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Constructivist Approach to Learning Activity: The Case of Junior Secondary Students' Misconception on the Three States of Matter in Basic Science, Nigeria

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Abstract

The paper focuses on the misconceptions of students on the states of matter and suggests the need for science teachers to adopt the 7E model in order to reduce these misconceptions and promote students' learning. The paper develops and proposes a learning activity based on a systematic review of scholarly articles, thesis, and curriculum that investigated the subject matter. The 7E model consists of phases such as elicit, engage, explore, explain, elaborate, evaluate, and extend. The researchers prepared a specific lesson plan on identifying the properties and structures of states of matter using the 7Es learning cycle specifying the teacher's activities and the corresponding students' activities. The 7E model is recommended for teaching states of matter based on studies that found the approach to be effective in helping students eliminate scientific misconception and improve understanding.

Keywords: States of matter, Misconception, 7Es learning cycle, Basic science

1. Introduction

In an effort to improve science and technology education, the Nigerian Government has revised its 6-3-3-4 policy on education which mandates children to spend six years at primary school level, three years at junior secondary school level, three years at senior secondary school level and four years at higher institution. The current 9-3-4 system, which replaces the 6-3-3-4 system, was introduced in 2004 and stipulates that a child spends nine years compulsory right from primary school level to junior secondary school level, three years at the senior secondary school level, and four year in tertiary institutions [1-3]. To facilitate full success of the 9-3-4 policy, the federal government of Nigeria backed by law introduced a Home-Grown School Feeding and Health Program (HGSFHP) that provides free basic health services and free balanced meal per day for every child that attends public primary and junior secondary school [4]. The main goal is to provide equal opportunity for children of Nigeria to study science thereby reducing illiteracy and providing education for all [3, 5].

The Nigerian government has adopted basic science and technology as a mandatory course at the basic educational level to provide a strong foundation for science and technology [6]. The basic science is presented such that the child acquires the conception of the fundamental unity of science, the common approach to scientific nature and be aware of the importance and function of science in daily life and in the world at large [4].

The states of matter is among the foundational topics of basic science under sub-theme of "You and Energy" which require students to understand the assumptions of kinetic theory of matter, molecular structure of solids, liquids and gases using kinetic theory of matter, distinguish between evaporation, melting, freezing, and boiling as captured in Nigerian Junior secondary school science syllabus [4]. Furthermore, observations have indicated that the states of matter concept are among the complex topics experienced by the students. The states of matter are believed to be complicated considering several research that reports student difficulties in understanding the concept. Gongden and John [7] and Gongden and Gongden [8] argued that students' low performance is as a result of difficulties they faced in understanding science concept which include poor understanding of the particulate nature of matter. Onwu and Randall [8] also hold that the concepts of atomic and molecular structure are very difficult for students' understanding. Alamina and Etokeren [10] argued that due to abstract nature of the science concepts, students develop different misconception in their understanding of particulate nature of matter. Similar observation was also made by Agogo and Onda [11] on students' difficult topics that lead to low achievements due to lack of effective approach. In the light of this, there is need for more research to determine an effective instruction suitable for science teachers and students. In this regards the presents study develops a module around 7E learning cycle to support teachers in the choice of content and strategy in teaching states of matter.

Tatar [12] opined that, although the states of matter is regarded as a simple and well-known topic, there is an increasing number of students and teachers

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misconception on the change of states. He further, content that, since "states of matter" is an important subject that concerns our daily lives, lacks complete ideas about the concepts may have a detrimental effect on the scientific understanding of the other concepts in the subsequent learning of science. The author further suggested that more studies on methods to reduce or eliminate such misconceptions should be conducted. Laliyo et al. [13] also argued that more studies should be conducted because some studies have found students' misconception of the states of matter to persist as they progress further. Hanson [14] argued that because of the lingering misconceptions that students hold coupled with low academic achievement, invariably, lead to loss of interest in studying science; thus, teachers should select and adopt instructional approach that investigate prior information of students, provides hands and mind on activities that support science teachers in dissemination of knowledge through inquiry activities. Aydin et al. [15] also support Hanson's assertion on the need for innovative approach to learning science.

