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Influence of Cognitive Ability on Students' Conceptual Change in Particulate Nature of Matter in Physics

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ABSTRACT
When students were exposed to cognitive conflict and 5E teaching models, this study looked at the impact of cognitive ability on their conceptual change in the particulate nature of matter in physics. With a sample of 195 first-year upper secondary school students, the study used a quasi-experimental design with non-equivalent groups. The data were collected using the Conceptual Change Test (PNMCCT) and the Test of Logical Thinking (TOLT). Through the process of test-retest utilizing the split-half approach, a reliability coefficient of 0.79 was achieved for PNMCCT, and Cronbach's alpha reliability index of the TOLT was found to be 0.81. The TOLT was used to divide the respondents into three levels of cognitive ability: low, average, and high cognitive capacity. Analysis of variance and analysis of covariance were used to analyze the data. When students were exposed to two conceptual change instructional methods, the results demonstrated that cognitive capacity had a substantial impact on conceptual change. It was suggested that students be encouraged to think critically and rationally about physics issues.

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Introduction

Research Background and Problem

True conception is critical since it aids children in remembering, retaining, and recalling concepts. Students gain a better awareness of the independence of concepts and the world around them when they have a concrete grasp of the material (Saleh & Mazlan, 2019). Students with a concrete understanding of physics may handle problems conceptually and culturally without memorizing formulas, ensuring their overall success (Saleh & Mazlan, 2019). Only competent instruction could lead to a true conception. However, according to Ukoh and Adewale (2014), there is a gap in the technique of teaching science in Nigeria, which they believe is a primary cause of students' poor performance in science topics. According to Shah and Khan (2015), the existing style of science instruction in Nigeria is unable to improve students' problem-solving skills, curiosity, or critical thinking.

Despite the importance of in-depth knowledge of physics in today's world, reports abound that Nigerian secondary school students perform poorly in external physics examinations as a result of misconceptions in some physics topics (Orji & Madu, 2016), a lack of grasp on many basic physics concepts, and difficulty in explaining concepts (West African Examinations Council [WAEC] Chief Examiner's Reports, 2014-2018). Similar studies have revealed that physics students' academic performance in upper secondary school has fallen short of expectations (Akanbi et al., 2018; Ugwuanyi et al., 2019; Ugwuanyi et al., 2020). The lack of usage of constructivist instructional methods by teachers, which foster conceptual understanding among students, can be the reason for students' poor academic accomplishment in physics. A student's conceptual transformation occurs when he or she moves from a personal knowledge of an idea to a more scientific grasp. Students' conceptions are a term which used to describe a student's grasp of an idea (Nduji & Madu, 2020). When confronted with an unusual scenario, one's conceptual views are changed, modified, or rejected (Orji, 2013). The phrase "conceptual shift" refers to a variety of learning transformation processes in which students' prior information is changed into scientific knowledge (Kokkonen, 2017). According to Orji (2013), a student's knowledge of a topic can be classified as scientific conception (SC), partial understanding (PU), alternative conception (AC), or naive conception (NC) (NC). In science, conceptual transformation refers to the process of significantly rearranging and transforming a learner's prior beliefs, it also refers adding new knowledge to what is already understood.

Physics educators and researchers are concerned with developing ways to improve students' ways of knowing in the subject through effective instructional models in order to solve this poor performance by physics students. Cognitive conflict and 5E instructional models are two of these instructional approaches. Smith (2011) defined cognitive ability as biological distinctions in the human brain's make-up that influence an individual's ability to profit from education. According to the cognitive dissonance model, contradictory cognitions operate as a motivator for the learner to acquire new concepts or beliefs, or to adjust existing beliefs, in order to lessen conflict between cognitions (Harmon-Jones, 2017). When an individual maintains two or more components of information that are related yet incompatible with one another, cognitive dissonance occurs. Dissonance is the term for this unpleasant state (Harmon-Jones, 2019). Six steps are involved in implementing the cognitive conflict in learning technique (Orji., 2013). Students are supplied with experiments in this model, according to Orji (2013), to generate students' alternative conception through anomalous experiments. Following that, students engage in tasks and encounter inconsistencies with their previous beliefs. This finally causes cognitive disagreement among the students. Students will be required to share the outcomes of their research with their peers and compare them to their earlier opinions. This allows kids to share ideas based on what they've observed during the exercises. The teacher gathers various thoughts and summarizes them with the class, allowing for the proper identification and explanation of correct concepts. Studies on topics like temperature and heat (Orji, 2013; Madu & Orji, 2015; Orji & Madu 2016) and courses in computational physics have used a cognitive conflict method (Akmam et al., 2018).

Theoretical framework

This research is based on Festinger's (1957) Cognitive Dissonance Theory (CDT), which proposes that cognitive inconsistency causes a motivational state that encourages regulation, mostly through a change of attitudes or behaviors. The theory is based on the sense of incompatibility between two cognitions, which can be described as any aspect of knowledge, such as attitude, emotion, belief, or behavior. Non-fitting relationships among cognitions, according to Festinger (1957), cause a state of discomfort known as dissonance, which is widely thought to involve unpleasant arousal and encourages people to cope with the circumstance, usually by modifying one cognition to the other. The term dissonance was used by Festinger (1957) to describe three distinct entities: the theory, the triggering situation, and the created condition.

There are some opposing viewpoints on cognitive dissonance theory. Some detractors asserted that cognitive dissonance cannot be objectively quantified and so cannot be recognized as such. Individual differences can cause cognitive dissonance, thus what causes it in one student may not cause it in another. This theory supports the cognitive conflict instructional paradigm because it explains how an anomalous situation can induce conflict in the learner, and how this conflict can be addressed through the conditions of dissatisfaction, intelligibility, plausibility, and fruitfulness. As a result, according to the cognitive dissonance model, contradictory cognitions operate as a driving force, pushing the learner to acquire new thoughts or beliefs, or to change existing beliefs, in order to alleviate cognitive conflict.

