventional approach could not bridge the gap between the achievement of high achievers and low achievers in the group.

From the research question one, the study found out that all the students had positive perceptions about the REACT strategy of teaching and learning when the approach was used to teach them concepts on molecular genetics. The students' positive perceptions were; searching for information, relating concepts to prior learning and sharing of information. They student held no negative perception or thought about the approach. Also, the teacher observed that the REACT strategy was time intensive as compared to the conventional approach.

Finally, from the research question two, the study revealed that most of the students had positive perceptions about the 7E learning cycle of teaching and learning when the approach was used to teach them concepts on molecular genetics. The students' positive perceptions were; understanding of concepts, lesson being interesting, searching for information and group work. However, few of the students held the perception that the teacher is passive when the approach was used to teach them. The teachers also observed that it took more time to complete the lessons using the 7E learning cycle.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The aim of this research was to determine the effectiveness of the REACT, 7E and conventional models of teaching on Ghanaian SHS students' achievement on concepts in molecular genetics as well as gouge the perceptions the SHS students have about the REACT and 7E models of teaching. The null hypotheses and research questions that guided this research are as follow:

H_{O1}: There is no statistically significant difference in the achievement scores of students exposed to the REACT model, the 7E model and the conventional approach.

H_{O2}: There is no statistically significant difference between the performance of high achievers and low achievers when exposed to the REACT model.

H_{O3}: There is no statistically significant difference between the performance of high achievers and low achievers when exposed to the 7E model.

H_{O4}: There is no statistically significant difference between the performance of high achievers and low achievers when exposed to the conventional approach.

Research question one: What are students' perceptions about the REACT model of teaching?

Research question two: What are students' perceptions about the 7E model of teaching?

To collect appropriate data to test the hypotheses and answer the research questions, the embedded mixed method approach in which the

qualitative aspect served a supportive role to the quantitative aspect of the research was utilised in this study. The quantitative design involved the use of quasi-experiment specifically the pretest-posttest non-equivalent group design. The qualitative design involved the use of semi-structured interview.

Three senior high schools in the Ajumako-Enyan-Essiam District were randomly selected. One intact Elective Biology class was randomly selected from each of the selected schools to participate in this research. The three intact classes were randomly assigned as the REACT, 7E and conventional groups with 27, 22 and 30 students respectively. A pretest on concepts in diversity of life and life processes in living things, which all the three groups had been thought, was administered to the students to find out if the average achievement level of the groups were at par and also to categorise members of each group into low achievers and high achievers. I taught concepts on molecular genetics to the REACT, 7E and conventional groups using the REACT, 7E and conventional models respectively. After each group had been taught with an intervention, a posttest on concepts on molecular genetics were administered to the students. Ten (10) students were randomly selected from each of the REACT and 7E groups and through semi-structured interview, the perceptions about each of the approaches were sought and audio recorded. The recorded interviews were transcribed.

The research involved both quantitative and qualitative data analyses. With the quantitative data, one-way analysis of variance and independent sample t-test were employed to test the null hypotheses. In the case of the qualitative data, the students' responses from the semi-structured interview on

their perceptions about the REACT and 7E models were analysed using thematic content analysis.

Summary of key findings

The following key findings were obtained from this study:

Differences in achievement among the REACT, 7E and conventional models of teaching

The one-way ANOVA revealed that there was statistically significant difference among the REACT, 7E and conventional groups in their posttest scores. The results showed that both REACT and 7E students performed better than their colleagues in the conventional. However, there was no difference between the achievement of REACT and 7E students.

The findings are supported by the result of the study by Qadri1, Ikhsan and Yusriza (2019) when they conducted a pretest-posttest experimental research to compare the effect of REACT and conventional approaches on students' performance in mathematics. Their study revealed that the students who were exposed to the REACT strategy outperformed their counterparts who were exposed to the conventional approach. Again, a study by Shaheen and Kayani (2015) also supports the finding of the current study when their study revealed that the 7E model increased Pakistani students' achievement in Biology more than the traditional instructional model.