According to Wang and Reeves [16], the need for instructors to guide students in learning process could perhaps be more important to meaningful academic achievement than the volume of information presented to them through instructional materials or other forms of instruction, which invariably lead to rote learning. The need for effective instruction and learning of science through effective and consistent medium of instruction in classroom activities has been ongoing for the past half-century [17]. For decades, science educators have been searching for appropriate strategies in teaching and learning science; these efforts were also made by stakeholders in science education (Ministry of Education, Science Teachers Association of Nigeria, STAN, and Mathematics Association of Nigeria, MAN,) advocating for science teachers to be more innovative and embrace modern approaches for teaching of science [18, 19].

The new 9-year basic education in Nigerian curriculum was designed to promote student learning of essential state of matter content and foster development of deep conceptual understanding through an inquiry-based model of instruction [4]. But the inability of science teachers to find effective strategy that match the curriculum is lacking [20]. According to constructivism, learning is an active construction of information structured based on somebody's understanding of knowledge or through social collaboration [21]. A constructivist approach emphasized that learning occurred through active social interaction among students, via information sharing and cultural experience. Students learning are meaningful if they are actively engaged during the learning process rather than being passive receivers of information from the teacher [22].

2. Student's Misconception on States of Matter

One of the most common misconception among students is the belief that gas is not a substance and has no weight or mass. Students also hold alternative conception regarding the bubbles that rise from boiling water [23]. Many students state that the bubbles rising in boiling water are composed of hydrogen gas and oxygen gas [24, 25]. Significant conceptual difficulties are reflected in the way that students make a distinction with regards to the states of matter transformation. Nguru [26] reported that students' misconceptions about liquids are because liquids are simply known to be in an intermediate state between solids and gases. In this context, the students thought the molecular spacing of liquids is overestimated. Likewise, several students have assumed that particles in the gas and liquid state are in continuous movement, there is no movement of particles in the solid-state [23, 25]. In another study, the students were reported to underestimate the molecular gas spacing and also ignored the movement of the particles in the gaseous state [27]. There have also been cases of misperceptions regarding particles size; the most common misconception of students is that gas is neither a material nor does it has weight or mass [12, 23].

Students' inability to comprehend electrostatic forces between particles leads to misconception involving the relationships between the states of matter of a single substance. Studies have shown that students believed that matter is continuous and smooth in the solid state based on their macroscopic observations [28, 29]. Several researchers have sought to establish how students understand the state of matter conceptually. The studies showed that students do not completely understand the key concepts of kinetic theory of matter and that they lack awareness difficulty in interpreting the subject [24, 30-32]. The explanations for these difficulties are probably the abstract and complex micro-structured nature of the definitions and barriers to the prior building experience of students [33]. Students actively develop awareness, not just in school, but also in real life through their experiences. Therefore, before they were instructed with the subject, they bring many conceptions into class that they have created in connection with their environment. Glynn et al. [34] highlighted the need for teachers to help students identify the positive and negative aspects of each misconception.

Such current knowledge structures influence their interpretations of implemented concepts, as learning consists not only of gaining new knowledge but also of communicating sequentially with existing concepts of students. Such existing concepts, as Krause et al [35] have suggested, can support or hinder learning. But Treagust [32] reported that works in the literature empirically validated the impact of existing conceptual awareness on the intellectual growth of the learner. Any of the previous experiences will promote school learning. Many of them, on the other hand, could be barriers to further learning as they clash with scientific knowledge widely recognized. Such definitions are classified in the literature as misunderstandings or alternate definitions [36, 37].

To achieve effective learning in science, misconception must be eradicated from individual. In this context, the role of the teachers in selecting effective and most relevant pedagogy is imperative [38]. It is very important to adapt an instructional approach that reduces students' misconceptions and subsequently improve students' learning of science; thus, the present study adapted 7E model. Several empirical studies and unique issues have established and demonstrated the potentials of the 7E model to have a huge effect on the quality and use on individual learning by inquiry [10, 39-49]. The 7E learning cycle is a procedure structured by and for teachers that want to expand the effect of instruction investigation into improved practice [50].