Both theory and the teaching approaches utilized in this study disrupt students' trust in their existing ideas through paradoxical experiences such as discrepant events, allowing them to replace their faulty assumptions with scientifically accepted beliefs. It is important to highlight, however, that the majority of the concerns raised in this hypothesis may be seen in the current study. Orji (2013) used this idea to carry out comparable research.

The constructivist theory of learning proposes that people construct knowledge and meaning from their experiences, which is the basis for the 5E teaching paradigm. Engagement, exploration, explanation, elaboration, and evaluation are the five cognitive phases of learning cycles in the 5E paradigm (Bybee et al., 2006). Students can reconcile new knowledge with old notions by understanding and reflecting on activities, according to the researchers, in addition to cultivating a comprehension of scientific principles, research skills, analytical thinking, and reasoning skills.

Review of Related Empirical Studies

According to recent studies, using the 5E instructional paradigm has a significant impact on students' learning since it promotes rational and scientific conversations that lead to knowledge (Gillies et al., 2012). It improves students' behavior and attitude toward science instruction (Lin et al., 2014), fosters students' ability to create connections between real-world occurrences and scientific concepts (Polgampala et al., 2016), and develops students' creative thinking (Polgampala et al., 2016). (Siwawetkul & Koraneekij, 2018). According to research, the cognitive conflict teaching paradigm is excellent at motivating conceptual change in secondary and college students (Akmam et al., 2018; Labobar et al., 2017; Orji & Madu 2016; Madu & Orji, 2015). The cognitive conflict technique improved students' conceptual competence significantly (Gunawan et al., 2021). The cognitive conflict strategy has a considerable effect on students' conceptual understanding of a mechanical wave, according to Makhrus and Hidayatullah (2021).

Hasanah and Wasis (2021) discovered that using a cognitive conflict method helped students to correct misconceptions about wave material. Cognitive refers to various ways of comprehending the world and making sense of life experiences, as defined by psychologists. Students, on the other hand, vary in their ability to make sense of their daily experiences. Cognitive ability is the name given to this attribute. Students with varied cognitive abilities accomplish differently when exposed to a constructivist instructional paradigm called Cognitive Acceleration Training Programme (CATP), according to Achor and Ejeh (2019). The cognitive ability of students is a strong determinant of their academic engagement (Lavrijsen et al., 2021). It was discovered that a student's cognitive capacity is linked to their metacognitive abilities (Saputri & Corebima, 2020). In contrast to the previous findings, Paraboni and da Costa (2021) discovered that there was no significant difference in performance between people with greater and poorer cognitive abilities.

Gaps in Literature

Previous researches on students' conceptions and conceptual change in physics have focused on concepts such as force and motion (Ugwuanyi, 2012); temperature and heat (Orji, 2013); light refraction (Nwankwo & Madu, 2014); electric resistance (Tao et al., 2018); real and virtual experimentation on the electric circuit as investigated by Zacharia (2017); and heat energy (Tao et al., 2018; Nduji & Madu, 2020). Furthermore, despite the fact that cognitive ability is one of the most essential factors for the study of individual differences among students, most researchers avoid utilizing it in the measurement of intelligence due to its history or load on them, according to Dworak et al. (2021). Furthermore, the findings of prior studies, as indicated above, produced a mixed bag of results in terms of the impact of cognitive capacity on student performance. This investigation was motivated by the gaps in the literature. As a result, since other research focus on other physics ideas, it is necessary to explore the impact of cognitive capacity on students' conceptual transformation, specifically on the particulate nature of matter. This study, therefore, aimed to determine the influence of cognitive ability on students' conceptual change in the particulate nature of matter concepts.

Methods

Research Design

The study used a quasi-experimental design with non-equivalent groups. According to Nworgu (2015), the design does not include people being assigned to experimental and control groups at random. Experimental conditions were given to intact classes at random in this investigation. In similar research, Adene et al. (2021), Ejimonye et al. (2020) Ejimonye, Onuoha et al. (2020), Offordile et al. (2021), Njoku et al. (2020), and Eze et al. (2021) have used this design.

Ethical Statement

The University of Nigeria's research ethics committee granted ethical permission for the study's conduct. Prior to doing this study, the researchers kept track of any ethical difficulties in research.

Consent Statement

Before the research could begin, the participants were given informed consent forms to fill out and sign. They were also free to ask inquiries if they were unsure of what to do.

Participants

The study was included 195 first-year upper secondary school physics students from 13 public senior high schools in the Bwari Area Council of the Federal Capital Territory (FCT) for the 2019/2020 session, out of a total of 5,312 first-year upper secondary school physics students. The sample was taken from two schools in the FCT's Bwari Area Council. Through simple random sampling by balloting, students in four intact classes, two from each of the two senior secondary schools in the Bwari Area Council of the FCT, were assigned to the two experimental groups. This meant that experimental group one (treatment with cognitive conflict model with a total of 98 students) had two intact classrooms of 50 and 48 students, while experimental group two (treatment with cognitive conflict model with a total of 98 students) had two intact classes of 48 and 49 students (treatment with 5E instructional model with a total of 97 students).

Instruments for Data Collection

For the research, two instruments were used which are Particulate Nature of Matter Conceptual Change Test (PNMCCT) and the Test of Logical Thinking (TOLT).

Particulate Nature of Matter Conceptual Change Test (PNMCCT)

The PNMCCT was developed by Ozalp and Kahveci (2015), who created a 25-item question on the particulate nature of matter (15 two-tier and 10 one-tier). The purpose of the test was to see how well students understood the topic of particle nature of matter. Some of the items in the original edition are true or false. These items were eliminated as part of the adaption measures by the researchers since true or false cannot be used to evaluate conceptual change. Other questions included three, four, or five multiple-choice answers. In addition, for the current edition, the researchers incorporated uniformity of the number of possibilities as well as an equal number of justifications in each of the items.