Differences in the achievement of low and high achievers in the REACT group

The results from the analysis of the posttest scores of the REACT group using independent sample t-test showed that there was statistically significant difference between the low achievers and high achievers in the REACT group. The high achievers performed better than the low achiever in the REACT group.

This finding of the REACT strategy not bridging the gap between the high achievers and low achievers is consistent with the study by Jelatu, Sariyasa and Ardana (2018) when they investigated the effect of GeoGebra-aided REACT strategy on students' understanding of concepts on geometry. Their study showed that the REACT strategy led to higher achievement in high ability students than low ability students in the understanding of concept on geometry, thus, the approach could not bridge the gap between their achievement.

Differences in the achievement of low and high achievers in the 7E group

In the 7E group, it was revealed that there was a statistically significant difference between the different achievement groups. The high achievers outperformed the low achievers in the group just as they did in the pretest.

The finding that the 7E learning cycle could not bridge the gap between the performance of low achievers and high achievers is supported by the study conducted by Yerdelen-Damar (2013) which indicated that, although the students exposed to the 7E outperformed the students who were exposed to

the traditional approach, the 7E was effective for promoting the physics achievement for high achievers than the achievement of low achievers.

Differences in the achievement of low and high achievers in the conventional approach

The results of independent sample t-test of the posttest scores of the conventional group showed that there was a statistically significant difference between the low and high achievers. The high achievers performed better than the low achievers in the group.

This finding of the current study that the conventional approach was not able to bridge the gap between the low and high achievers is consistent with the study by Sam, Owusu and Anthony-Krueger (2018) when they compared the effect of 3E, 5E and conventional approaches on students' achievement in high school biology. Their study revealed that the high achievers performed better than the low achievers when they were taught using the conventional approach, thus, the conventional approach did not bridge the gap between their achievement.

Perception of students about the REACT model

Thematic content analysis of the students' response from the semi-structured interview revealed that all the students had positive perceptions about the REACT strategy after the approach has been employed to teach them. The students held the perception that the REACT strategy of teaching made the lessons understandable, helped them to search for information, related their prior knowledge to the new concept that was taught and also facilitated information sharing among themselves. This finding supports some

of the findings of Karsli and Yiğit (2016) and Günter (2018) when found out that students perceived the REACT strategy to have made them understand the concepts taught to them, related the new concepts to what they already know and aided them to share information. Also, the teacher observed that the REACT strategy-based lesson demanded a lot of time which will make it very difficult for teachers to employ in their teaching since it may not help them complete the syllabus.

Perception of students about the 7E learning cycle

Thematic content analysis of the students' response from the semi-structured interview revealed that most of the students had positive perceptions while few had negative perception about the 7E learning cycle after the approach has been employed to teach them. The students held positive perceptions that the 7E learning cycle made the lessons interesting, helped them to understand the concepts taught to them, groupwork was helpful and helped them to search for information. The negative perception the students had about the 7E learning cycle was that the teacher is passive during teaching period. This finding of the current study supports the study of Saraç and Sekerci (2018) when they found out that students perceived the 7E model to have given them the opportunity to work in group and hence they were actively involved in the lesson, made them excited about the lesson and increased their interest to learn. Also, the teacher observed that because the 7E learning cycle involves several phases, more instructional periods were used to complete the lessons.

Conclusions

Based on the findings of this research, it can be concluded that learners exposed to REACT and 7E models out performed their counterparts who were exposed to the conventional approach when the approaches were used to teach them concepts in molecular genetics. Therefore, the REACT and 7E models were more effective in teaching and learning of concepts in molecular genetics.

Again, it can be concluded that students had positive perceptions about the REACT strategy and the 7E learning cycle as instructional strategies.

Recommendations

Based on the findings of the study, the following recommendations are made for educational practices and policies:

1. Teachers should employ, REACT strategy and 7E learning cycle in their teaching to encourage students to actively construct their knowledge.
2. Curriculum developers can prescribe the REACT and 7E models of teaching as examples of constructivist teaching approaches when they are developing Elective Biology syllabus for teachers to employ to teach Biology concepts as a means to improve students' achievement in the subject.