The 7E learning cycle is driven by principle that directs, teaches, and strengthens both practice and study in educational settings. The 7Es learning process is a naturally oriented inquiry approach focused on construction theory [50]. In this study, the learning conditions of the constructivist are discussed alongside the seven learning phases. This study examines the 7Es study of teaching states of matter. The 7Es learning process consists of 7 steps: Elicit, Engage, Explore Explain, Elaborate, Evaluate and Extend. The practice involves the three states of matter subjects and were considered at each point of the 7E learning process. Therefore, the application time of these plans are determined by these phases. In 1962 Atkin and Karplus discussed the first course in print following the creation of one of the most famous courses called a 5E model and the Biological Curriculum Analysis (BSCS) in 1989 by Bybee and in 2003 Eisen kraft into the 7E learning process [38].

The use of the 7E model ensures that the students participate actively by doing practical hands-on-designs during the teaching and learning process [50]. This corroborates Vygotsky's social cultural theory that visualizes the learning situation as social and collaborative activity involving teacher-student interaction, student-student interaction as well as student-resources interaction [52]. The 7E model is blended with various suggested approaches and strategies such as student-centered learning, problem solving, inquiry, hands-on activities, collaborative learning, constructing own knowledge from multiple sources, and sharing ideas in multiple ways as well as respecting and judging other ideas. The 7E model is context and culture wise of the students, teaching ought to be done according to context setting and students' learning culture so that what was learned can be extended to the larger society [53]. Drawing on the aforementioned, it is evident that there is need for science teachers to adapt teaching approaches that identify and reduce the misconceptions held by students. The influence of the 7Es model in the teaching and learning has been positively reported to eliminate misconception and improve understanding of science concepts [47,42,51,57,61].

In the light of the previous studies, it has been established that sufficient understanding on macroscopic and microscopic particulate properties of matter and transformations of changes of states is essential for learning more advanced subjects such as the concept of atoms and molecules that are invisible to the straightforward eyesight [54]. This finding is further backed by Adadan and Ataman [55] who argued that particulate nature of matter (PNM) is one of the foundational concepts that promote, shape, and constrain the understanding of subsequent concepts in science, particularly in chemistry. However, the fact that conceptual understanding of the topic has been described to be difficult considering the abstract nature of the concept [13]. In addition, the continued low students' achievements, because of ineffective instructional approach adapted by the science teachers [20, 56], necessitate the quest for further investigation into basic science instruction.

3. The 7E Model (7E Learning Cycle)

A recent study has shown that the 7E learning cycle model has a positive impact on some teaching content and was found to be an effective tool for teaching concepts [57]. Other advantages associated with the 7E learning cycle include positive impact on student achievement [47,51], increase student awareness overtime [44] and allowed students to build or enhance positive attitudes towards courses and provide students with science, experimental and practical thought [42, 49, 61]. Application of the 7Es model in science learning increases students' success and conceptual achievement more efficiently because the model has been prepared to give students the chance to explore ideas. This is due to the fact that the phases of the model are teacher/student friendly. Thus, effective learning takes place. Though the 7Es learning cycle can be time-consuming because each phase should be carried out with great attention to details, it is found that the learning cycle provides a greater opportunity for the acquisition of scientific conceptions than the traditional methods [45].

The 7Es learning cycle is an example of an inquiry learning approach based on constructivist learning. The learning cycle model is an instructional sequence that is consistent with the nature of inquiry in science and with the natural way children learn science [50]. When science teachers use the 7E Instructional Model, they will engage in a practice that is unique from those of a conventional teacher approach. Thus, students learn in ~~a~~ different way from experience in a conventional classroom; this is evident from the findings in the available literature [44, 57-64]. The 7Es learning cycle focuses on examining the learner's previous knowledge of what they first want to know before learning the new content. This contributes to an effective learning process through seven steps: reviewing prior knowledge, motivating interests, surveying and searching, explaining, expanding knowledge, evaluating, and applying knowledge based on curriculum and lesson plans research. Eisenkraft [50] extended the 5E model to a 7E model that emphasizes knowledge transfer. The newer model adds an "elicit" stage before "engage" and an "extend" stage after "evaluate" [65].

According to Celik, et al [43], by using the learning cycle, students can learn science concepts, correct their incorrect or inadequate information, become well acquainted with ideas, and apply the learning they learn in school to their everyday lives. Findings from studies conducted on the effect of 7Es instruction in the learning cycle show that the instructional cycle model widens the academic achievement of students, improves their interest in science and enhances knowledge over time [44, 58, 66]. Similarly, the study conducted by Siribunnam and Tayraukham [67] on the student's 7Es learning cycle showed statistically significant differences between students' achievement and analytical thinking.