To maintain uniformity, the researchers divided each item into four multiple-choice answers and four justifications. Only questions from the original instrument were kept from concepts and topics where students had naive ideas. As a result, a total of 20 two-tier items were created based on concepts and issues where students had naive conceptions. The PNMCCT was divided into two sections. Section A consisted of replies concerning the students' school and class codes, whereas section B consisted of 20 two-tier items about the students' conceptual change in particulate nature of matter notions. Students are needed to choose one of the four possibilities lettered from A to D and one rationale from the reasons from 1 to-4 in one example of these items, particularly item number 5. Here is an example of a question like this:

Which statement is true regarding ice and water molecules?
(A) Ice molecules are solid; water molecules are liquid.
(B) Both ice and water molecules are solid.
(C) Both ice and water molecules are liquid.
(D) Molecules cannot be in solid or liquid phase
Reason:
1. Being in solid or liquid phase of matter is related with the interactions between its molecules
2. Molecules are always in liquid phase.
3. Ice molecules are solid because ice is solid and water molecules are liquid because water is liquid.
4. Molecules are always in solid phase.

The instrument is graded by matching any of the four options to the correct justification for the choice. No conception (NC) receives one-point, alternate conception (AC) receives two points, partial conception (PC) receives three points, and true conception (TC) receives four points (Sesli & Kara, 2012). This method of assessment was chosen to represent the students' understanding of the themes.

Test of Logical Thinking (TOLT)

The second instrument Test of logical thinking (TOLT) was adopted from Tobin and Capie (1981). The instrument was designed and used to measure students' cognitive ability levels. TOLT consists of eight two-tier multiple-choice items and two items where students are required to complete a list of combinational reasoning. The test consists of ten multiple-choice items designed to measure students' five reasoning abilities namely, proportional reasoning (items 1 & 2), probabilistic reasoning (items 3 & 4), controlling variables (items 5 & 6), correlational reasoning (items 7 & 8), and combinatorial reasoning (items 9 & 10). The students were required to select a response from five possibilities and then they were provided with five justifications from which they choose. The correct answer is the correct choice plus the correct justification. Cronbach's alpha reliability index of the test was found to be 0.81 by Tobin and Capie (1981). Each item of the TOLT was given a numeric value of 1 if both response and reason were correct, and 0 if incorrect (Tobin & Capie, 1981), except for the last two items that required students to list combinations. In these two items, the score ranged from 0 to 1 depending on the number of combinations listed by the student. The total score for the test is ten (10). Students' cognitive ability level in the test is grouped as (4-10) high ability, (2-3) average ability while

(0-1) low ability. The basis for this grouping is that a student must obtain a correct score in at least four areas of the reasoning abilities or obtain the correct scores in at least two areas of the reasoning abilities before such student is considered as high cognitive ability. While an average ability student is expected to at least obtain a correct score in at least two areas of the reasoning abilities or get the correct scores in at least one area of the reasoning abilities. Finally, a student is considered low ability if the student cannot score correctly on any of the items in the instrument or obtain the correct scores in any of the areas of the reasoning abilities.

Instruments' Validation and Reliability

Face validation was performed on the instruments and lesson plans by five experts: two from the Measurement and Evaluation unit of the Department of Science Education, two from the Physics Education unit of the Department of Science Education, and one from the Educational Psychology unit of the Department of Educational Foundations. Specifically, the experts were asked to check the extent to which each of the instruments measures what it is supposed to measure, as well as the language used in writing the items in the instruments, the extent of coverage of the items in the instruments, and the language used in writing the items in the instruments, the items' adequacy in relation to the students' class in emphasis and the clarity of instruction to the research subjects. The experts face validated copies of the lesson plans as well. Validators' comments and constructive criticisms were used to make changes to the instrument and instructional materials.

The researchers put the PNMCCT instrument to the test on 20 senior secondary one (SSI) students from Government Secondary School Karu in Abuja Municipal Area Council (AMAC) of the Federal Capital Territory (FCT). The reliability of PNMCCT was assessed using Cronbach's alpha formula after trial testing. The instrument's internal consistency index was found to be 0.75. Similarly, the temporal stability of the PNMCCT was examined through the test-retest procedure utilizing the split-half approach and was found to be 0.79 since the instrument was delivered to the same students as a pretest and posttest under similar settings. Tobin and Capie (1981) have thoroughly documented TOLT's reliability, which was determined to be 0.81 using the Cronbach's Alpha technique. The reliability index of the three instruments revealed that they are all reliable. Because the responses to the items of the instruments were scored in a polytomous manner, i.e., each item of the instruments had no preferred answer, this reliability estimate was chosen for the two instruments (right or wrong).

Implementations of the Research

Prior to the commencement of the experiment, the researchers organized training for the research assistants on how to implement cognitive conflict and 5E instructional models using the prepared lesson plans. The training involved practical demonstrations of the steps involved in the two instructional models by the research assistants with a class of senior secondary one (SS1) students in another school within the vicinity. They were briefed on how to carry on with the experiment. PNMCCT was then administered to the students before the commencement of the treatment as a pretest. The data obtained by students served as pretest scores for the study. The TOLT was equally administered before the treatment. The TOLT was used to categorize the students into different cognitive ability levels. The test scores from 0-1, 2-3, and 4-10 were used as a basis for categorizing the students into low, average, and high cognitive ability levels respectively. After the pretest, treatment was administered to the students in each of the groups which lasted in 4 weeks

Experimental Group 1

The students of experimental group 1 were taught physics concepts using a cognitive conflict instructional model.

Experimental Group 2

The students of experimental group 2 were taught physics concepts using the 5E instructional model

Treatment Procedure

This research was conducted by exposing the students to two different experimental groups during the teaching of physics concepts. Both groups of students were exposed to 6-week treatment conditions after which each group of the students attempted the same PNMCCT questions. At the end of the treatment, a posttest was administered to the two groups. The test was conducted at the same time and the scripts were collected immediately for marking. Finally, the pretest and posttest scores were subjected to data analysis. For the scoring purpose, each of the 20 items in PNMCCT was scored based on the level of conception for the reasonable option.

Data Analysis Procedure

Collected data were analyzed using mean and analysis of variance. Analysis of variance (ANOVA) and analysis of covariance (ANCOVA) were used to test the hypotheses formulated for the study at a $p = 0.05$ probability level.