Suggestions for Further Research

This study compared the effect of the REACT strategy, 7E learning cycle and conventional approach on SHS students' achievement in teaching

molecular genetics. Therefore, future studies can be conducted on the effect REACT and 7E learning cycle on the other level of the educational system, other Biology concepts and other subject areas like Chemistry, Physics and Mathematics. Also, future studies can be conducted on tracking the effect of REACT and 7E models of teaching on the performance of low achievers.

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APPENDICES

APPENDIX A

ACHIVEMENT TEST (PRETEST)

A Test on the Diversity of Life and Life Processes in Living Things

Answer all 30 questions.

For each of the questions, circle the correct answer from the four (4) options given.

Time allowed: 40 minutes

1. The life process by which energy is released from the breakdown of food is termed as…….
   a. digestion
   b. excretion
   c. nutrition
   d. respiration
2. To which kingdom do insects belong to?
   a. Animalia.
   b. Plantae.
   c. Prokaryotae.
   d. Protoctista.

3. Which of the following processes is **not** a characteristic of all living things?
   a. Excretion.
   b. Photosynthesis.
   c. Reproduction.
   d. Respiration.
4. Euglena is considered as both a plant and animal because it has ……..
   a. chloroplast and cytoplasm
   b. flagellum and chloroplast
   c. flagellum and nucleus
   d. flagellum and cytoplasm
5. From which of the following is the scientific name of an organism derived from?
   a. Class and species.
   b. Family and species.
   c. Genus and species.
   d. Order and species.
6. Which of the following organisms exist in colony?
   a. Amoeba.
   b. Chlamydomonas.
   c. Spirogyra.
   d. Volvox.

7. Which of the following statements about viruses is true?
   a. Viruses are bigger than bacteria.
   b. Viruses are living things.
   c. Viruses can only multiply inside a living cell.
   d. Viruses have nucleus.
8. Air enters the tracheal system of the cockroach through the ……..
   a. cerci
   b. Malpighian tubules
   c. spiracles
   d. tracheoles
9. The egg of a butterfly hatches into a larvae called a ……..
   a. caterpillar
   b. chrysalis
   c. nymph
   d. pupa
10. Which of the following statements about the cell wall of Spirogyra is true?
   a. It contains cellulose.
   b. It contains chitin.
   c. It contains chloroplast.
   d. It contains cytoplasm.

11. A mushroom digests food substance outside its body and then absorbs the nutrients. This mushroom is considered as?
    a. Autotrophic.
    b. Heterotrophic.
    c. Holozoic.
    d. Saprophytic.
12. In which one of the following organisms does alternation of generation occurs?
    a. Cockroach.
    b. Moss.
    c. Rhizopus.
    d. Spirogyra.
13. Where are fertilized cockroach eggs stored?
    a. Cercus.
    b. Maxilla.
    c. Ommatidia.
    d. Ootheca.
14. In terms of the mode of nutrition, Rhizopus is considered as …….
    a. holophytic.
    b. holozoic.
    c. parasitic.
    d. saprophytic.

15. Bacterium is classified under the kingdom *Prokaryotae* because it……

    a. has cell wall made of chitin

    b. lacks nuclear membrane

    c. is disease causing organism

    d. possess mitochondrion

16. The main objective in the classification of living things is ……

    a. for easy identification and communication

    b. to demonstrate the diversity of living things

    c. to ensure that each organism is names properly

    d. to establish an evolutionary trend

17. Which of the following organisms exist as a cell?

    a. Amoeba.

    b. Moss.

    c. Rhizopus.

    d. Spirogyra.

18. What role does the wall of zygospore of Spirogyra plays?

    a. It provides protection against drought.

    b. It prevents the internal content from the ultraviolet ray of the sun.

    c. It prevents the zygospore from being grazed upon.

    d. It prevents the zygospore from developing.