The 7Es model affords students opportunities to design and plan experiments, record data, and develop hypotheses during the explore phase [49]. Students in this phase test the ideas and questions generated during the previous step through concrete, hands-on activities that begins to clarify their knowledge and understanding of the subject [38]. The explained stage is more teacher-led than the other stages of the 7Es Model. In the explain phase students are presented with content, scientific laws, or models to explain the phenomena witnessed during the previous phase [68, 69]. A crucial part of this phase involves assistance by the teacher or sometimes by the use of resources that elicit students to a deeper understanding of the topic of study [50].

In a State of Matter class, the teacher and the students examine the observations and data collected. "Elaboration" is the stage during which students apply their understanding to other situations [38]. Eisenkraft [50] suggested that numerical problems for students to solve be introduced at this point, and thus the basic science student will be given sample problems and alternative experiments to study during the elaboration phase. In the study cited above, students who participated in the elaboration phase of the 5Es Model lab devoted to light reflection and mirrors were better equipped to transfer knowledge that they had constructed to other types of problems than those who had not participated in this phase [70]. The sixth stage in the 7Es model, "evaluation," allows for summative assessments by the teacher while encouraging students' self-assessment of their understanding and abilities [62]. In this current study, this last stage will include students report and the unit test. Through the evaluation stage, the teacher gains insight into the students' grasp of the topic and their ability to differentiate the state of matter and the nature of particle in the motion of the different state. Based on students' assessments, teachers may need to re-evaluate the cycle and repeat certain stages [62].

3.1 The Sequence of States of Matter Lesson Plan Based on 7E learning cycle.

Topic: Investigating the particle theory of matter.

The Behavioral Objectives:

i. At the end of the lesson, Students should be able to:
- Identify the properties that make up matter to be solid, liquid or gas.
- Describe the arrangement of atoms in each state of matter (solid, liquid and gas).
- Identify and relate each state of matter and its unique properties.

ii. *Student's acquisition of Science Process Skills*
- Students should be able to apply their sense organs or observational tools to predict certain events about matter.
- Through observation students should be able to compare one or more properties of the three state of matter.

Table 3.1: Sequence of the Learning Activities

S/N	Stages	Activities: Teacher	Activities: Students	Instructional materials
1	Elicit	• To generate students' prior experience, the teacher uses an open-ended question. E.g., "Can water move from place to place? "What are the bubbles that make up boiling water? "Give an example of things we can feel but can't touch" questions like this evoke the student's prior knowledge.	• Students should identify objects either (water form, air form or wood form .	• Piece of Ice • Water • Container
2	Engage	• The teacher leads the discussion of matter particles; the teacher informs the class that matter particles are in constant motion. The teacher will provide the student table with real items that are solid, liquid and gas or gas containers, and number each category. • Ask students to observe the level of attraction between the phases of the matter. Give each student three sheet of paper and ask them to sketch a picture of beaker on each paper. • The teacher provide feedback by going around the class **(please see Activity 1)**	• Students will classify the materials provided as solid, liquid or gas • Each group will present and explain how the materials were classified. • Students listen to the teacher while he explains plan activity. Students draw a beaker. Students imagine putting a solid object in the beaker. Use small pieces of paper as molecules.	• Piece of Ice • Water • Container Beaker, paper, glue.
3	Explore	• The teacher continues to explain that matter particles have spaces between them. Demonstration of sand and water: Fill one cylinder with 50 ml of sand and another with 50 ml of water. Drain 50 ml of the water into 50 ml graduated sand cylinder and ask students why they do not have a 100 ml volume. Making sure that air bubbles hit the surface are indicated. • The teacher again Pour 50 ml of water in one graduated cylinder and 40 ml of isopropyl alcohol in another graduated cylinder. Pour the alcohol into the water and have a student read the resulting volume. • The teacher leads a discussion based on his demonstration (**please see activity I1)**	• Students listen and observe while teacher demonstrates particles of matter having space between them.	• Sand • Water • Cylinder • Alcohol
4	Explain	• To explain to the students that as the temperature of matter increases, so does the particles move faster. • Teachers give example of ice cube (ice block) and ask students what happens if the size of the ice cube increases. **(Please refer to activity III)**	• Students listen to the teacher as he explains the effect of temperature on the matter. • Students respond to some of the questions raised by the teacher. • Students then cut and stick images of solid, liquid and gas in the table extension. • Students draw diagrams	• Piece of ice cube (ice block)