Findings

Table 1

Analysis of Variance of the Influence of Cognitive Ability on the Students' Conceptual Change Scores in Particulate Nature of Matter

Cognitive Ability	n	Mean	SD	df	F	p	Partial Eta Squared
High	26	75.87	1.08				
Average	72	63.00	2.32	1,191	18.906	.000	.253
Low	97	60.14	2.67				

Table 2 shows that after the instruction, students with high cognitive ability had mean conceptual change score ($M = 75.87$, $SD = 1.08$), the average cognitive ability students had a mean conceptual change score ($M = 63.00$, $SD = 2.32$), while the low cognitive ability students had a mean conceptual change score ($M = 60.14$, $SD = 2.67$). İt was further revealed that there is a significant influence of cognitive ability on students' conceptual change in particulate nature of matter, F (2, 191) = 18.906, $p < .050$, $\eta^2 = .253$. The effect size of .253 implies that 25.3% variation in the conceptual change scores of the students is attributed to their cognitive levels. The Post Hoc pairwise comparison test result is as shown in Table 2.

Table 2

The Pairwise Comparison Test for the Significant Difference in Students' Mean Conceptual Change Scores Based on Cognitive Ability Levels

(I) cognitive Ability	(J) cognitive Ability	Mean Difference (I-J)	Sig.
High	Average	12.87*	.001
	Low	15.73*	.000
Average	High	-12.87	.000
	Low	2.86*	.067
Low	High	-15.73*	.000
	Average	-2.86*	.067

Table 2 that the mean conceptual change scores of students of high cognitive ability and low cognitive ability contributed most to the significant influence of cognitive ability on students' conceptual change in particulate nature of matter in physics.

Table 3

Percentage Analysis of Students' Conceptual Change Scores Based on Cognitive Ability Levels

	High Cognitive Ability (n = 26)		Average Cognitive Ability (n = 72)		Low Cognitive Ability (n = 97)	
Levels of conception	Pretest Frequency (%)	Posttest Frequency (%)	Pretest Frequency (%)	posttest Frequency (%)	Pretest Frequency (%)	Posttest Frequency (%)
TC	9(1.7)	480(92.3)	4(0.3)	1326(92.1)	7(0.3)	1661(85.6)
PC	31(6.0)	32(6.1)	58(4.0)	89(6.2)	58(3.0)	210(10.8)
AC	372(71.5)	5(1.0)	1075(74.7)	20(1.4)	1445(74.5)	52(2.7)
NC	108(20.8)	3(0.6)	303(21.0)	5(0.3)	430(22.2)	17(0.9)

Table 3 shows that at the pretest, 1.7% of the students with high cognitive ability had TC, 6.0% had PC, 71.5% had AC and 20.8% had NC; while 0.3% of the students with average cognitive ability had TC, 4.0% had PC, 74.7% had AC and 21.0% had NC while 0.3% of the students with low cognitive ability had TC, 3.0% had PC, 74.5% had AC and 22.2% had NC. However, at the posttest, 92.3% of the students with high cognitive ability had TC, 6.1% had PC, 1.0% had AC and 0.6% had NC; 92.1% of the students with average cognitive ability had TC, 6.2% had PC, 1.4% had AC and 0.3% had NC while 85.6% of the students with low cognitive ability had TC, 10.8% had PC, 2.7% had AC and 0.9% had NC. This implies that a greater percentage of the students with high cognitive ability had a true conception of particulate nature of matter than those with average cognitive ability and low cognitive ability and those with average cognitive ability had a greater percentage than those with low cognitive ability in the whole items of the instrument.

Table 4

Mean Analysis of Conceptual Change Scores of Students Taught Particulate Nature of Matter Using Cognitive Conflict Instructional Model and 5E Instructional Model

		Pretest		Posttest					Partial Eta Squared
Group	n	Mean	SD	Mean	SD	df	F	p	
Cognitive Conflict Model	98	34.00	1.67	62.33	1.67	1, 192	35.851	.000	.576
5E Instructional Model	97	33.29	2.14	66.45	1.45				

Note. η^2 = Effect size

Table 4 shows that students taught particulate nature of matter using cognitive conflict instructional model had a mean conceptual change score of (*M* = 34.00, *SD* = 1.67) while those taught using the 5E instructional model had a mean conceptual change score of (*M* = 33.29, *SD* = 2.14) at the pretest. However, after the instruction, the group taught with cognitive conflict model had a mean conceptual change score of (*M* = 62.33, *SD* = 1.67), while the group taught with the 5E instructional model had a higher mean conceptual change score of ($\bar{X}$ = 66.45, SD = 1.45). It was further found that there is a significant difference in the conceptual change scores of the students taught using the cognitive conflict instructional model and 5E instructional model in favour of those taught using the 5E instructional model, F (2, 192) = 35.851, $p < .050$, $\eta^2 = .576$. The effect size of .576 implies that 57.6% variation in the conceptual change scores of the students is attributed to their exposure to the cognitive conflict instructional model.

Discussion

The findings of the research demonstrated that cognitive capacity had a substantial impact on students' levels of conception in the particle nature of matter. This suggests that the levels of conception between the students with high and low cognitive abilities were the most important factors in the considerable influence of cognitive ability on students' levels of conception of the particle nature of matter. The fact that the structure and content of learning methods enable students to extend their views and engage in diverse thinking may have contributed to this conclusion. Depending on the cognitive abilities of the students, constructivist instructional therapies may boost their interest. However, the type of unusual circumstance provided by the teacher, as well as the models' level of exploration and thinking during the instructional procedures, may combine to impact their conceptual transformation.

This finding is consistent with that of Ezeugwu et al. (2016), who discovered a substantial difference in mean achievement between students of various cognitive capacities, favoring those with high cognitive skills. Achor and Ejeh (2019) discovered a substantial difference in the mean achievement score of low, moderate, and high ability level students when they were subjected to a cognitive acceleration training program (CATP). That is, when students with varying degrees of ability were exposed to CATP, they did not all attain the same results. Students with poor cognitive capacity improved more than students with moderate and high cognitive ability were subjected to the cognitive acceleration training program, according to the study.