19. The gametophyte of a fern ……..

    a. forms gemmae

    b. forms sporangia

    c. has short roots

    d. is multicellular

20. Amoeba is a unicellular organism that reproduces asexually by a process known as …….

    a. binary fission

    b. conjugation

    c. gametangial fission

    d. longitudinal fission

21. Select the correct sequence of ranking the taxa.

    a. Class → Species → Family → Genus.

    b. Class → Species → Genus → Family.

    c. Class → Family → Species → Genus.

    d. Class → Family → Genus → Species.

22. The taxon, order, comes in between……..

    a. class and family

    b. species and genus

    c. species and family

    d. family and genus

23. The Kingdom Protoctista include major phyla…….

    a. Bryophyta and Phaeophyta

    b. Euglenophyta and Ascomycota

    c. Rhizopoda and Chlorophyta

    d. Zoomastigina and Lycophyta

24. Which of the following is the highest taxa in the classification of plants?

    a. Class.

    b. Division.

    c. Order.

    d. Phylum.

25. To which kingdom do arthropods belong?

    a. Animalia.

    b. Plantae.

    c. Prokaryotae.

    d. Protoctista.

26. Which of the following features in Euglena is typical of plant cells?

    a. Chloroplast.

    b. Eye spot.

    c. Flagellum.

    d. Pellicle.

27. Paramecium has two ……..

    a. anal pores

    b. cytostomes

    c. Gullets

    d. Nucleus

28. The division of a single cell to produce two identical cells in unicellular organisms is called …….

    a. binary fission

    b. columella

    c. Conjugation

    d. Sporulation

29. Which of the following is **not** characteristic of dicotyledons?

    a. Flower parts are in multiples of three.

    b. Net-veined leaves.

    c. Seeds with two cotyledons.

    d. Tap root system.

30. To which of the following groups do mosses belong?

    a. Bryophytes

    b. Conifers.

    c. Cycads

    d. Ferns.

APPENDIX B

ACHIEVEMENT TEST (POSTTEST)

A Test on DNA, RNA and Protein synthesis

Answer all questions. For each of the questions, circle the correct answer from the four (4) options given.

Time allowed: 40 minutes

1. DNA and RNA are made up of nucleotides. Each of the nucleotide consists of ……..., ……, and …….....

a. side chain, carboxyl group, glucose
b. side chain, sugar, nitrate group
c. sugar, nitrogenous base, carboxyl group
d. sugar, nitrogenous base, phosphate group

2. identify the four nitrogenous bases found within ribonucleic acid.

a. adenine, thymine, cytosine, guanine
b. adenine, thymine, guanine, uracil
c. adenine, uracil, guanine, cytosine
d. adenine, uracil, phosphate, ribose

3. DNA contains deoxyribose sugar whiles RNA concains……...

a. fructose sugar.
b. galactose sugar.
c. lactose sugar.
d. ribose sugar.

4. Which of these statements best explains the form and purpose of one kind of nucleic acid?

a. DNA, a double helix, functions primarily as an archive of genetic information.
b. DNA, a single helix, functions primarily as an archive of genetic information.
c. RNA, a double helix, functions primarily as an archive of genetic information.
d. RNA, a single helix, functions primarily as an archive of genetic information.

5. DNA and RNA differ in such a way that each of them uses different ……. within their nucleotides.

a. Base pair.
b. Hydrogen bond.
c. phosphate
d. Sugars.

6. The DNA in living things is ……. Which resulting in the production of mRNA.

a. Duplicated
b. Replicated
c. Transcribed
d. Translated

7. The molecule that is important in translating the triplet codons of mRNA into the protein molecules is the ……

a. DNA
b. RNA
c. rRNA
d. tRNA

8. Which of the following statements is **true**?

a. During transcription, the mRNA is synthesized in the 3' to 5' direction.
b. The mRNA is translated from 5' to the 3' end.
c. The mRNA is translated from 3' to 5' end.
d. The mRNA is translated irrespective of direction.