Table 3.1 (*Continued*)

	Stages	Activities		Instructional materials
		Teacher	Students	
5	Elaborate	• Divide the class into groups of eight. • Ask students to form a cluster of cycle holding a ball. Inform the class that the ball represents the energy that will be transferred to the outside of the circle. • Inform the students that they represent the molecules as they hold the ball. • Have students stand up and create a human model of the particle theory. • Call out some state of matter and ask student to orient themselves as liquid, gas or solid. • **(please refer to activity IV)**	• Student form groups • Students will record as many things as they can from the activities they have participated and write a report and present to the class. • Students perform some activities guided by the teacher. • Students will read out, point to be awarded to the group with most outstanding presentation.	• Ball • Beaker • Paper • Water • Sand • Cylinder
6	Evaluate	• Evaluate students' knowledge based on class activities and presentations. • Ask student why the food color pour inside the water spread all over the water? • What can they infer about the movement of the particles? • Why did the measure of 50 ml of water and 40 ml of alcohol did not give us 90 ml? **(please refer to Activity V)**	• Students respond to the teacher's questions. • Students are asked to speak about what they have experienced in groups to relate their previous experience to a new experience.	
7	Extend	• Ask students to classify matter to the different part of our body system. • Ask students to identify solid, liquid and gases around us and how this are use in our daily lives.	• Students will classify matter to the different part of our body system. • Students will identify solid, liquid and gases around us. • Students connect the experience to daily life	

Adopted from Virginia Department of Education [70]

3.2. Class Activities

Activity 1: Particles of matter attract each other

i. Inform students that the molecular arrangement of the particles in the different phases of matter will be examined in this activity. They will observe that the level of attraction between the particles changes in each phase of matter.

ii. Give each student three sheets of paper and place the shape of the beaker on each sheet. (Display a real beaker for them to draw).

iii. Ask students to imagine putting a solid object, such as a wooden block inside the first beaker they had drawn. Then tell them to use cotton balls or small circles of paper to serve as the molecules in the solid object and arrange them inside the beaker. Students may need to first sketch the outline of the object and then fill it with the molecules.

iv. Walk around the classroom and check the student diagrams. Provide feedback so that the errors can be corrected. Once their diagrams are correct, tell them to stick or tape their molecules to the paper. Ask students to imagine filling the second beaker with a liquid like water. Tell them to organize the molecules of the liquid inside the beaker. And once the diagram has been checked and corrected, have students stick or tape their molecules to the paper.

v. Finally, ask students to imagine filling the third beaker with gas like air. Tell them to organize the "molecules" of the air inside the beaker. And once the diagram has been checked and corrected, have students stick or tape their molecules to the paper.

Activity 2: Particles of matter have spaces between them

i. Sand and water demonstration: Fill one graduated cylinder with 50 ml of sand and one graduated cylinder with 50 ml of water. Place 50 ml of water in a graduated cylinder filled with 50 ml of sand and ask students why the resulting volume is not equal to 100 ml. Be sure to point out the air bubbles that are rising to the surface. Alcohol and water demonstration: pour 50 ml of water into one graduated cylinder and 40 ml of isopropyl alcohol into another graduated cylinder. Add the alcohol to the water and have the learner review the resulting volume. The level of the solution should be approximately 88 ml. Learners are often surprised at this result because they assume that since both materials are liquids and have similar properties, they will add up to 90 ml. Promote a discussion that leads learners to recognize that water and alcohol particles fit together and reduce the overall volume.