This finding is in line with Abdullahi et al., (2019), who found that people with a high cognitive level are more likely to be influenced by the social learning method than those with a low cognitive level. This could be explained by the fact that persons with higher cognitive levels are more open to new experiences than those with lower cognitive levels. As a result, when compared to low-cognitive-level learners, high-cognitive-level learners are more inclined to explore new ideas and learn from others due to their curiosity. This may improve the likelihood of high-cognitive-level learners interacting with and learning from their classmates, as opposed to low-cognitive-level learners, who may find social learning too scary due to their close proximity.

This study is in line with Finn et al. (2014), who discovered that people with high cognitive levels have technical skills that aid collaboration. The cognitive ability of students is a strong determinant of their academic engagement (Lavrijsen et al., 2021). In contrast to the previous findings, Paraboni and da Costa (2021) discovered that there was no significant difference in performance between people with greater and poorer cognitive abilities. According to Paraboni and da Costa (2021), there was no significant difference in performance between people with better cognitive abilities and people with lower cognitive abilities. One possible explanation is that students with higher cognitive abilities have more experience and, as a result, engage in more exploratory and elaborative activities during the learning process, leading to more scientific views of many ideas.

It was also found that the 5E instructional model is significantly more effective than the cognitive conflict instructional model in improving students' conceptual change in the particle nature of matter. The superiority of the 5E instructional model over the cognitive conflict in enhancing students' conceptual change in the particulate nature of matter could be attributed to the fact that the 5E instructional model consists of five cognitive stages of learning cycles that can increase learning motivation as an instructional model. This is due to the fact that students are actively involved in the learning process in the 5E instructional paradigm. It also aids in the development of students' scientific attitudes and makes learning more relevant. Learning, more than the cognitive conflict instructional model, is clearly an active process that assures active engagement of students in the teaching-learning process. The findings are consistent with Okafor's (2016) research, which revealed that the 5E learning cycle model had a substantial impact on students' geometry achievement and retention. This discovery is related to Umahaba's (2018) finding that the 5E instructional paradigm improved students' ability to answer more difficult problems in chemistry performance tests. Orji (2013) found that cognitive conflict was effective in improving students' conceptual transformation, which is consistent with this conclusion. The study did, however, relate the cognitive conflict approach to conceptual change pedagogy, but not to the 5E instructional paradigm. The findings are consistent with Labobar, Setyosari, Degeng, and Dasna (2017), who observed that students' misunderstanding of concepts was high before therapy using the cognitive conflict method, but it was reduced after treatment. The study concluded that students' conceptual shifts were influenced by cognitive conflict techniques. Wartono, Batlolona, and Putirulan (2018) revealed that cognitive conflict techniques may be utilized to eliminate misconceptions and improve students' learning accomplishment, confirming the findings of Labobar, Setyosari, Degeng and Dasna (2017).

Limitations of the Findings

This study is obviously faced with challenges that may limit the generality of the findings. One of these challenges is the class size (50 and 48 students for experimental group one and 49 and 48 students for experimental group two) may be too much to handle under experimental conditions. Again, teaching for conceptual change using cognitive conflict and 5E instructional models requires enough time. The one hour allotted for each lesson affected the school timetable to the extent that many teachers complained that the lesson encroached into their own lesson time. So, this time issue distorted the lessons in most cases. The characteristics difference of age and social background of the learners in this study may also pose a challenge in their concept formation and information processing as associated with learning involving conceptual change. Due to the inherent limitation of the quasi-experimental study which does not permit randomization of subjects may affect the generality of the result. Although ANCOVA may have helped in homogenizing the groups but cannot eliminate these differences.

Conclusion and Recommendations

The finding indicated that cognitive ability significantly influenced students’ conceptual change in the particulate nature of matter in physics. This may be that some of the high cognitive ability students may have leverages the students’ interaction with peer, discussion, and evaluation stages in the instructional models to construct more knowledge than other students who may be trying to resolve cognitive conflict caused by the kind of anomalous situation presented by the teacher. It was also confirmed that the 5E instructional model is significantly more effective than the cognitive conflict instructional model in improving students’ conceptual change in the particle nature of matter. It is therefore recommended that:

1. Students should be encouraged to develop critical and rational thinking towards physics concepts. This will help to their performance in the subject.
2. Curriculum planners and scientific organizations should provide appropriate and adequate activities that will enhance the cognitive development of the learners at the appropriate stage of development.

3. Physics teachers should balance students' cognitive ability and instructional materials during physics lessons.
4. 5E instructional model should be adopted by physics teachers during physics instruction.

Conflict of Interest

The authors declared no potential conflict of interest.

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APPENDIX A

Particulate Nature of Matter Conceptual Change Test (PNMCCT)

SECTION A: Demographic Data of Student

Information: please provide the information as it applies to you.

SCHOOL CODE: ---

STUDENT CODE: ---

CLASS CODE: ------------------------------TIME: 60 MINTUES

SECTION B: Test

Instruction: In this test, there are 20 questions on particulate nature of matter. Please read the questions carefully. Please circle the option that is closest to your understanding of the question and then tick the reason statement that most appropriately explains the choice of your option.

(1) Which of the following statements is true about the atoms of any element?

(A) The number of protons in an atom of an element is unique to each element.

(B) The number of protons and neutrons in an atom of an element is unique to each element

(C) A proton in an atom of one element is identical to a proton in an atom of another element.

(D) The number of protons in an atom of an element is the same for all elements.

Reason:

1. Any outside change made to gold affects the gold atoms in the same way.
2. Therefore, the rest of the volume of the atom is empty space.
3. All properties of gold exist in its atoms as well.
4. Atom of gold is the purest

(2) If a teaspoon of sugar is put into a glass of water at room temperature, which of the following statement is mostly correct.

(A) A chemical reaction occurs between sugar and water.

(B) A physical change occurs then a chemical reaction

(C) *sugar* molecules move *to* fit themselves between the molecules of *water*

(D) Sugar molecule is formed immediately

Reason:

1. When sugar is dissolved in water, a new compound forms.
2. Sugar melts in water.
3. When sugar is dissolved in water, it turns into water.
4. When sugar is dissolved in water, water molecules surround sugar molecules.