9. How does the enzyme called helicase function?

a. It adds new nucleotides to the DNA helix.
b. It forms bonds between DNA nucleotides.
c. It forms the DNA helix.
d. It separates DNA strands.

10. Which of the following removes the RNA primer during replication?

a. DNA ligase.
b. DNA polymerase I.
c. Helicase.
d. RNA primase.

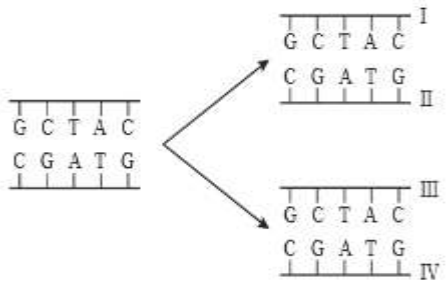
11. A biochemist isolated and purified molecules needed for DNA replication. When some DNA was added, replication occurred, but the DNA molecules formed were defective. Which of the following had been left out of the mixture?

a. Helicase
b. Ligase
c. Nucleotides
d. Polymerase

12. Proofreading and repair in DNA replication happen ……

a. at any time during and after synthesis of DNA.
b. only before DNA synthesis.
c. Only in the presence of an excision repair mechanism.
d. Only in the presence of DNA polymerase.

13. The following picture shows a short section of DNA molecule before and after replication. Which strands in the two replicated DNA are from the original DNA?



a. I and II
b. II and III
c. III and IV
d. I, II, III and IV

14. Which of the following is **not** a component of a nucleic acid?

a. Base pair.
b. Hydrogen bond.
c. Peptide bond.
d. Ribose sugar.

15. DNA replication occurs in a cell during ……

a. interphase of mitosis
b. metaphase of meiosis I
c. anaphase of mitosis
d. prophase of mitosis

16. Which of these nitrogenous bases is **not** found in a DNA?

a. Adenine.
b. Cytosine.
c. Guanine.
d. Uracil.

17.What is produced during transcription?

a. DNA molecules
b. RNA molecules
c. RNA polymerase
d. protein molecules

18. Which of the following is **true** about codons and amino acids?

a. Each amino acid is specified by only one codon.
b. Each codon specifies a different amino acid.
c. Several different codons can specify the same amino acid.
d. Some amino acids have no link to a codon.

19.During translation, the type of amino acid that is added to the growing polypeptide depends on the……

a. codon on the mRNA and the anticodon on the rRNA.
b. anticodon on the mRNA and the anticodon on the tRNA.
c. anticodon on the rRNA and the codon on the mRNA.
d. codon on the mRNA and the anticodon on the tRNA.

20.In eukaryotes, transcription takes places in…….

a. the cytoplasm
b. the mitochondrion
c. the nucleus
d. the ribosome

21. The two strands of a DNA must run in……. direction(s) and must be ……. if they are to bond with each other.

a. opposite; complementary
b. parallel; not complementary
c. parallel; complementary
d. the same; not complementary

22. Which of the following nucleotide sequences represents the complement to the DNA strand 5´ – AGATCCG - 3´?

a. 3´ – AGATCCG - 5´
b. 3´ – CTCGAAT - 5´
c. 3´ – TCTAGGC - 5´
d. 5´ – CTCGAAT - 3´

23. Which type of RNA is made from deoxyribonucleic molecule?

a. All the RNAs.
b. mRNA.
c. rRNA.
d. tRNA.

24. Which of the following serves as a "connector" in protein synthesis and bridges the gap between mRNA and proteins?

a. DNA sequences.
b. promoter sequences.
c. rRNA sequences.
d. tRNA sequences.

25. Which of the following is the function of ribosomes during protein synthesis? Ribosomes…….

a. attach to the mRNA molecule and travel along its length.
b. attach to the DNA and travel along its length to produce an mRNA molecule.
c. translate mRNA into tRNA.
d. transcribe mRNA to tRNA.