Activity 3: As temperature increases, particles of matter move faster

i. Have students take advantage of the drawings they created in Activity 1 of the lesson. Start by talking about what happens when the temperature of a solid object, such as an ice cube, rises. Students are going to say that the ice cube melts. Ask students to describe the physical differences between water and ice. Address the fact that solids have definite shapes and volumes; whereas liquids have definite volumes but take the shape of their containers. Have students look at their diagrams and point out that there is more space between the particles in the liquid than in the solid that enables the particles to move past each other. Also explain the reason that there is a space between the particles.

ii. A small group of eight students cluster in a circle holding a ball to demonstrate the need for particles to move to transmit energy. The ball represents the energy that will be transferred to the outside of the circle. The students (as molecules) must transfer the ball from the middle of the circle to the outside. Let students stand up and construct a human component theory model. Tell the students that the classroom is a big container. Let students stand up and act as molecules. Call a process of matter and tell students to concentrate and move as though they were a molecule in that period. "the bottom of the container" is in the room. When "solid" is called, all students should stand close together at the bottom of the container and shake or hop in place. For "liquid," students should move a little faster and slide past each other closely. When "gas" is called, students should move quickly and spread across the room.

4. Conclusion and Recommendation

Based on the reviewed literature, the essential role of 7E learning cycle in teaching and learning of states of matter has been highlighted. The current investigation has a wide range of implications for students, teachers, curriculum planners, states and federal ministry of education, and educators. There is evidence that teaching a content course using instructional material prepared around 7E learning cycle can enhance active learning and motivate students' learning, as a result increases students' achievement and reduce student's misconception on the transformation of matter and its changes of states. Therefore, this paper has provided a better understanding of constructivism school of thought on instruction, more specifically the activity plan on states of matter.

Moreover, the teachers need to consider and determine students 'possible misconceptions prior to the content instruction to foster meaningful learning as well as to avoid the building of more misconceptions. To facilitate effective learning and to prevent the development of further misconceptions, teachers need to recognize and evaluate the potential misconceptions of students prior to content instruction. In addition, teachers need to be mindful of the difficulties faced by students when learning the properties of solid, liquid and gasses.

The 7E learning cycle, distinctively from constructivist school of thoughts, highlights the necessity of prior knowledge activation in the first stage of the learning cycle. In addition, it connects the recently acquired knowledge with the future subjects or context with the final stage. Also, in learning cycle, students investigate the related materials to explore states of matter transformations. During instruction, the science teacher act as facilitator to encourage students to explore the information by themselves. Science teacher direct probing questions to students, provide appropriate materials, guide and monitor the progress of students learning, and encourage student inquiry.

Considering these features, 7E learning cycle is recommended to science teachers in their bid to transform students learning of science. It is recommended that 7E learning cycle be integrated into Basic Science Content Lessons. Using 5E and 7E models at science teaching and learning process are strictly recommended. Therefore, ministry of education should encourage science teachers to take in-service courses related to the philosophies of constructivism for proper application of learning cycle instruction. Furthermore, science teachers need to be well prepared by developing lesson plans around the 7E learning cycle. The universities and colleges of education should contribute to the development and implementation of these trainings. The practice is important not only for in-service but also pre-service science teachers. The courses given at the universities and colleges of educations in the aim of preparing pre-service teachers on teaching strategies should embed the learning cycle approach.

The 7E learning cycle not only enables students to discover their background knowledge, but also to learn in collaboration with their group members by participating actively in the courses; consequently, it also promotes their social construction. Lessons that only use verbal technique would surely be boring, thus reducing student interest. The 7E learning cycle is prepared to elicit student attention, attract students' interest. In the light of reviewed studies, the 7E learning cycle grounded on constructivist is believed to reduce misconception thereby enhancing student's achievement. In view of this, the researchers recommend the adoption of 7E learning cycle approach in teaching and learning of States of matter.

The 7E learning model has been shown to have contributed significantly to students' achievement and removing conceptual misconceptions. Based on reviewed empirical studies demonstrating students' misconceptions on states of matter transformation and several research affirming the influence of 7E learning cycle in students learning science, the following recommendations were made:

(a) Basic science teachers should adapt mind and hands-on 7E-learning cycle and other various inquiry teaching strategies to enhance students' learning of matter.

(b) At the preservice level, the use and implementation of constructivist teaching strategies in the classrooms should be stressed in the methodology courses being offered by the student-teachers at the universities and colleges of education.

(c) At the in-service level, seminars and workshops should be established by ministry officials, zonal educational authority, and local education authority to educate practicing teachers on how to embed the constructivist learning approaches in schools at all levels.

(d) Further experimental study should be carried out to determine the extend 7E learning cycle enhances students learning in basic science.

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