(3) Which of the following is correct about the atom of iron in solid phase?

(A) The atoms of iron do not move in solid phase.

(B) Atoms of iron do not exist in solid phase.

(C) Atoms of iron die once the iron is rusted.

(D) Atoms of iron stay in one point and don't move.

Reason:

1. Atoms form a mean distribution and vibrate in solid phase.
2. Atoms do not move in solid phase because there is no space in between them.
3. Atoms do not move in solid phase since it is the most regular phase of matter.
4. Iron is too hard for its atom to move in solid phase.

(4) Water takes the shape of the container. Accordingly;

(A) The shape of water molecules changes depending on the shape of the container.

(B) Water molecules escape once the water is poured into another container.

(C) Water molecules have a definite shape.

(D) Water molecules can only be present in steady water.

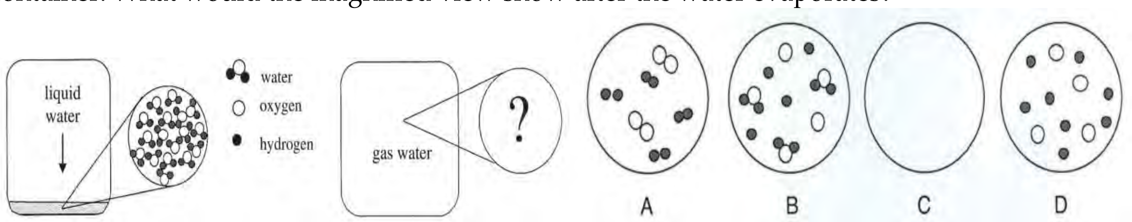
Reason:

1. Since water molecules are solid their shape does not change.
2. Water molecules are negatively charged hence it must attract the container

3. Whatever the shape of the container is, the shape of the molecules does not change.
4. Water molecules have the shape of water droplets.
(5) Which statement is true regarding ice and water molecules?
(A) Ice molecules are solid, water molecules are liquid.
(B) Both ice and water molecules are solid.
(C) Both ice and water molecules are liquid.
(D) Molecules cannot be in solid or liquid phase
Reason:
1. Being in solid or liquid phase of matter is related with the interactions between its molecules
2. Molecules are always in liquid phase.
3. Ice molecules are solid because ice is solid and water molecules are liquid because water is liquid.
4. Molecules are always in solid phase.
(6) Which of the following is correct?
(A) Atom of hydrogen is the smallest of all the atoms
(B) An atom of hydrogen is positively charged
(C) An atom of hydrogen is neutral
(D) Atom of hydrogen is the same as atom of any other element.
Reason:
1. Hydrogen is the first element on the periodic table.
2. Atom is the smallest particle of an element
3. Atom primarily consists of electron and proton.
4. Hydrogen atom has no electron.
(7) When water is held in the refrigerator, it freezes and turns into ice. During this, water molecules................
I. Do not alter II. Freeze III. Shrink IV. Expand
(A) Only IV (B) Only I (C) I and II (D) I, II and III
Reason:
1. Since the temperature decreases during freezing, the temperature of molecules decrease as well, therefore molecules freeze.
2. Since the temperature decreases during freezing, the temperature of molecules decrease therefore molecules freeze and their volume decrease.
3. Freezing does not make any change on molecules.
4. Since the temperature decreases during freezing, the temperature of molecules decrease therefore molecules freeze and their volume increase.
(8) When a piece of iron melts through heating, iron atoms...............
I. Shrink II. Melt III. Expand IV. Do not alter
(A) Only IV (B) Only III (C) I and II (D) II and III
Reason:
1. Since volume decreases during melting, iron atoms shrink.
2. Since iron is heated during melting, its atoms heat up as well, therefore the atoms melt and their volume increases.
3. Melting does not cause a change in atoms.
4. The temperature of atoms does not change during melting but atoms melt therefore their volume increases.

(9) Assume a beaker (heat resistant glass container) of pure water has been boiling for 30 minutes. What is/are in the bubbles in the boiling water?

(A) a mixture of air and water
(B) Oxygen gas and hydrogen gas
(C) heat energy
(D) Water vapor (water in the gaseous state)
Reason:
1. The hydrogen and oxygen atoms in water molecules break away from each other to form gases.
2. Heating gives the particles more energy and they are able to break away from their attractions. As the particles break apart, the air between the particles is released in the form of bubbles.
3. Heat energy is absorbed by the water and released as bubbles.
4. The forces between the water molecules are overcome, and the water molecules break free from the liquid to form steam.
(10) which statement is true reagarding atom
(A) Atoms can disappear after time.
(B) Atoms are smaller size of element
(C) Atoms move, so they are alive
(D) Atoms are the smallest particle of an element
Reason:
1. Two or more atom form an element
2. Atoms can be heated up and die off
3. Atoms own the electrons in their orbits.
4. Atom of an element is distinct from atom of any other element
(11) The circle on the left shows a magnified view of a very small portion of liquid water in a closed container. What would the magnified view show after the water evaporates?



Reason:
1. Water molecules have decomposed into oxygen atoms and hydrogen atoms.
2. Water molecules have escaped into the air.
3. Water molecules have decomposed into oxygen and hydrogen gas.
4. Water molecules have become vapor and spread further apart.

(12) Crystals of sugar are placed in a beaker (heat-resistant glass container) of water (Case I). If the mixture is left to stand long enough (Case II), which of the following is correct.

(A) The sugar crystals can no longer be seen and the water will taste sweet.
(B) The sugar crystals can no longer be seen and the volume of the water will increase.
(C) The sugar crystals can no longer be seen but reappear at a later time
(D) The sugar crystals can no longer be seen and the water has no taste.

Reason:

1. The sugar molecules gain heat from the surrounding and melt, forming a liquid. This liquid mixes with the water.
2. The sugar fills the air spaces in the water and therefore 'disappears'.
3. Water molecules surround sugar molecules on the surfaces of the crystals and pull them away from the crystal lattice.
4. The sugar crystals will only dissolve when stirred. Stirring causes the sugar crystals to break up into smaller particles that will then spread in the water and can no longer be seen.