26. One of the mRNA codons specifying a certain amino acid is 5´-CUA-3´. What will be the anticodon for this codon?

a. 3´-AUC-5´.
b. 3´-GAT-5´.
c. 3´-GAU-5´.
d. 5´-GAT-3´.

27.Which of the following base pairing is **not** possible to occur in nucleic acids?

a. A pairing with T
b. A pairing with U
c. G pairing with C
d. G pairing with U

28. A double stranded Deoxyribonucleic acid has 20% of Thymine, what will be the percentage (%) of Cytosine of this DNA?

a. 20%
b. 30%
c. 40%
d. 50%

29. Which of the following is responsible for the addition of new nucleotides to a growing DNA strand?

a. DNA polymerase
b. DNA helicase
c. RNA primer
d. Primase

30. Which of the following organelles is **not** associated with protein synthesis from a DNA?

a. Cytoplasm
b. Nuclear membrane
c. Nucleus
d. Plasma membrane

APPENDIX C

ANSWERS, DIFFICULTY AND DISCRIMINATION INDICES FOR ITEMS ON THE ACHIEVEMENT TEST (PRETEST)

Item	Answer	Difficulty Index	Discrimination Index
1	D	0.77	0.20
2	A	0.97	0.06
3	B	0.97	0.06
4	B	0.33	0.40
5	C	0.83	0.33
6	D	0.57	0.47
7	C	0.80	0.10
8	C	0.37	0.33
9	A	0.50	0.60
10	A	0.23	0.07
11	D	0.23	0.20
12	B	0.43	0.33
13	D	0.70	0.33
14	D	0.87	0.07
15	B	0.50	0.33
16	A	0.90	0.07
17	A	0.93	0.13
18	A	0.57	0.33
19	B	0.60	0.13
20	A	0.50	0.33
21	D	0.87	0.13
22	A	0.63	0.47
23	C	0.33	0.10
24	B	0.33	0.27
25	A	0.47	0.40
26	A	0.87	0.13

Continuation of table

Item	Answer	Difficulty Index	Discrimination Index
27	D	0.27	0.27
28	A	0.30	0.33
29	A	0.60	0.13
30	A	0.73	0.13

Source: Field survey (2019)

APPENDIX D

ANSWERS, DIFFICULTY AND DISCRIMINATION INDICES FOR ITEMS IN THE ACHIEVEMENT TEST FOR THE POSTTEST

Item	Answer	Difficulty Index	Discrimination index
1	D	0.95	0.25
2	C	0.31	0.53
3	D	0.86	0.08
4	A	0.82	0.33
5	D	0.45	0.33
6	C	0.59	0.25
7	D	0.50	0.25
8	B	0.45	0.50
9	C	0.59	0.58
10	D	0.14	0.42
11	A	0.14	0.08
12	D	0.45	0.50
13	B	0.18	0.33
14	C	0.41	0.42
15	A	0.64	0.17
16	D	0.91	0.33
17	B	0.41	0.25
18	A	0.36	0.17
19	D	0.50	0.25
20	D	0.59	0.08
21	A	0.45	0.17
22	C	0.54	0.17
23	B	0.27	0.17
24	D	0.41	0.25
25	A	0.23	0.25
26	C	0.36	0.33
27	D	0.50	0.42

Continuation of table

Item	Answer	Difficulty Index	Discrimination Index
28	B	0.41	0.25
29	A	0.32	0.08
30	D	0.82	0.05

Source: Field survey (2019)

APPENDIX E

SPSS OUTPUT OF DESCRIPTIVES STATISTICS OF ANOVA FOR POSTTEST SCORES

	N	Mean	Std. Deviation	Std. Error	95% Confidence interval for Means: Lower Bound	95% Confidence interval for Means: Upper Bond	Minimum	Maximum
REACT	27	16.48	3.567	.686	15.07	17.89	10	24
7E	22	15.18	3.936	.839	13.44	16.93	8	25
Conventional	30	11.50	3.093	.565	10.34	12.66	6	16
Total	79	14.23	4.104	.462	13.31	15.15	6	25