(13) one of the following does not support the existence of photon
(A) light could be quantized into particles
(B) The rest mass of a photon is 0 hence it cannot exist.
(C) different atoms emit distinct light some times
(D) ionization of atom is never possible

Reason

1. Photon show spectra for different atoms
2. Photon show spectra for only one atom
3. Photon show one kind of spectrum for all atoms
4. Photon show spectra for only soap bubbles

(14) Absorption spectrum is a continuous spectrum with
(A) a continuous band with dark lines
(B) a continuous band with bright lines
(C) Black and white continuous background
(D) Different colours like the sun set

Reason

1. Destructive interference is formed
2. Wavelength of radiation are missing
3. The black lines show a present of light
4. The coloured parts represents the total light that is focused

(15) which of the following is true about Emission spectrum
(A) gas is excited by a high voltage to produce a discharge
(B) gas is excited by high current to produce electron
(C) gas is excited by pressure to increase its volume and thus show light
(D) at high pressure more electron travels faster

Reason

1. Some electrons have sufficient energy to excite atoms to a higher energy level
2. Some electrons have sufficient energy to excite atoms to a lower energy level
3. Some electrons stay in their current energy level
4. Some electrons need sufficient energy to neutralize any given atom

(16) The radiation curves from a black body could be used to explain the fact that
(A) Electrons have distinct values of energy

(B) Electrons have distinct charge of either positive or negative
(C) Electrons have distinct values of energy if positively charged
(D) Electrons have no charge
Reason
1. Electron lose its energy in an irregular pattern
2. Electron cannot lose energy
3. Electron continuously gain energy from the surrounding
4. Electron lose its energy in well define steps

(17) which of the following statement could be wrong about the crystalline solids?
(A) definite shape, are rigid and incompressible
(B) In most cases soluble in water and contains high level of impurities
(C) have sharp melting points and irregular or curved surfaces
(D) Lacking a shape, do not form the three-dimensional lattice structure and contains impurities
Reason
1. The particle of the crystalline solid and molecule of water are inseparable
2. Their atoms have to form layers which can be arranged by physical means
3. The arrangement of their atoms can be achieved in gaseous state
4. Particle of the crystalline solid grow out from its solution when cooled to freezing point

(18) which statement is likely to be true about the arrangement of particles in crystals?
(A) Several packing arrangement of particle are possible
(B) There are two possible packing arrangement
(C) Particles are only arranged at the bottom of the container
(D) Particles lie adjacent to the surface
Reason
1. The particles repeat only in two direction
2. The particles repeat over and over in all directions
3. The particles float on the surface of the container
4. The particles repeat over and over in an unknown direction

(19) Which of the following statement is mostly true about the crystal substance?
(A) In crystal the particles are arranged to form a transparent material
(B) In crystal the particles are arranged in regular repeating position in all direction
(C) In crystal the particles are arranged in a positively-negatively charged manner
(D) In crystal the particles are arranged in a form that it can be reshaped into another pattern
Reason
1. The smallest repeating particle is called unit cell
2. Atoms are arranged to form compound
3. Temperature determine the how the atom will be formed
4. The arrangement gives possible formation of two atoms

(20) A mixture of sodium chloride salt and broken pieces of glass could best be separated using
(A) Crystallization from the solution of the mixture
(B) Magnetization of the glass particle , dissolution of the salt and then evaporation
(C) Hand picking of the glass particle
(D) Distillation of the mixture
Reason
1. Crystalline substances are soluble, have definite melting point and definite shape
2. Crystalline substances are insoluble and definite melting point
3. Crystalline substances are soften when heated
4. Crystalline substances are all anhydrous and have definite shape

Adapted from Ozalp and Kahveci (2015)

APPENDIX B

TEST OF LOGICAL THINKING (TOLT)

SECTION A: Demographic Data of Student

Information: please provide the information as it applies to you.

SCHOOL CODE: --
STUDENT CODE: ---
CLASS CODE: ------------------------------TIME: 60 MINTUES

SECTION B: Questions and Reasoning

Directions: A series of eight problems is presented. Each problem will lead to a question. Record the answer you have chosen and reason for selecting that answer.

1. Orange Juice #1

Four large oranges are squeezed to make six glasses of juice. How much juice can be made from six oranges?

a. 7 glasses
b. 8 glasses
c. 9 glasses
d. 10 glasses
e. other

Reason:

1. The number of glasses compared to the number of oranges will always be in the ratio 3 to 2.
2. With more oranges, the difference will be less.
3. The difference in the numbers will always be two.
4. With four oranges the difference was 2. With six oranges the difference would be two more.
5. There is no way of predicting.

2. Orange Juice #2

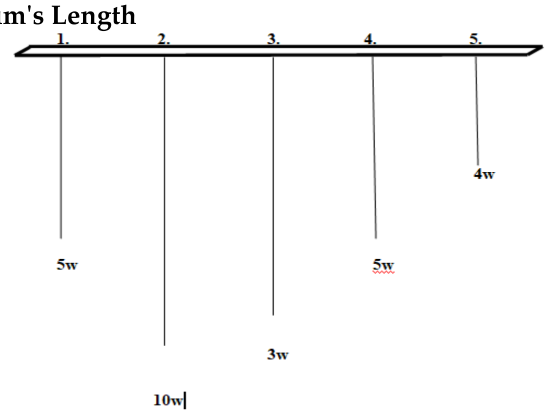
How many oranges are needed to make 13 glasses of juice?

a. 6 1/2 oranges
b. 8 2/3 oranges
c. 9 oranges
d. 11 oranges
e. other

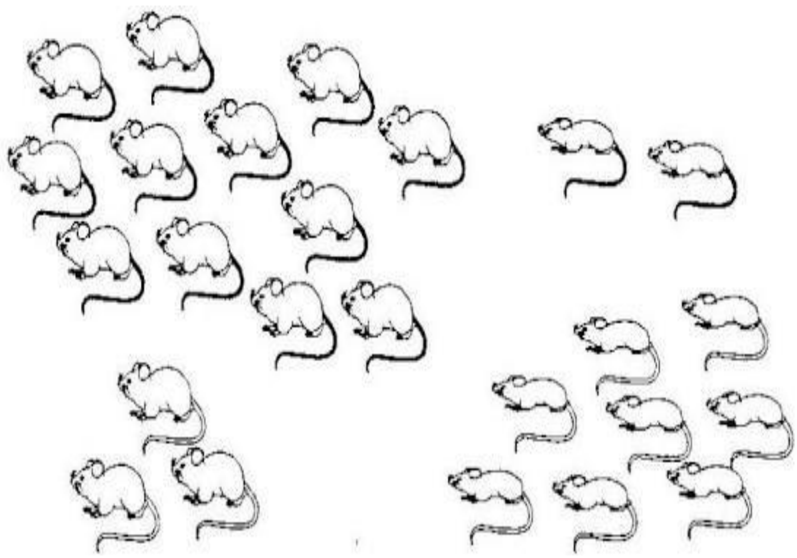
Reason:

1. The number of oranges compared to the number of glasses will always be in the ratio of 2 to 3
2. If there are seven more glasses, then five more oranges are needed.
3. The difference in the numbers will always be two.
4. The number of oranges will always be half the number of glasses.
5. There is no way of predicting the number of oranges.

3. The Pendulum's Length



Suppose you wanted to do an experiment to find out if changing the length of a pendulum changed the amount of time it takes to swing back and forth. Which pendulums would you use for the experiment?
a. 1 and 4
b. 2 and 4
c. 1 and 3
d. 2 and 5
e. all
Reason
1. The longest pendulum should be tested against the shortest pendulum.
2. All pendulums need to be tested against one another.
3. As the length is increased the number of washers should be decreased.
4. The pendulums should be the same length but the number of washers should be different.
5. The pendulums should be different lengths but the numbers of washers should be the same.
4. The Pendulum's Weight
Suppose you wanted to do an experiment to find out if changing the weight on the end of the string changed the amount of time the pendulum takes to swing back and forth. Which pendulums would you use for the experiment?
a. 1 and 4
b. 2 and 4
c. 1 and 3
d. 2 and 5
e. all
Reason:
1. The heaviest weight should be compared to the lightest weight.
2. All pendulums need to be tested against one another.
3. As the number of washers is increased the pendulum should be shortened.
4. The number of washers should be different but the pendulums should be the same length.
5. The number of washers should be the same but the pendulums should be different lengths.
5. The Vegetable Seeds
A gardener bought a package containing 3 squash seeds and 3 bean seeds. If just one seed is selected from the package, what are the chances that it is a bean seed?
a. 1 out of 2
b. 1 out of 3
c. 1 out of 4
d. 1 out of 6
e. 4 out of 6
Reason:
1. Four selections are needed because the three squash seeds could have been chosen in a row.
2. There are six seeds from which one bean seed must be chosen.
3. One bean seed needs to be selected from a total of three.
4. One half of the seeds are bean seeds.
5. In addition to a bean seed, three squash seeds could be selected from a total of six.
6. The Flower Seeds
A gardener bought a package of 21 mixed seeds. The package contents listed:
3 short red flowers
4 short yellow flowers
5 short orange flowers
4 tall red flowers
2 tall yellow flowers
3 tall orange flowers

If just one seed is planted, what are the chances that the plant that grows will have red flowers?
a. 1 out of 2
b. 1 out of 3
c. 1 out of 7
d. 1 out of 21
e. other
Reason:
1. One seed has to be chosen from among those that grow red, yellow or orange flowers.
2. 1/4 of the short and 4/9 of the tall are red.
3. It does not matter whether a tall or a short is picked. One red seed needs to be picked from a total of seven red seeds.
4. One red seed must be selected from a total of 21 seeds.
5. Seven of the twenty one seeds will produce red flowers.
7. The Mice
The mice shown represent a sample of mice captured from a part of a field. Are fat mice more likely to have black tails and thin mice more likely to have white tails?
a. Yes
b. No

Reason:
1. 8/11 of the fat mice have black tails and 3/4 of the thin mice have white tails.
2. Some of the fat mice have white tails and some of the thin mice have white tails.
3. 18 mice out of thirty have black tails and 12 have white tails.
4. Not all of the fat mice have black tails and not all of the thin mice have white tails.
5. 6/12 of the white tailed mice are fat.
8. The Fish
Are fat fish more likely to have broad stripes than thin fish?
a. Yes
b. No


Reason:
1. Some fat fish have broad stripes and some have narrow stripes.
2. 3/7 of the fat fish have broad stripes.
3. 12/28 are broad striped and 16/28 are narrow striped.
4. 3/7 of the fat fish have broad stripes and 9/21 of the thin fish have broad stripes.
5. Some fish with broad stripes are thin and some are fat.

9. The Student Council

Three students from grades 10, 11, 12 were elected to the student council. A three member committee is to be formed with one person from each grade. All possible combinations must be considered before a decision can be made. Two possible combinations are Tom, Jerry and Dan (TJD) and Sally, Anne and Martha (SAM). List all other possible combinations in the spaces provided.
More spaces are provided on the answer sheet than you will need.

STUDENT COUNCIL

Grade 10. . . . Grade 11. . . . . Grade 12
Tom (T). . . . Jerry (J). . . . . Dan (D)
Sally (S). . . . Anne (A). . . . Martha (M)
Bill (B). . . . Connie (C). . . . Gwen (G)

10. The Shopping Center

In a new shopping center, 4 store locations are going to be opened on the ground level.
A BARBER SHOP (B), a DISCOUNT STORE (D), a GROCERY STORE (G), and a COFFEE SHOP (C) want to move in there. Each one of the stores can choose any one of four locations. One way that the stores could occupy the 4 locations is BDGC. List all other possible ways that the stores can occupy the 4 locations.
More spaces are provided on the answer sheet than you will need.

Adopted from Tobin and Capie (1981).